An Assessment of Opportunities for Low Carbon Growth in Kenya

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Summary

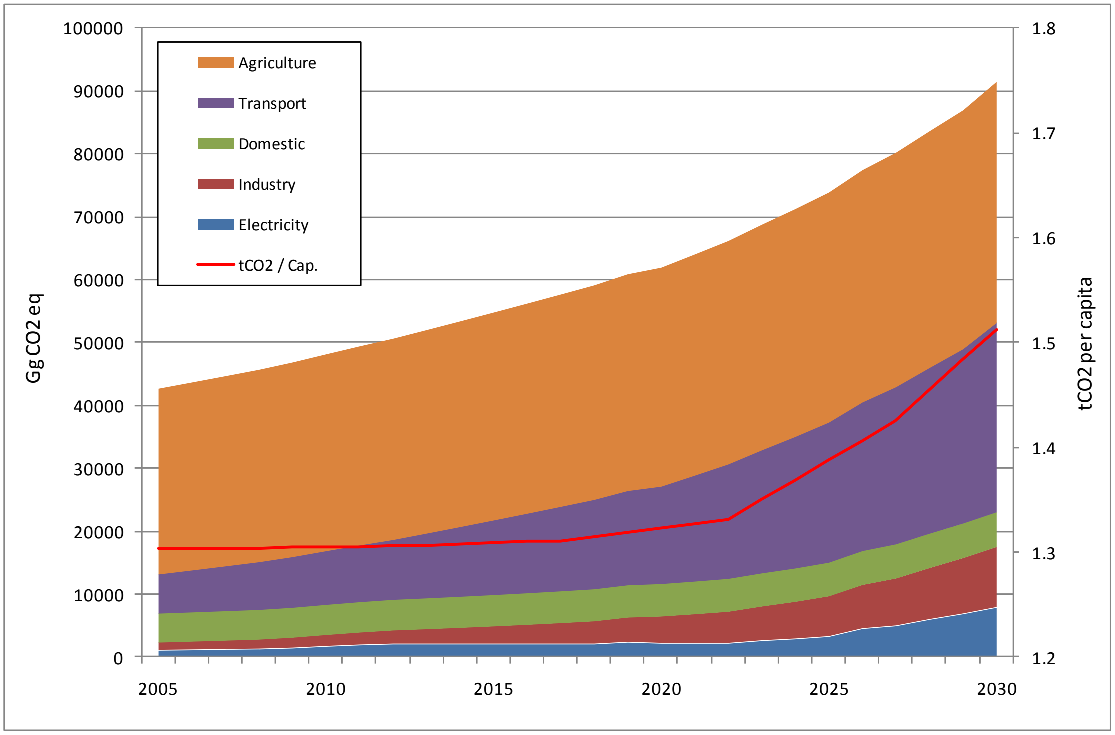
The DFID/DANIDA funded SEI study on the 'Economics of Climate Change in Kenya' is assessing low carbon growth, the impacts and economics costs of climate change in Kenya, and adaptation financing needs (based around costs and benefits of adaptation). As part of the work, the study is estimating the potential for low carbon growth in Kenya, looking at the potential changes in emissions, and low carbon growth opportunities, consistent with planned development. This report summarises this work.

Background

- Kenya has a relatively low carbon economy, indicated by per capita emissions of 1.3 tCO_2 (excluding LUCF). This is primarily due to a low carbon energy sector, with high renewable electricity generation and household energy dominated by biomass use.
- The only published estimates of emissions for Kenya are from the 1st National Communication (2002) for the year 1994. The largest emitting sector is agriculture, primarily comprising CH_4 emissions from livestock. The next most significant sector is energy consumption, primarily from consumption of oil products in transport and industry, and biomass burning.
- Whilst the 1994 inventory indicates that Kenya is a net sink due to the removal from the forest sector such estimates are subject to significant uncertainties due to unreliable stock information and a simplistic estimation approach. This LUCF sector of the inventory needs considerable development to improve estimates (which may have been undertaken for the forthcoming 2nd National Communication). In addition, the inventory for 1994 does not account for emissions from soils; alternative estimates for this source (CAIT) suggest that Kenya was a net emitter in 1994.
- Although it has low emissions in global terms (ranked 76th globally), Kenya has a plan for significant growth in the economy, outlined in its strategic development plan, Vision 2030. However, emissions are growing quickly - using historic estimates, energy sector emissions increased by 50% between 1994 and 2005, and these are likely to continue in the future in realising the Vision.
- A key issue is the likely emissions from this planned (business as usual) development pathway, and whether Kenya can achieve the same level of growth through an alternative low carbon pathway. A part of this latter pathway would be any additional advantages and economic benefits that would arise from following an alternative plan. This also links with the analysis of potential climate change impacts, and the need to develop climate resilient growth. This study has investigated these issues through analysis of future projected emissions and low carbon alternatives.

Future projections

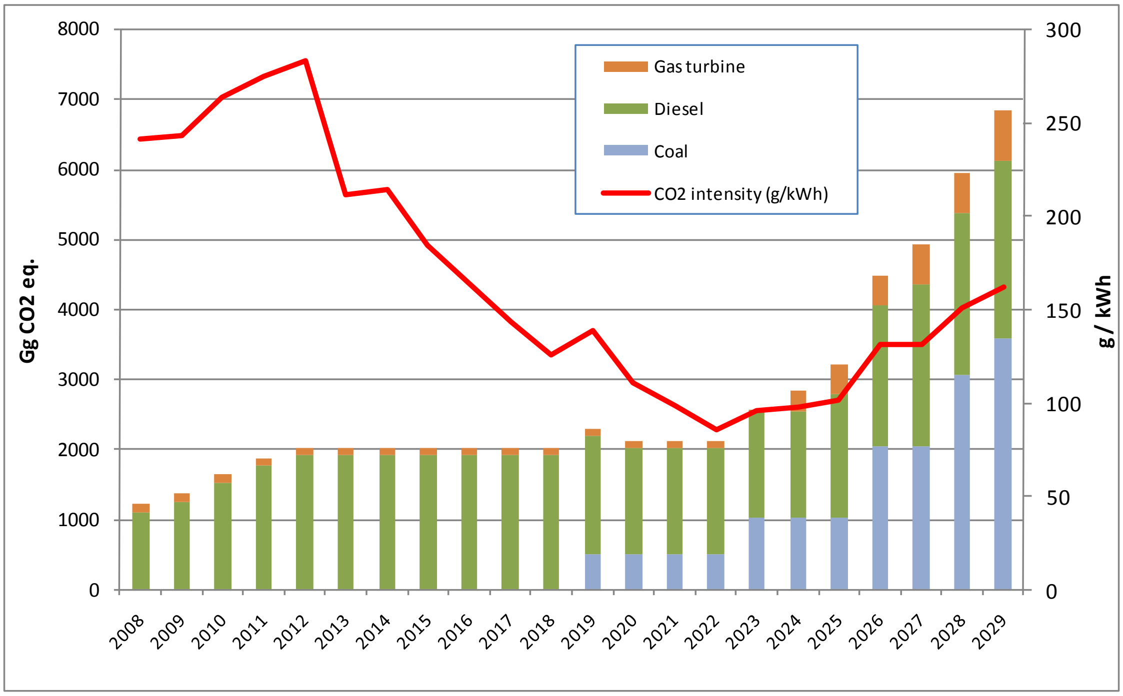
- The study has found that in many areas, Kenya is already initiating measures and policies that are consistent with low carbon development, and these provide practical demonstrations of the benefits of such a policy. The most obvious progress is in the electricity sector, where carbon intensity is predicted to fall with planned policy proposals, as well as reducing energy costs and improving the environment. There has also been progress in a wide range of other sectors.
- Nonetheless, the future challenge is significant. As set out in the Vision document, annual economic growth rates of 10% are predicted, while population is expected to almost double by 2030, from 34 million in 2007 to 63 million in 2030. High rates of urbanisation rates are also projected, rising from 9 million in 2007 to 43 million in 2030.
- These GoK projections have been used to develop a future 'business as usual' emissions scenario consistent with the Vision document. Some sensitivity analysis has been undertaken to investigate the potential implications of key assumptions.
- Using a simple projections approach, the economic growth and development associated with Vision 2030 is projected to increase emissions of greenhouse gases by over two times between 2005 and 2030 (from 42 to 91 Mt CO_2). It is also estimated that Kenya's per capita emissions could increase to over 1.5 tCO_2 by 2030, note this is a lower relative rise as future population increases reduce per capita emissions.
- A summary of the potential growth in emissions is shown in the figure below.



Projections of Kenya's GHG emissions (Gg CO2 eq.), 2005-2030

Analysis of the Electricity sector

- Kenya already has a low carbon electricity sector. The overall plans for the electricity sector indicate an even lower carbon generation mix in future years, dominated by geothermal capacity and high levels of imports (dominated by hydro generation) from Ethiopia. This low carbon electricity will result in low carbon energy for the consumers in end use sectors.
- However, these reductions are potentially offset by planned use of coal fired generation, and post 2020, the reductions in emissions in the power sector may be reversed if the planned development in the least cost plan are implemented.
- The emissions profile for the sector under the least cost plan is shown below. The graph shows the total absolute increase in emissions from the sector. Note that the red line reflects the average carbon intensity of the Kenyan electricity mix. It can be seen that the carbon intensity is currently falling, but would increase post 2020 with the introduction of more coal.
- These increases in emissions in the sector would occur at exactly the time when international negotiations are likely to get much stricter, and where the opportunities for future credits is likely to be more financially advantageous to Kenya, i.e. they represent a lost opportunity for Kenya for future credits, because of the 'lock-in' of high emission plant.



Projected CO_2 emissions by generation type (2008-2029)[1], and CO_2 intensity of generation (g/kWh)[2]

- The study has investigated other low carbon options as an alternative, developing a lower carbon alternative pathway to the least cost plan. It finds that there are other lower cost opportunities for renewable power generation, which would allow further access to international carbon credits.
- It is clear that renewable electricity generation makes economic sense, not only for centralised generation but for off-grid application, particularly for rural areas where access is limited and alternative diesel generation is very expensive. For example, solar systems are widely used in rural homes and communities.
- In addition to the direct economic benefits of low carbon alternatives, the study finds that this alternative low carbon pathway would have wider economic benefits from reducing air pollution, reduced environmental impacts associated with coal extraction and greater energy security and diversity.
- Any future plan has challenges for implementation, and may be vulnerable to climate impacts in future years. On implementation, large-scale investment is required in plant and transmission systems; however, there are opportunities for carbon financing as shown in recent plant expansions. Vulnerability may come from over-reliance on hydro (imports and domestic), particularly during drought years when the demands on water are significant. This latter point is extremely important. There is a need to consider the potential effects of climate change on the electricity sector itself. Other parts of the study have shown that there are projected scenarios which might increase the vulnerability of the Kenyan power sector to future climate, notably in relation to future hydro power. There is a need to undertake a climate risk screening analysis for the electricity generation plans, and to adjust the plans accordingly. This includes both domestic generation, but also for planned imports, especially as these are from climate sensitive technologies (hydro).

Analysis for other sectors

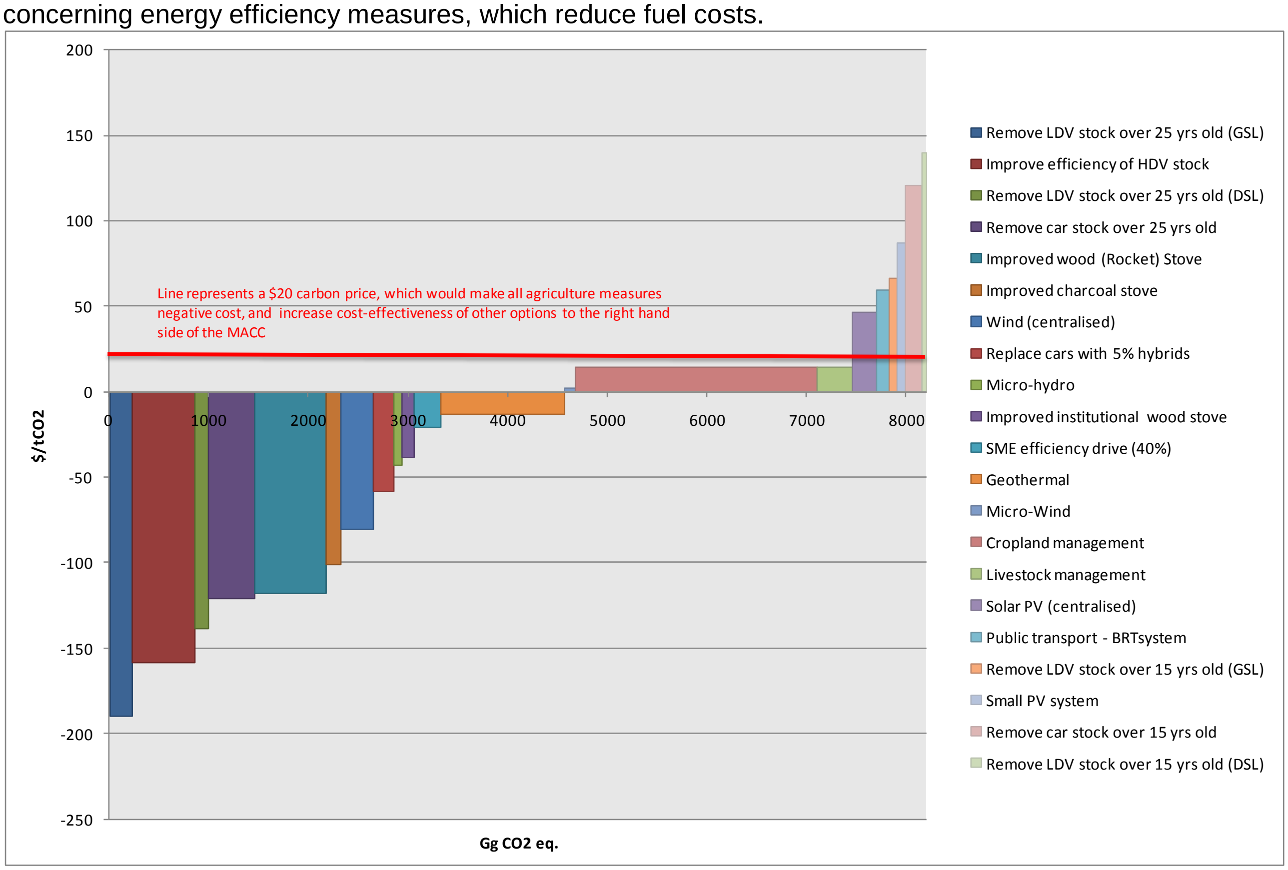
- As shown in the projections above, electricity generation emissions are a small proportion of future Kenya GHG emissions. Therefore a much wider economy-wide view is needed to advance low carbon growth.

[1] Assumed efficiencies: gas (45%), coal (35%), diesel (35%). All oil based generation assumed to be diesel not HFO, so emissions might therefore be underestimated.
[2] Generation levels adjusted for losses before intensity calculation

- The key driver of future emissions in these projections is the transport sector, particularly due to increasing private car use and freight on roads. Whilst it is very difficult to project agriculture emissions in the absence of detailed information, it is likely that livestock and arable output will grow with population demand, a strong export sector and changing agricultural practices e.g. increased use of fertilisers.
- In addition to being the largest emitting sectors, these are often the most challenging sector for ensuring low carbon reductions. However, a range of low carbon options are available at low cost but which will require extremely effective policies for implementation.
- Biomass remains an important energy source in future years; more efficient use could see reduction in resource pressures on the fuelwood supply, as well as other benefits. The projections also incorporate significant switching to electricity (due to large scale electrification envisaged). This ensures Kenya maintains a low carbon residential sector in future years.

Opportunities for carbon reduction

An indicative cost curve for Kenya (below) demonstrates that Kenya can move to a lower carbon pathway without significantly impacting on growth; in fact, many of the measures would make the economy more productive and competitive (all these below the $0 line, i.e. with a negative cost $/tCO$_2$). Many lower carbon options therefore promote rather than undermine the ambitions of growth. This is particularly the case concerning energy efficiency measures, which reduce fuel costs.



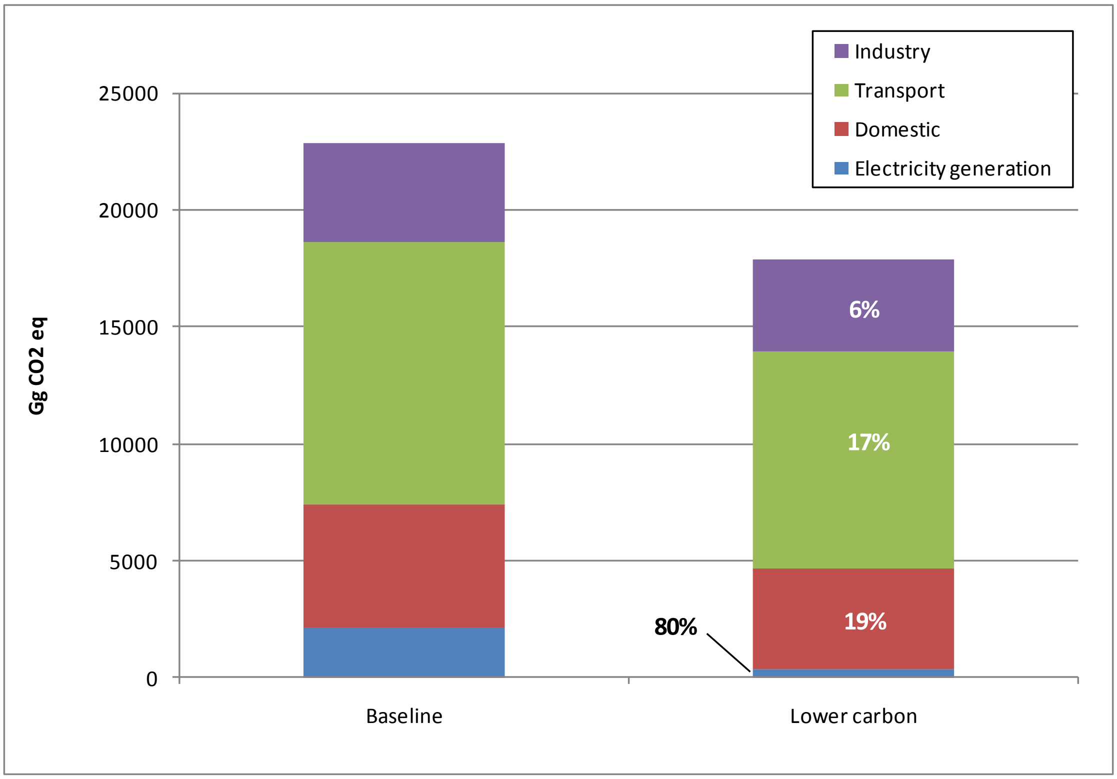
Indicative MAC curve of selected abatement measures for Kenya in 2020

All future cost and benefits are discounted at 10%, using the net present value.[3] The first measure listed in the legend is the most cost-effective, shown as the bar furtherest left on the MACC figure. Subsequent measures are listed in order of cost-effectiveness. The cost curve identifies that significant 'no regrets' potential is available (almost 50% of stated potential), particularly from improvements in transport vehicle efficiency, and performance of domestic stoves. The agriculture sector options are low cost (<$15 /tCO$_2$), resulting in no regrets / low cost options accounting for over 80% of stated potential.

[3] Agricultural and public transport measures use costs derived directly from literature and therefore the discount rate is not known.

The carbon credits that could be available for emission reductions are not included in the estimates in the above cost curve analysis. If they were, the negative cost potential would increase, and the less cost-effective options would appear more attractive, as shown by additional measures below the red line, which represents a $20 carbon price. This is an important point in the context of future potential and financing.

The emission reduction potential shown in the above MAC curve for 2020 is compared against the 2020 baseline for energy using sectors (Figure 27). These sectors have the potential to produce savings of 22% relative to the baseline. Of the potential savings, over 80% can be realised at negative or low cost.



Kenyan emission in 2020 under the baseline and *lower carbon* case

* The % labels in the *Lower carbon* case denote % reduction by sector relative to baseline

The inclusion of agriculture sector emissions results in an overall reduction of 13%. This is lower than the 22% reported above due to the high level of the emissions from this sector.

The measures shown in the above cost curve are listed below, showing what the policy driver might be for introducing a given option, and the co-benefits of the measure if indeed the measure was being appraised for carbon mitigation.

Option	***Policy driver***	***Co-benefits (as a GHG mitigation measure)***
Expanding use of renewables (centralised)	Expanding capacity to meet future needs based on strong resource base	Reduce reliance on / payments for foreign fossil imports More cost-effective across many types Leverage carbon finance to fund investment Potential to build regional expertise, and export No air quality pollution
Decentralised generation from renewables	Rural electrification	Lower cost than alternative fossil generation Limit requirements for expensive grid expansion Sustainable energy for local economic growth No air quality pollution
Introducing improved stoves	Reduce biomass demand	Reduce indoor air pollution, and therefore health impacts Reduce fuel costs Protecting fuel Saving economic / leisure time (wood collection)
Improving efficiency of road transport fleet	Reducing reliance on fossil fuel imports	Reduce reliance on / payments for foreign fossil imports Reduce costs of vehicle use Reduce air pollution Reduce road traffic accidents (due to newer cars)
Planned public transport scheme for Nairobi	Meeting urban transport demand	Reduce congestion Reduce air and noise pollution levels Save travel time / enhance productivity Reduce road traffic accidents
Tackling energy inefficiency in SMEs	Reducing industry fuel costs, increasing competitiveness	Reduce fuel costs, enhance competitiveness Enhance energy security Reduce air pollution
Improve livestock and cropland management	Improve agriculture productivity and reduce land degradation	Protect / enhance arable land quality Safeguard rural livelihoods Increase economic productivity of sector
REDD / Afforestation	Protect forestry-dependent economy and energy supply security	Protect biodiversity, and dependent sectors Ensure security of wood fuel supply

The analysis demonstrates that many of the options are important and consistent with objectives of sustainable economic growth. The costs analysis suggests that many of the above measures are also cost-effective, and can save money for the economy rather than add significant financial burden. Further work is required to develop other options and provide a more comprehensive picture of the different opportunities, building on this emerging picture of a lower carbon future.

A Low Carbon Pathway

In many sectors, Kenya is already on a low carbon pathway because of the significant renewable resources it has. This is particularly demonstrated in the low carbon intensity of the electricity generation system, the dissemination of renewable decentralised technologies (solar PV systems for homes), and the widespread use of biomass. This suggests that it is very much in the interest of Kenya to be low carbon e.g. due to the prevalence of renewable resources, this type of energy is more cost-effective than fossil-based alternatives.

The Kenyan government increasingly recognises the importance of embracing lower carbon technologies. In a recent budget speech, the Minister of Finance stated the following - *In order to move forward in* *transforming Kenya into a green economy, we will establish a Green Energy Facility to offer interest free long-term loans to firms that opt to replace conventional high cost energy generation with low cost green energy alternatives.*[4]

Such initiatives are key, as whilst Kenya has a relatively low carbon intensive economy, very high projected rates of economic and population growth are likely to see carbon intensity increase under a business as usual scenario. The question is whether it is in the interest of Kenya to push for lower carbon growth. Fundamentally, this is likely to be based on whether the additional costs of an alternative low carbon growth path outweigh the benefits. In addition, there is also the question of whether the low carbon growth path is also as resilient to future climate impacts predicted, including extreme weather events (droughts and flooding) which appear to be more frequent even in recent years.

The apparent benefits of a low carbon growth path are firstly economic. This is demonstrated in the electricity sector, which is projected to remain relatively low carbon under the baseline because of the abundance of cost-effective renewable generation potential, both in-country (geothermal) and in neighbouring countries (hydro, particularly in Ethiopia). There are however concerns that a significant future reliance on hydro may leave the system vulnerable to shortages (due to reduced rainfall or water scarcity due to demand elsewhere), and a move to more reliable fossil generation. Therefore, the issue of climate resilience is key. The low carbon generation system will also provide low carbon electricity to a rapidly expanding consumer base, displacing biomass and kerosene in the household sector. This change in consumption and a continuing significant contribution from biomass means that this sector will remain relatively low carbon in future years.

Secondly, a move to a lower carbon pathway can also mean technology improvements; economic modernisation may well push technology advancement forward, realising this important synergy. Thirdly, lower carbon growth opens the door to carbon financing; while access to such financing needs to improve for lower income countries like Kenya, it is clear that a range of financing options are being discussed that could make lower carbon options more economically attractive. Fourthly, many lower carbon options offer a range of co-benefits to social welfare, health, energy security and wider environmental quality.

Finally, as Kenya develops and meets its objectives of becoming a modern economy with increased quality of life (as set out in the Vision 2030), it may be treated differently as a developed nation under any future climate agreement. This could include setting carbon reduction targets; therefore, the carbon footprint of large-scale investments (e.g. power plant, transport systems) in the next 10-20 years should include assessment of the risks of *lock*-in to higher carbon technologies, particularly for investments that last 40-50+ years. Such investments once made are sunk and very expensive to stop operating in a lower carbon world.

Recognising the benefits as outlined above, in particular that a lower carbon pathway does not necessarily lower growth and require significant additional financing, this and subsequent analyses should focus the mind of policy makers on the opportunities for low carbon growth, particularly as the 2nd implementation plan for the Vision 2030 is developed. Importantly, it also supports many of the policy objectives that need to be met for sustainable development as discussed.

There are however significant challenges. One of the most significant is population growth and rapid urbanisation, which will put additional pressure on planning (including spatial planning) for a lower carbon future. These drivers will increase demand on energy, food and water, leading to increases in emissions. This means that opportunities for implementing lower carbon alternatives needs to be an integral element of the planning and policy making system. This would in effect remove the need to balance climate objectives (adaptation / mitigation) against economic growth consideration because they would be inextricably linked.

In conclusion, because of its location, availability of resources, and socio-economic conditions, the study concludes that there are significant economic benefits for Kenya in following a low carbon development path, as well as large environmental and social benefits. A low carbon pathway is strongly in Kenya's self interest, and would also provide potential extra investment from carbon financing. This is also important given the goal to become a middle income country by 2030, as countries of this development level will need to be

[4] Budget speech for the Fiscal Year 2009/2010 by Hon. Kenyatta, Minister for Finance, June 11 2009

reducing GHG emissions from the planned baseline level, if the global target to limit global temperature change to 2 degrees is to be achieved.

Specific recommendations from the study are as follows:

- In this initial study, emissions projections, consistent with Vision 2030 as far as possible, suggest significant increases in emissions in future years, particularly in the agriculture sector but also in a rapidly growing transport sector. There are, however, large uncertainties around Kenya's national emissions and growth path. Whilst the broad conclusions of large increases in emissions are relatively robust, further work is needed to improve these initial estimates and to give a degree of confidence in the analysis and this is a priority research areas.

- In many areas, Kenya is already initiating measures and policies that are consistent with low carbon development. This includes the electricity sector power emissions. However, the current plans do not maximise the economic potential that could be gained. In many sectors, the current plans are likely to ‘lock-in’ Kenya to a higher emission pathway, which will reduce future economic opportunities and are also likely to reduce future economic growth. An example already existing in the electricity sector with the planned implementation of coal fired generation. These need to be identified and ideally, alternatives considered.

- The study has outlined an alternative low carbon path for Kenya. This initial analysis estimates very real economic, environmental and social benefits from adopting a low carbon development path. These include both direct economic benefits (no regret opportunities), additional economic benefits from carbon financing, and wider economic benefits from ancillary benefits of these policies, including reduced imports, improved air quality, improved energy security, reduced pressure on natural resources. The key aim for Kenya is to continue this switch to a lower carbon pathway, to further realise these benefits, and to maximise the potential for the flow of carbon credits under existing and future mechanisms. Further assessment of how far Kenya goes down the low carbon pathway is needed, to robustly assess the full costs and benefits.

- Unlike other countries, power generation is a very low proportion of total emissions, and will continue to be so in the future under the baseline Vision 2030 projections. It is therefore a priority to tackle these other sectors, because in contrast to the power sector, emissions from these sectors are already increasing, and are projected to rise dramatically in the future along the development pathway towards a middle income country. These must also be addressed to achieve low carbon growth – and we emphasize that addressing the electricity sector is only a small part of the overall story. A key conclusion and recommendation is for the need for Kenya to move beyond the narrow interpretation of low carbon in just the electricity sector, and progress at an economy wide level.

- While the electricity generation sector plans project a low carbon future, there are some risks, and therefore more work should be undertaken to consider the following:
  - Exposure to climate impacts. Kenya will be very exposed to regional variability in rainfall due to domestic and imported reliance on hydropower. There is a need to build climate risk screening into future low carbon plans across all sectors
  - Exposure to system reliability problems. A high renewable system can carry risks if specific resources do not achieve projected generation, hydro being the obvious example. Kenya maybe reducing exposure in future years by maintaining fossil based generation
  - Energy security concerns. Future reliance on imports are premised on large infrastructure projects being completed, and political stability in the region

- Agriculture and transport remain the large emission growth sectors. For transport, while efficiency gains offer significant opportunities, the demand for private transport is going to increase significantly. This is a much harder to problem to solve but will require a robust strategy that considers improved public transport, demand management, and urban planning. Key barriers include large upfront costs associated with transport schemes, and costs to private individuals to purchase newer efficient vehicles, or more advanced technologies. The transport strategy that accompanies the Vision 2030 needs to be more robust in firstly assessing how the growth in transport demand will be met, taking account of sustainability issues. For agriculture, although low carbon options appear low cost, they are difficult to implement due to many small holdings and fragmentation of the land; therefore high transaction costs could be envisaged.

- The domestic sector remains a large consumer of biomass due to population growth, but has a much lower per capita usage. This is largely due to large-scale access to electricity, enabled by increasing urbanisation but also efforts to expand rural electrification. More research is needed to establish alternative pathways that do not see large scale electrification.

- The strategy for the forestry sector is also very important; large scale afforestation is planned as is the need to protect existing cover. New financing schemes such as REDD / REDD+ will be critical in ensuring that this happens due to the significant investment required. Kenya needs to be well positioned to take advantage of the schemes that may emerge post-Copenhagen.

- To realise the many low carbon opportunities requires the mainstreaming of mitigation policy across all part of the economy and across all of Government. Following from the points above, it would be extremely beneficial for Kenya to undertake a detailed assessment of a low carbon strategy including a detailed investment and financial flow analysis. This would identify no regret and low cost options that are justified on the basis of ancillary benefits. It would also be advisable for Kenya to strengthen its capacity to develop and implement proposals for any future schemes (programme CDM, NAMAs, REDD, etc). This would also require significant development of projections, which form the basis of understanding cost-effective potential. In combination, there is also a need to investigate the potential for further funding by exploiting synergies with adaptation.

- Related to this there is a need to re-assess the Vision 2030 document in light of the potential for low carbon growth and opportunities for growth, but also potential barriers to growth that might arise from the future global carbon market, particularly in relation to key growth sectors that have high carbon intensity or international links.

  This action is vital to address the issues outlined. More importantly it would give Kenya a first mover advantage to act quickly, and to seek funding for this plan, through whatever negotiating positions and mechanisms emerge.

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23/11/2009

Technical report on Low Carbon Growth Issues produced as part of the DFID/DANIDA funded study on the Economics of Climate change in East Africa.

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The Stockholm Environment Institute (SEI) is the main contractor for this resource centre assignment. SEI is an independent, international research institute. Their researchers have been engaged in environment and development issues at local, national, regional and global policy levels for over a quarter of a century. The Institute was established in 1989 following an initiative by the Swedish Government to create an international environment and development research organisation. Since then, they have established a reputation for rigorous and objective scientific analyses of complex environmental, developmental and social issues. They are well known for work on scenarios, sustainability modelling and vulnerability assessments, which improve public policies and catalyse global transitions to a more sustainable world. They seek to be a leader in the field of sustainability science, understanding the interaction between nature and society, and improving the capacities of different societies to move to more sustainable futures.

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5 Consortium comprises Harewelle International Limited, NR International, Practical Action Consulting, Cranfield University and AEA Energy and Environment.

1) Introduction

The DFID study *Economic Impacts of Climate Change in Burundi, Kenya and Rwanda* has a number of key aims, as set out in the Terms of Reference:

- To assess the potential impacts of climate change on key sectors on the economy and non-market sectors (such as health) so countries can understand what is at stake for them.
- To stimulate government, private sector and civil society actions to develop and implement policies to adapt to and mitigate (depending on international incentives) climate change.
- To provide an evidence base to inform and guide government's negotiation position for COP 15.

This report focuses on the second objective, assessing opportunities for low carbon growth that reinforce progress towards the ambitious development goals of Kenya. In addition, it assesses opportunities that are compatible with and where possible enhance adaptation goals and strategies, and benefit other policy areas (e.g. environment and health, energy security). In this way, Kenya can move towards being a low carbon society, ensuring strong economic growth, reducing reliance on fossil imports and benefiting from future international incentives on climate change. The UK Government in their recent *Road to Copenhagen* report stated that *by taking action now, developing countries have an opportunity to adopt a different growth path, leapfrogging outdated technologies to become some of the first movers towards a sustainable economy* (DECC 2009).

It is important that the rapid economic development that Kenya is aiming for is not compromised by low carbon growth, particularly because Kenya is a low emitter in absolute and per capita terms relative to other developed and developing countries. Even in future years, the level of emissions under a rapid growth scenario will still remain relatively low in absolute terms. Low carbon options must therefore not result in unsustainable cost increases, or in economic terms, any additional costs should not outweigh the additional benefits. This analysis attempts to focus on examples where low carbon options could be integrated into strategic economic planning, and to highlight the associated benefits (economic, social and environmental). It is therefore not a full low carbon strategy assessment but rather a first review of the opportunities that could lead to a lower carbon growth path.

An overview of the steps in this analysis is provided in Figure 1 below.

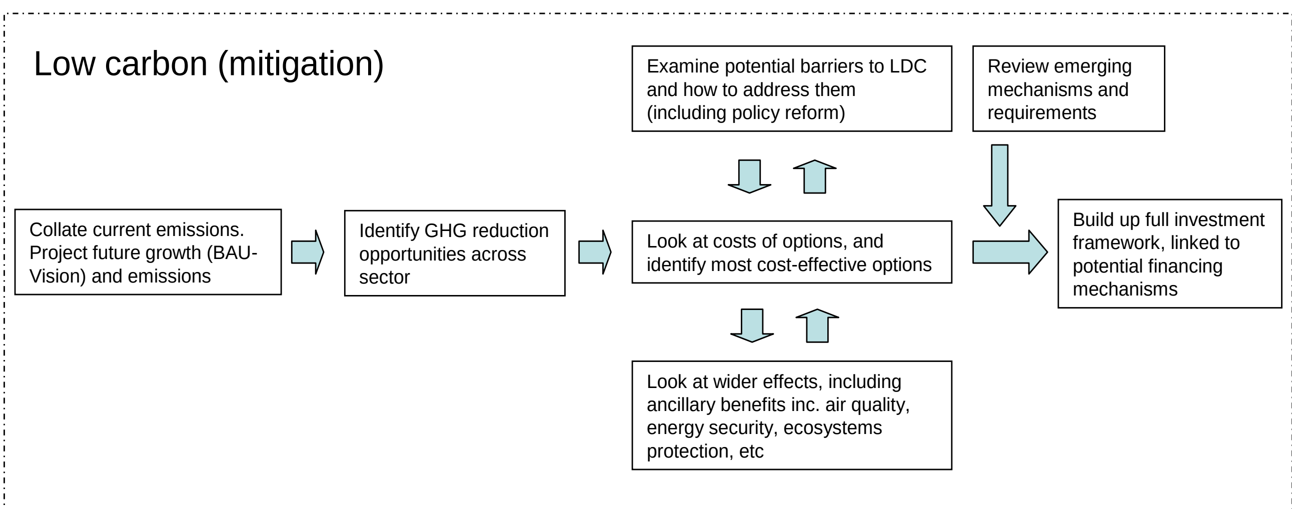


Figure 1. Schematic overview of low carbon growth analysis

Section 2 of the report describes the current GHG emissions level, provides an overview of the key emission sources and describes how they have changed since the first assessment under the First National Communication.

Section 3 of the report describes the emissions projections (for each sector) that are being developed to produce a reference scenario, for Kenya based on the assumptions around economic growth, population growth and urbanisation.

Section 4 outlines the potential options for emission reductions in future years, including case studies of options being implemented in Kenya. This section draws on the wider literature to examine the main options, and their cost-effectiveness plus a range of wider effects. It also seeks to identify the main barriers to implementation.

Section 5 presents possible low carbon growth pathways for Kenya, indicating the cost-effectiveness of different options.

Section 6 presents policy recommendations emerging from the analysis, to help inform the Kenyan position on low carbon growth prior to Copenhagen 09, with a view to developing a full investment framework.

2) Current GHG emissions in Kenya

In global terms, Kenya is a low emitting country, both on an absolute and per capita basis. In 2000, according to comparisons provided by WRI CAIT (Climate Analysis Indicators Tool), Kenya ranked 76th in the world in respect of total emissions (exclude LUCF sinks / sources), and 157th in the world on a per capita basis (1.5 tCO_2 per capita).[6]

The only national published estimates of GHGs in Kenya that the team has been able to find during the study are those submitted in Kenya's First National Communication (GoK 2002), and are for the year 1994. More recent work has been undertaken on the Second National Communication; however these estimates have not been available during the study period, scheduled for publication early next year.

GHG emissions reported under the First National Communication

Kenya's First National Communication (GoK 2002) provides estimates of GHG emissions for 1994 based on revised inventory guidelines published by IPCC in 1996. Total GHG emissions in 1994 were estimated to be 21,466 Gg CO_2 eq, excluding LUCF. Emission estimates by GHG are shown in Figure 2 and Figure 3 by sector, excluding and including the LUCF sector.

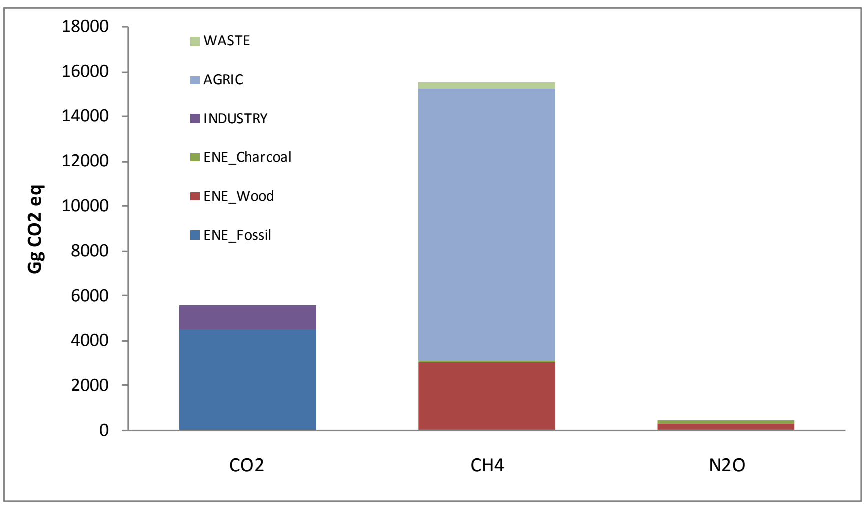


Figure 2. CO_2 eq. emissions (Gg) in 1994 by GHG (excluding LUCF)

[6] World Resources Institute Climate Analysis Indicators Tool (v6.0) http://cait.wri.org/ The 2005 CAIT value is much lower at 0.3 tCO2 / capita because the dataset only includes CO_2 emissions. In this project, emissions of 1.3 tCO2e / capita in 2005 have been estimated.

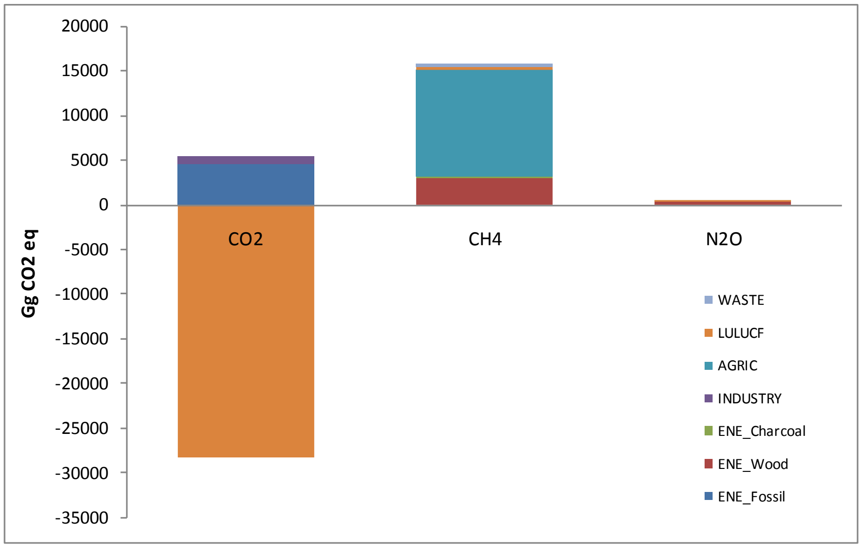


Figure 3. CO_2 eq. emissions (Gg) in 1994 by GHG (including LUCF)

This assessment estimates that emission removals from the LUCF sector total 28,000 ktonnes CO_2 eq. Approximately 34,000 Gg are sequestered and 6,000 emitted (due to forest removal and land use practices). This annual sequestration of CO_2 by forests shows Kenya to be a net sink of GHGs, with a total of -6,534 Gg CO_2 eq. According to the 1st National Communication, most of the removals were estimated to be from non-forest trees (e.g. farm grown trees) and plantations rather than natural forests (GoK 2002).

It is important to stress that LUCF estimates from the 1994 inventory are subject to significant uncertainties due to lack of data on the forestry stock, and the use of a simple tier estimation approach. New estimates should soon emerge as part of the 2nd NC publication, which should provide more robust estimates based on a more up-to-date IPCC guidance and improved stock information.[7] In addition, since 1994, rates of deforestation will undoubtedly have reduced

In terms of total national emissions of greenhouse gases, agriculture is estimated to be the largest source, due to methane emissions from enteric fermentation in livestock (accounting for 95% of total emissions). Sugar cane and rice production account for most of the remaining methane emissions. N_2O emissions from this sector are low due to the limited application of fertilisers in Kenyan agriculture. Energy is the second largest source, with the majority of emissions from the transport sector (emitting 65% of total CO_2 through consumption of oil based products) but also some emissions arising from household / cottage industry biomass burning (CH_4 emissions). CO_2 emissions arising from the burning of biomass are not included in the official inventory, as these are viewed as a renewable source, and carbon-neutral. The third largest source of emissions (although much smaller than agriculture and energy) is the industry sector, primarily due to CO_2 process-based emissions from cement and lime production.

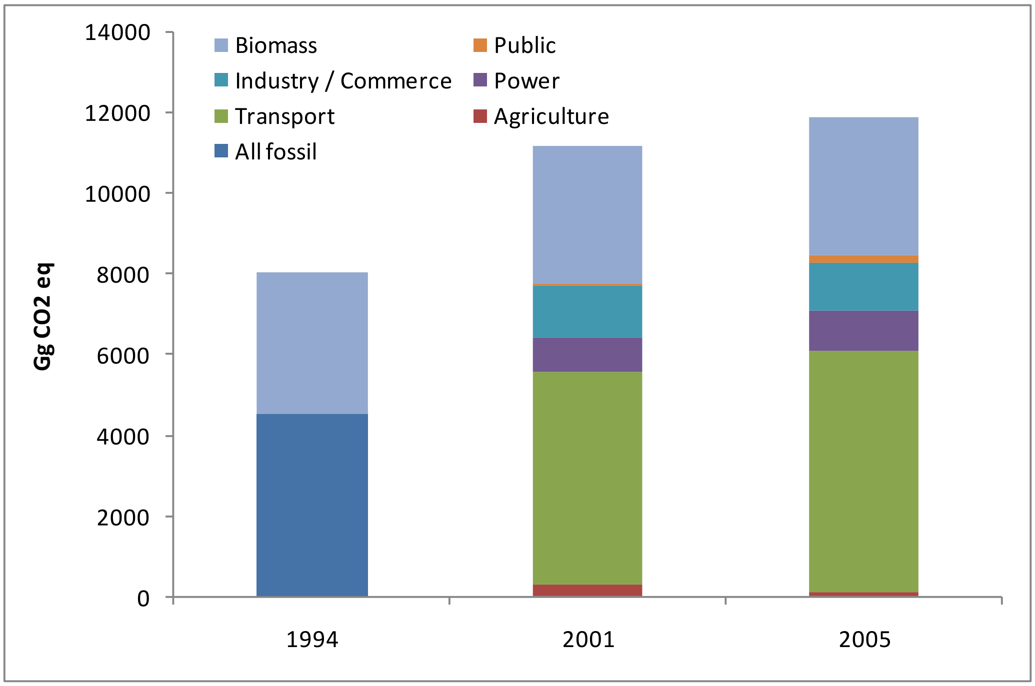
A major missing sector appears to be N_2O emissions from agricultural soils, which are not reported. This is particularly apparent given that Kenya has such a large agriculture sector. The MNP EDGAR dataset (Olivier et al 2005), one of the sources used by the CAIT database, puts Kenya's emissions of N_2O at 19,600 Gg CO_2 eq. This equates to 40% of the CAIT estimate of 48,100 Gg CO_2 eq.

Revised GHG estimates for the energy sector

The Second National Communication is under development although these numbers have not been available for use in this analysis. Some work has been done in the course of this analysis to update the

[7] Recent estimates of forest stocks still appear to be highly uncertainty (Kenya Forest Service (2009))

energy sector emissions, using published energy statistics from the Government of Kenya[8], and a basic Tier 1 estimation approach, based on the latest IPCC inventory guidelines (IPCC 2006). These updates have been compared to those from the 1st National Communication (for 1994) in Figure 4.



*** Biomass value used for 2001 / 2005 sourced from 2000 consumption data**

Figure 4. CO_2 eq. emissions (Gg) from energy sector (petroleum products and biomass) (1994-2005)[9]

The revised estimates show a significant increase from 8,000 to 12,000 Gg CO_2 eq. The largest contributor is the road transport sector, as was probably the case in 1994 (although the sector splits for 1994 are not available). Estimates of biomass between 1994 and 2000 (shown in the 2001 / 2005 columns in the absence of more recent information) are at a similar level, at around 3.5 Mt CO_2 eq. The comparison of these estimates is reasonable, as there have been limited changes in Tier 1 inventory approaches for these energy sectors.[10]

[8] Kenya National Bureau of Statistics, http://www.cbs.go.ke/
[9] Non-biomass estimates from the energy sector are based on aggregated petroleum product data (without the product split) using a Tier 1 estimation approach; they have been estimated in the absence of information from the Second National Communication
[10] 1994 estimates are based on IPCC Revised 1996 guidelines whilst estimates for this study use 2006 guidelines (IPCC 2006)

3) Projected GHG emissions for Kenya

Vision 2030

The blue print for the development of Kenya over the next 20-25 years is set out in the Government's Vision 2030 document (GoK 2007). In this document, the Government states that Kenya aims to be a *globally competitive and prosperous country with a high quality of life by 2030* and a *middle-income country providing high quality of life to all its citizens.* The economic growth targets set are high (compared to recent growth rates achieved), with an aim to achieve an average GDP growth rate of 10% per annum by 2012. Millennium Development Goals (MDGs) are expected to be met by the 2015 deadline. The Vision 2030 is planned to be implemented in successive five-year Medium-Term Plans, with the first such plan covering the period 2008 – 2012 (GoK 2008).

Note that alternative projections of economic growth will affect the potential level of emissions, and the potential for low carbon growth opportunities. For the study, the primary baseline used has been consistent with the Vision 2030 document. However, some sensitivity analysis has been undertaken to investigate the likely implications of alternative economic projections.

The purpose of economic growth is to increase the level of development, crucially reduce poverty levels and increase standards of living for a large part of the population. The specific economic objectives will be supported by improved and expanded infrastructure and greater provision of modern energy services that are affordable. In addition, increased investment in social provision – sanitation, health, education, and housing – will be strengthened. Strengthening political institutions and democratic process are also key to realising the Vision.

The projected economic growth is predicted to be driven by key sectors including tourism, agriculture, wholesale / retail, manufacturing, BPO, and financial services (see Box 1).[11]

[11] Note that many of the specific targets in the Vision 2030 document relate to the short term, as set out in the 1st Medium Term Plan (2008-2012). Few quantitative targets / indicators are provided for the longer term.

Box 1. Vision 2030: Key sector for economic growth

- Expand tourism sector: by 2012, quadruple tourism's GDP contribution to more than KShs. 200 billion; and raise international visitors from 1.6 million in 2006 to 3 million; *implies potential doubling of aviation emissions*. Kenya wants to be in the top 10 long haul destinations.

- Increasing value in agriculture through greater processing of products and increasing yields, increasing productivity and utilization of medium / high potential land (only 31% used for agriculture or 5% of land area) and developing ASAL areas (84% of Kenya) for livestock / crops. A growth rate of 7% (currently 5%) over the next five years is the near term objective.

- Modernisation of wholesale and retail sector, including developing informal businesses into formal sector modern business, and creating a duty-free zone to promote Kenya as business hub in East Africa. Improving infrastructure and business environment also key.

- Increasing manufacturing goods share in regional market, from 7 to 15% and create global niche products e.g. in the agro-industry sector and increase local production capacity. Currently, largest sectors (in GDP contribution terms) are food processing (29%), refining (11%) and textiles / apparel (7%). Most industries produce basic products rather than skill-intensive products e.g. pharmaceuticals.

- Provision of business services to rest of the world – known as Business Process Offshoring (BPO), and development of financial services sector

Source: GoK (2007)

Higher GDP levels and a rapidly expanding population will drive increased demand for energy, transportation and food, inevitably leading to significant increases in GHG emissions and other associated environmental problems unless energy or emissions can be decoupled from growth. The population in 2030 is projected to be more than double that of today, with very high levels of urbanisation (+60% by 2030), as shown in Figure 5 below. Nairobi, with 3 million inhabitants, is projected to have more than 14 million inhabitants by 2030 (according to Vision 2030). It is suffice to say that any country would face significant challenges of addressing environmental issues when faced with high economic growth and rapid population.

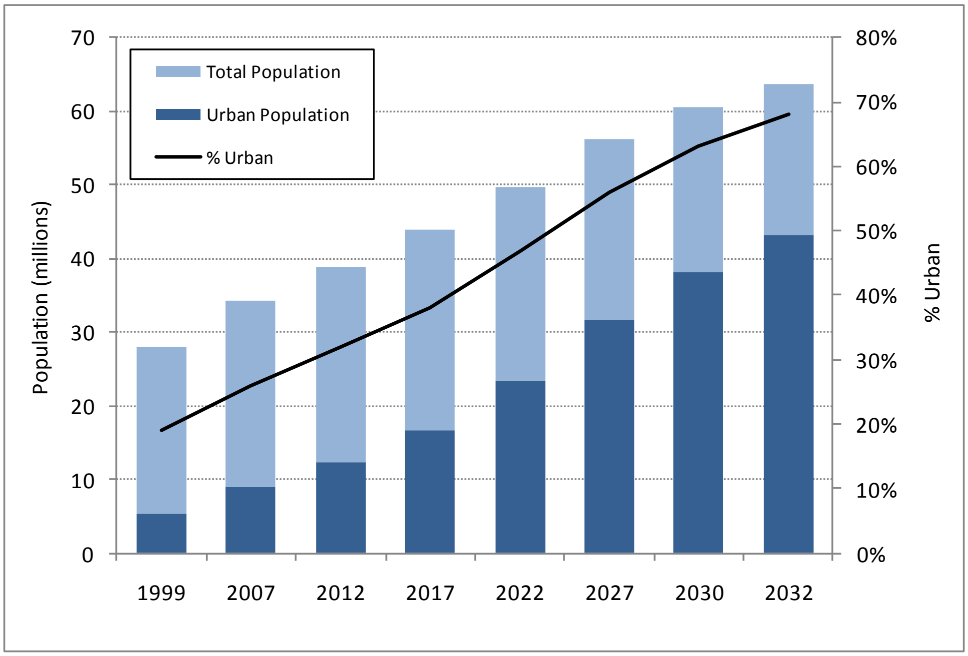


Figure 5. Population growth and rate of urbanisation in Kenya, 1999-2032

Note that the estimate of the total population is similar though slightly lower than the United Nations[12], which estimates a population of 41 million in 2010, 52 million in 2020 and 63 million in 2030 for Kenya (median variant). However, there are greater differences for urbanisation rates and the population growth of Nairobi. The 2007 UN World Urbanization Prospect Revision[13] estimates that the urban population of Kenya will grow from around 8 million currently to 13 million by 2020 and 20 million by 2030. It predicts a much lower population growth for Nairobi than predicted in the Vision, rising from around 2.8 million currently (2005) to around 4.9 million by 2020 and only 5.9 million by 2025. These different growth projections are important when looking at the potential uncertainty in future emissions and also abatement potential.

As highlighted above, the Vision 2030, as far as possible, provides the basis here for assessing future growth in GHG emissions. This seems reasonable, given that this is setting the broader ambition and goals for Kenya's development, which are being implemented through the 5-year Medium Term Plans. However, for some sectors this has proved difficult because there is limited quantification of the longer term (2030) ambition in the current Vision document, with greater focus on near terms activities (pre-2012) in the MTDP.

Projections for each sector are now assessed in turn.

Electricity Generation

In the context of enabling future economic growth in Kenya, the electricity generation sector has a pivotal role to play, in delivering modern energy services that are affordable. Future generation also has the potential to be low carbon, given the wealth of renewable sources in Kenya and sub-Saharan Africa. A low carbon generation system could have significant benefits for ensuring prices are affordable in the medium and long term,[14] enhancing energy security, reducing payments for fossil fuels and reducing air pollution and also other environmental burdens. These benefits of course will only be ensured if the supply of electricity is reliable, and system operation is not compromised (e.g. by a renewable-dominant system). In this context,

[12] World Population Prospects, 2008 Revision Population Database (Median variant)
[13] http://www.un.org/esa/population/publications/WUP2005/2005WUP_DataTables3.pdf
[14] Prices may go up in the short term. The average price of electricity is expected to increase because new power development is carried out on the basis of a rolling 20-year Least Cost Power Development Plan. The Plan requires that the next least cost project be brought into production. This has implications on future tariffs, which are likely to increase over time, and it also means that new sources of electricity to be developed are likely to be more expensive than those already developed *ceteris paribus* (Mwakubo et al. 2007).

the resilience of the energy system to future climate change itself is important. This is assessed in the main climate change impacts and adaptation section, which has investigated the potential effects of climate change on the main hydro system of the Tana river.

Currently, the electricity generation sector is viewed as acting as a barrier to economic growth, with high costs cited as one of the main problems (UNEP 2006). The cost of electricity in Kenya is four times that of South Africa, and more than three times that of China. Unreliability of supply compounds the problem of high cost. On average, Kenyan companies lose 9.5% of production because of outages and fluctuations (excluding the losses from damaged equipment). These issues have come to the fore this year due to the prolonged drought, and this has led to significant power restrictions, and high economic costs (from outages). This repeats a pattern seen in previous extreme seasons, and is discussed and assessed in the main climate change impacts section of the study.

Network problems also result in large amounts of unmet demand. Many people have paid connection fees and are yet to receive electric power. In 2000, the unmet demand for electricity was approximately 25% (Mwakubo et al. 2007).

Box 2. Summary of issues with current electricity system in Kenya

- **Relatively high energy costs.** Energy cost in Kenya is US$0.150 per KWh. This is high compared with Mexico (US$0.075), Taiwan and China (US$0.070), Colombia (US$0.064) and South Africa (US$0.040)

- **Losses due to power outages.** Due to over-reliance on hydroelectricity, the frequency of power outages is high (33 per cent compared with the average for Mexico, China and South Africa, which stands at 1 per cent). Production lost due to these outages is approximately ~9.3% (compared with the average for Mexico, China and South Africa, which stands at 1.8 per cent)

- **Long wait for connection.** It takes approximately 66 days to obtain electricity connection in Kenya (compared with an average of 18 days in Mexico, China and South Africa)

- **Grid losses**. Losses are estimated to be 18.4%, inclusive of distribution and theft, which is considered high relative to other countries. This figure is expected to decline to 15% by 2007 and 12% by 2025

Source: GoK (2007), UNEP (2006)

Existing system

The current system size is small relative to the population, at 1.3 GW installed capacity (in 2006/07). This is reflected by the very low per capita electricity consumption levels. Generation is dominated by hydropower (57%), primarily from hydro stations on the Tana River, followed by thermal power, primarily diesel (33%), and finally geothermal (10%) (KPLC 2008).

Installed capacity for the year 2006/07 is provided in Table 1 below.

Table 1. Capacity of electricity generation plants in Kenya, 2006/07

Generation type	*Installed capacity (MW)*	*Effective capacity (MW)*	*% Effective capacity*
Hydro	737.3	719.4	57%
Geothermal	128	128	10%
Wind	0.4	0.4	0%
Diesel (Central)	205	190	15%
Diesel (Rented)	150	146	12%
Gas	73.5	70	6%
Cogen	2	0	0%
Total system	**1296.2**	**1253.8**	**100%**
Diesel (Isolated, Off grid)	11.3	9.7	

Electricity purchased in 2006/07 was 6,169 GWh in 2006/07, across 924,520 customers (across all sectors). Access to grid based electricity is limited, with the distribution system primarily limited to urban areas. The % of rural households using electricity is <4%. For the low income urban population, it is 26%, while for higher income groups it is >80%. It is estimated that 15.3% of the 33 million population have access to commercial electricity, putting per capita consumption at 121 kWh (ESD 2005). Rural access is increasing rapidly, albeit from a low base; under the Rural Electrification Programme (REP) customers increased by 22,323 to reach 133,047 in 2006/07, representing a 20% growth from the previous year.

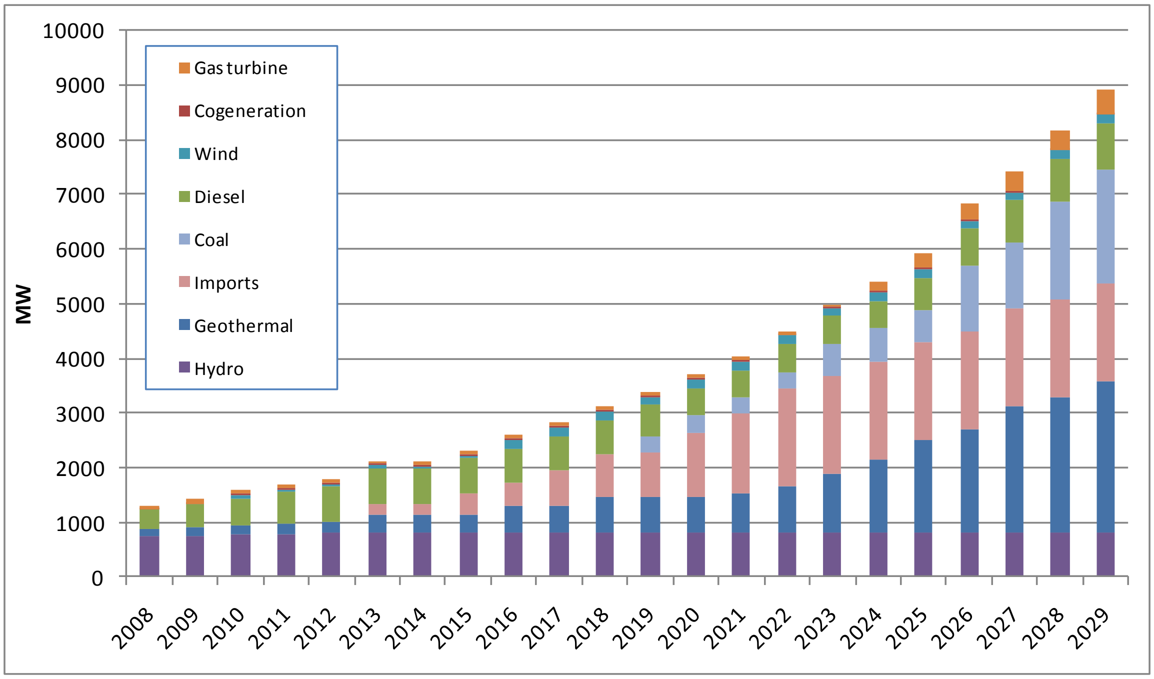
Other renewable resources (solar and wind) are also being used to produce electricity, albeit it at a low level at present; current wind installed capacity is 750kW, 600 kW of which is grid connected. However, the potential is much greater, with identified 'good' sites (>7m/s) providing up to 100 MW, with the best resources in the north of the country (see Turkana Wind Farm project Case Study). Some 120,000 rural households have solar systems; combined with other systems, this equates to over 4MW capacity (ESD 2005).

The Least Cost Power Development Plan (LCPDP)

The Kenyan government has put in place a Least Cost Power Development Plan (LCPDP), which plans for new build of generation capacity out to 2030 based on the forecasted growth in demand for electricity. The growth targets outlined in Vision 2030 provide the basis for this growth in demand. The plan takes into account planned projects and formulates the mix based supply mix requirements, costs of generation and resource availability (KPLC 2008). The LCPDP is consistent with Vision 2030 and provides an official view of new capacity requirements in the future. It has therefore been used as the basis for emission projections used in this study.

Total generation is projected to increase from 6,928 GWh in 2008/09 to 47,913 GWh in 2028/29 based on an average growth rate of 10% in the forecast period.[15] This requires an additional 7.6 GW on current installed capacity (of 1.3 GW) between 2008 and 2029 (as shown in Figure 6 below). The main growth is through imports (an additional 1790 MW in 2029 relative to 2008), geothermal (an additional 2640 MW) and coal (an additional 2100 MW). Imported power is primarily sourced from Ethiopian hydropower. Gas was not considered due to lack of regional resources for supply.

[15] Supplied electricity is about 18% lower due to plant own use (1.2%) and system losses (16.8%). In later years, losses are assumed to be lower, at 14.5%.



* Small cogeneration capacity level is bagasse cogeneration at Mumias sugar

Figure 6. Growth in installed capacity by generation type (2008-2029), LCPDP (KPLC 2008)

The generation by plant type has been calculated as part of this study to try and match the profile provided in the LCPDP and is shown below. It is therefore an approximation, as the assumed utilization factors are not provided in the LCPDP. Geothermal is used as a baseload plant whilst new coal plant are not, but presumably a back-up when other plant are offline. Hence, for coal, a 20% utilization factor has been assumed while for geothermal this is set at 85%.

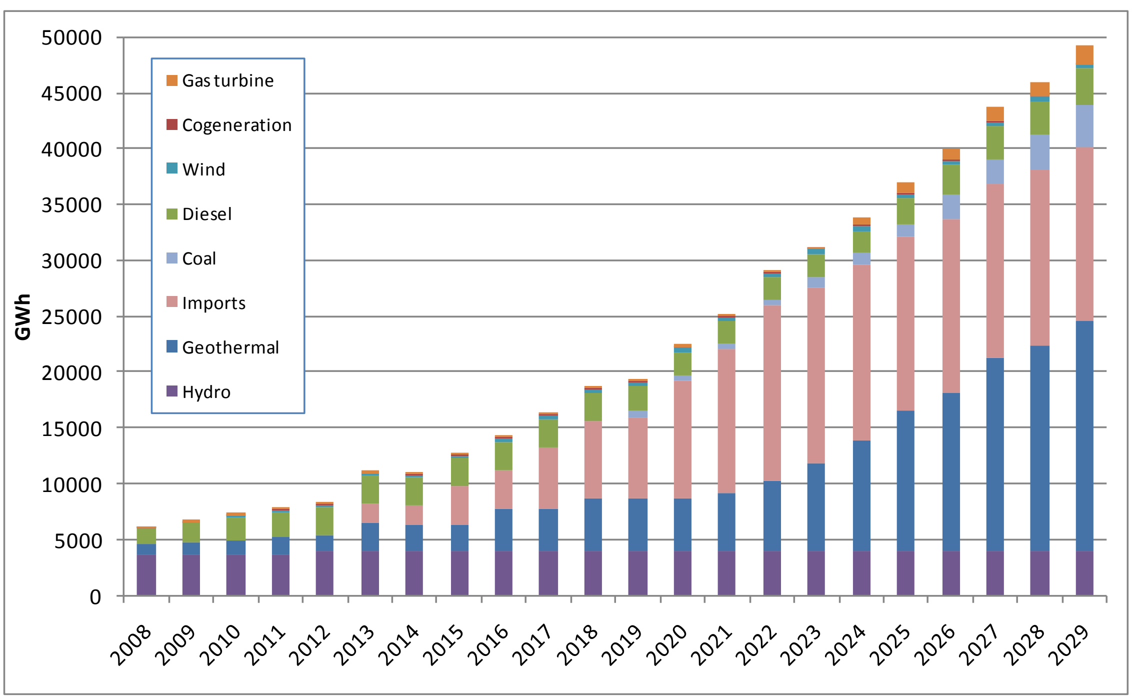


Figure 7. Projected generation levels by type (2008-2029)[16]

[16] Estimated based on assumed utilisation factors, approximated to generation levels observed in the LCPDP

Grid system development and integration

The increase generation capacity will require a significant amount of upgrade and extension work to the current transmission and distribution system. This is to ensure the system can deal with the greater load, improve reliability, increase access to regional markets / providers (through additional interconnectivity) and increase the customer base, particularly in rural areas. Many different grid system projects are already committed, as set out in the LCPDP (KPLC 2008).

KPLC is implementing a plan to increase its customer base by 1 million through a scale up policy in five years from 2009/10, having just registered its one millionth customer in January 2008. In addition to the Rural Electrification Programme, the Energy Access Scale-Up Project aims to increasing access to electricity in rural areas in Kenya from the estimated 5% to 20% by 2010 and 40% by 2020.

Regional markets will become increasingly important if Kenya's forecast demands are to be adequately met. Based on our calculations (as above), imports could meet 35% of total demand in 2017, rising to over 50% by 2021. This then drops to 43% by 2025 and 32% by 2029 as the contribution from domestic geothermal generation increases. A major source of the imports will be Ethiopia, the proposed interconnector for which is at the feasibility assessment stage. This regionalisation of the electricity network may also hold prospects for countries being able to benefit from the sale or use of low carbon electricity in reducing per capita emissions.

Some imports to Kenya already come from Uganda (between 30-50 MW); however, much greater regional integration is being considered by the East African Community (EAC). A study has been undertaken by Kenya, Uganda and Tanzania, assessing the viability of interconnected grids. Based on this study, a pooling arrangement is being pursued under the EAC and the proposed East African Community Power Pool (EACPP). In the wider Eastern African region, increased regional power grid integration through the Eastern African Power Pool (EAPP) is also being considered. There has been assessment of linking in with the Southern African Power Pool (SAPP); an interconnector project with Tanzania is near inception using Dutch funding. Both this interconnector and the Ethiopia project are projected (in context of the LCPDP) to be completed between 2012 and 2014. Another important regional initiative called the Nile Basin Initiative (NBI) has been assessing the feasibility of greater integration of electricity distribution systems across NELSAP countries.[17] Pertinent to Kenya under this initiative is the second interconnector with Uganda, which will enhance power exchange between the two countries particularly after Uganda increases its capacity through planned hydropower projects.

Projected emissions

The electricity projections above have been used to estimate the potential CO_2 emissions from the system, calculated using the forecast generation levels, using typical assumptions to characterise generating efficiency (on an annual basis). The emissions are shown below. Emission levels increase markedly after 2020, due the use of coal generation, increasing by about three times from a level of 2000 Gg CO_2. This is shown in Figure 8, on the left hand axis.

The analysis has also calculated the average carbon intensity of generation, estimated from dividing the total emissions by total electricity generated. This gives an estimate in terms of gCO_2/kWh. This estimate provides a means to show the relative carbon emissions per unit of generation over time, and so map whether the overall system is following a lower carbon path. This is shown on the right hand axis and on the red line in the graph.

[17] Nile Equatorial Lakes countries (NELSAP) covering Uganda, Rwanda, Burundi, Tanzania, Democratic Republic of Congo (DRC) and Kenya

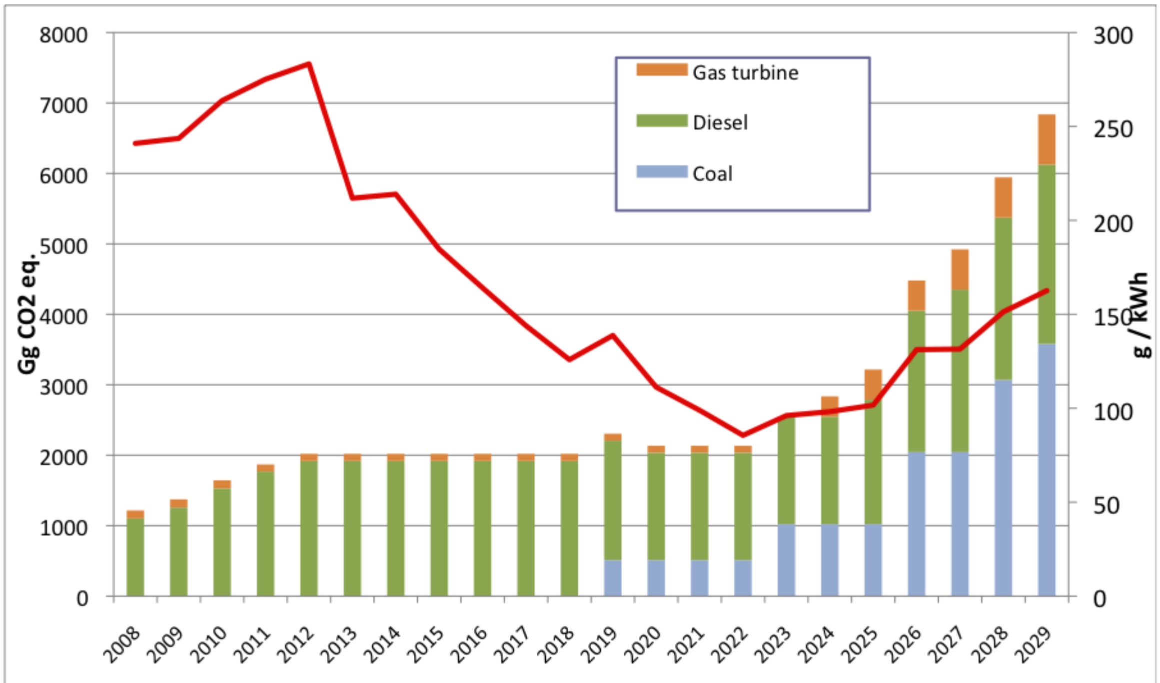


Figure 8. Projected CO_2 emissions by generation type (2008-2029)[18], and CO_2 intensity of generation (g/kWh)[19]

The carbon intensity of the generation system is relatively low in 2008, due to the high contribution from hydropower (230 gCO_2/kWh). This drops to very low levels by 2022 because the increasing system capacity is primarily driven by imports and new geothermal plant. Only after this point does the intensity start to increase due to coal and additional oil-based generation though still remains at a relatively low level (150 gCO_2/kWh), and below that observed for the current system. However, the increases post 2020 are important because they correspond to a time when there is likely to be much greater pressure on global carbon reduction, and also far greater opportunity (in terms of total and price per unit) for carbon credits.

A choice of coal in the generation mix to introduce coal in early year, and the planned increase in a decade or so, therefore has the potential to '**lock-in' high carbon coal plants** into the Kenyan generation mix. We consider that this might significantly reduce future carbon reduction potential, for example associated with programmatic or national mechanisms.

There are a range of uncertainties and issues that require further consideration in the above projections (although beyond the scope of this assessment). These include:

- **Heavy reliance on imported electricity from hydropower primarily from Ethiopia.** The LCPDP estimates that up to 1,000 MW can be imported from Ethiopia before the year 2020. Phase II of the project (post 2020) would see imports increase to a maximum total of 2000 MW. An important aspect of the LCPDP analysis that seems to be missing is the impact of future climate change on hydropower resources. Current evidence appears to suggest greater variability in rainfall although not reductions in annual averages. Greater variability could have significant impacts for given years, particularly with Kenya already heavily dependent on domestic hydropower. In the 2000 drought, the worst since 1947–51, the contribution of hydroelectric energy to the national grid was reduced by 41 percent, from 3,063 GWh in 1999 to 1,794 GWh (Mogaka et al 2006). Vulnerability is increased as most domestic hydropower is on the River Tana, which means that problems in this catchment area could threaten overall hydro potential.[20] Only Turkwel power station is on a different water catchment

[18] Assumed efficiencies: gas (45%), coal (35%), diesel (35%). All oil based generation assumed to be diesel not HFO, so emissions might therefore be underestimated.
[19] Generation levels adjusted for losses before intensity calculation
[20] In July 2009, the Kenya Electricity Generating Company said poor and late rains had forced the closure of the 14 megawatt Masinga plant on the Tana River, the country's largest plant. http://news.bbc.co.uk/1/hi/world/africa/8128681.stm

basin. Risks will be reduced once the Sondu Power project is completed and online (Mwakubo et al 2007).[21] The Vision 2030 document (GoK 2007) already highlights the high reliance on hydropower (and vulnerability to drought), stating that the frequency of power outages is higher than other countries.

The energy security issues are also significant; climate variability and the lower availability of water for hydro generation could be compounded by political turbulence which disrupts electricity imports. In addition, the potential of hydro resources will only be realised if the significant infrastructure investment in Ethiopia go ahead.
Figure 9 shows a situation whereby a forecasted 30% reduction in imports from Ethiopia is replaced by diesel (30%) and coal generation (70%).

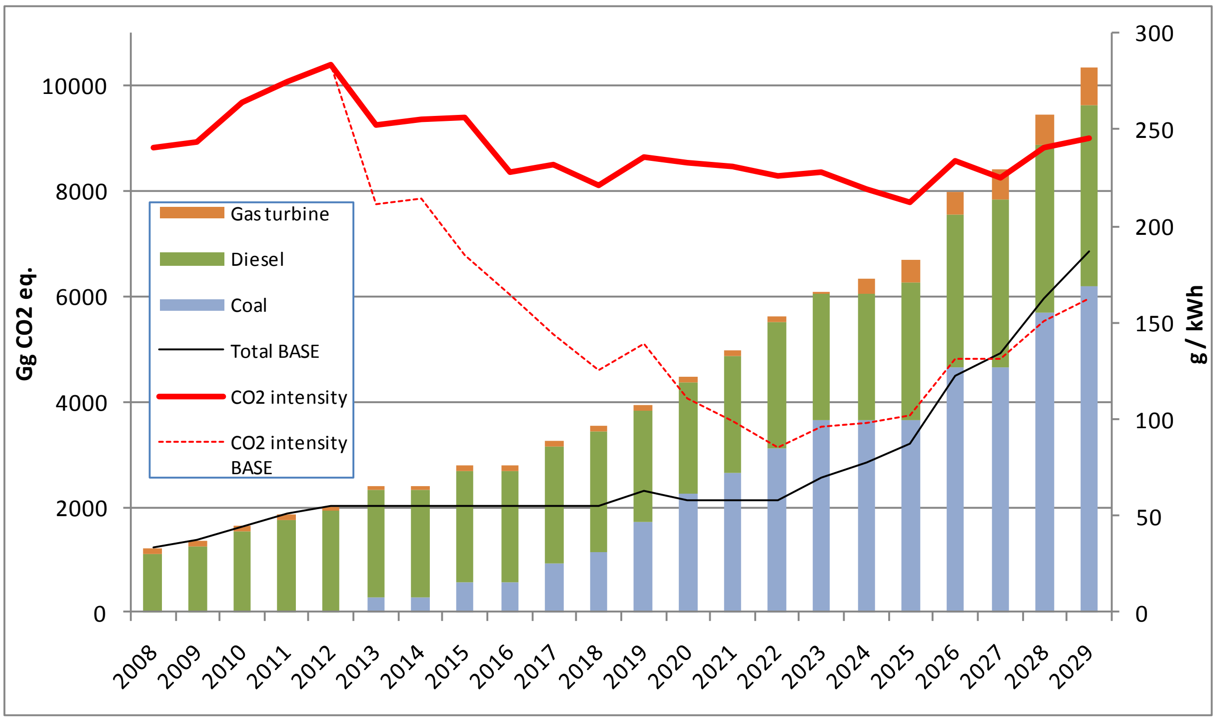


Figure 9. Projected CO_2 emissions by generation type (2008-2029), and CO_2 intensity of generation (g/kWh)[22]- Lower Import sensitivity case

In this Lower Import case, the emission intensity of generation is at a similar level to that observed in 2008, and significantly higher than the reference case (shown by the dashed red line). Total emissions are about 50% higher in 2030 than the reference case (level shown by black line), as would be the investment requirements due to the significant additional indigenous generation requirements.

Given the level of reliance on imported electricity, and predicted climate impacts, this issue requires additional analysis particularly from an energy security and systems reliability perspective. The risks of a high hydro future are considered again in section 5, when discussing options for a lower carbon future, with reference to recent analysis undertaken for Tanzania (ECA Working Group 2009).

- **Increasing scarcity and demand for water resources.** Another important factor will be the increase demand for water in future years (competing with electricity generation), due to population

[21] An assessment of power development options in the Nile Equatorial Lakes region has been undertaken through NELSAP (2006); for the Lakes regions in Rwanda and Tanzania, modelled changes in precipitation and temperature did not adversely affect runoff required for hydro electricity generation.
[22] Generation levels adjusted for losses before intensity calculation

growth, agriculture demand. One of the medium term aims of the Vision 2030 (GoK 2008) is to exploit the agriculture potential in Kenya. Specifically, the amount of land under irrigation will be increased by 30 per cent by establishing additional 25 small-scale irrigation schemes throughout the country and several large-scale irrigation schemes mainly in the Tana River, Athi River, Mwea, Yatta, Nyando, and Nzoia basins. Careful consideration will need to be given to the competing needs of the agriculture sector, and generation from hydro electricity, and how greater demands on water are managed i.e. the seasonal release of water from dams to meet generation needs versus agriculture sector irrigation requirements.

- **Grid system stability.** It is not clear from the LCPDP how much work has been undertaken to look at grid system operation as both the supply and demand profile changes over time. On the supply side, there is greater reliance on imports and baseload geothermal plant; how well this supply mix can cope with changing patterns of demand is unclear. For example, will the thermal plant be able to cope with a more variable ('peaky') demand profile? Increasingly urbanized, higher income populations with access to electricity may result in a system with more severe peak demand periods, perhaps driven by evening use of air conditioning and other appliances. A warming climate may compound such an issue.

It is clear that the future Kenyan system, as set out in the LCPDP is relatively low carbon due to the large amount of renewable generation. This could of course change if less imported electricity is available, and coal resources (indigenous and from Mozambique) are exploited. In view of the above uncertainties, realising such a system will require further system planning, perhaps including the use of integrated energy system tools (MARKAL-TIMES / MESSAGE), and significant levels of investment. The role of decentralised generation could also be integrated into this planning, as this also can offer cost-competitive low carbon electricity, particularly in rural areas.

The role of decentralised generation

The LCPDP (KPLC 2008) does not consider the role of other (often smaller scale) renewable technologies (such as wind, solar, biomass and small hydro) in any great detail although it does state that *they are expected to play a role in the country's future energy supply balance*. It also mentions that a Feed-In Tariff (FIT) scheme is being adopted by the Ministry of Energy which will guarantee electricity prices and encourage investment. Current renewable projects implemented or planned are described in Section 4 of this report.

Domestic sector and traditional industry / commerce

Current situation

Firewood and charcoal[23] account for almost 75% of final energy consumption, and meet most (>90%) of the energy needs of the urban poor and rural communities, as well as traditional industries. Such sectors have very limited access to electricity[24] or other modern fuels, often due to availability but also high poverty levels resulting in such alternatives being unaffordable.

Biomass is sourced from many different forest types, including closed and protected forest. Only 3% of Kenya's land area is covered by forest, which produce about 45% of the biomass energy resources including wood wastes (GoK 2005). The balance is derived from farmlands in the form of woody biomass as well as crop and animal residues.

Unsustainable harvesting, with limited effort on reforestation, has led to significant soil degradation, and deforestation. Demand for wood fuel is higher than supply; in 2005, the country was projected to have a wood fuel deficit of 4.1 million tonnes in 2005. About 47% of the Kenyan households use charcoal. Some

[23] Production and trade of charcoal is actually illegal but still accounts for a large part of the energy sector
[24] Consumption in Kenya is extremely low standing at 121 kilowatt hours (KWh) per capita (compared to 503 in Vietnam or 4,595 for South Africa). The national access rate stands at approximately 15%, while the access rate in the rural areas is estimated at 4% (GoK 2008).

82% of urban households use the fuel compared to only 34% of households in rural areas. Total charcoal production is about 2.4 million tonnes (UNEP 2006).

Developing projections

Projecting future use of biomass is problematic because it is dependent on resource availability (set against growing population, land-use changes, etc), switching to alternatives, urbanization and income levels. Many of these variables are set by assumptions made for other sectors:

- Resource availability. At present there is a wood fuel deficit; however, if forestry targets are met as set out in Vision 2030, there will no longer exist. However, population pressures will also increase over time, and there will be pressures on land-use.
- Switching to alternatives. Electricity generation is projected to increase significantly, due to population growth, improving access (particularly in rural areas but also because of rapid urbanisation), and increasing middle and high income consumers. The use of alternatives in this sector is also increasing, such as LPG and kerosene. Relative affordability of different options is also an important factor.
- Technology improvements. Another factor will be the number of efficient stoves and proposed programmes to enhance overall efficiency of the stock.

Long term projections for this sector have been developed in a UNEP (2006) analysis, which also focuses on transport sector (as described in the next section). Under a business as usual scenario, future fuel consumption is estimated as follows:

Table 2. Consumption of household fuels (Terajoules) under a BAU scenario in UNEP 2006 analysis

Household fuel	***2004***	***2030***
Agr. Residues	68,666	252,979
Wood	246,764	199,439
Charcoal making	170,720	128,000
Charcoal consumed	25,600	12,800
Kerosene	10,750	16,644
LPG	1,987	3,311

Total biomass increases overall, remaining the dominant source of household energy. Wood fuels (including charcoal) reduce due to ongoing shortage of supplies, with growing demand met by significant increases in agricultural residues.

However, the projections in the UNEP study above are inconsistent with the Vision 2030 assumptions that assume large scale reforestation (presumably reducing the wood fuel deficit) and rapid electrification. In the UNEP study, urbanization rates are fixed at the level seen in 1999 (35%), while Vision 2030 projects almost double this number by 2030. Therefore, the UNEP projections have not been used directly, but instead built on to develop a set of projections that are more consistent with Vision 2030 development.

Indicative projections have been made for this study. These are based on a number of assumptions

- It uses the UNEP (2006) fuel totals in 2004; based on Kenyan energy statistics (for 2000) and additional 3% demand is met by electricity.
- It assumes a rate of switching to electricity that is critical to the overall projection. This will be influenced by the rate of urbanisation, expansion of the grid system, particularly rural provision, and to a lesser extent the uptake of decentralised technologies. This will also be a function of access versus consumption, which will be influenced by cost of connection / electricity tariffs.

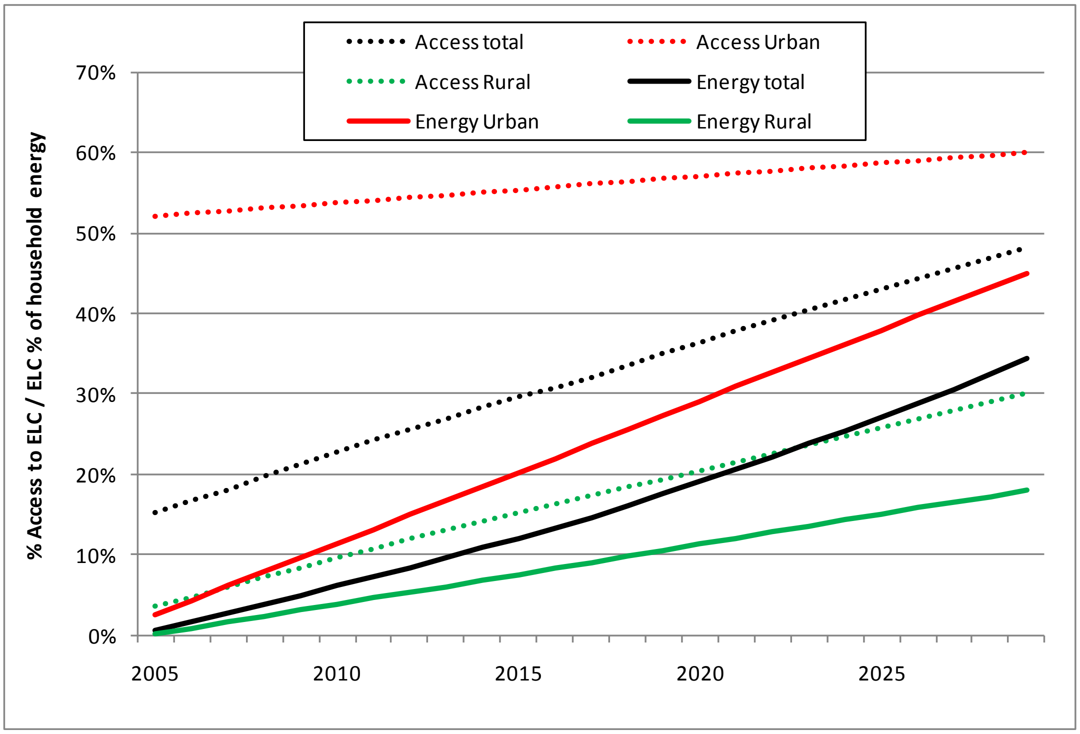


Figure 10. Population access rates to electricity (dashed line), and % contribution of electricity to household demand (solid line)

Access rates to electricity are shown in Figure 10 above, with total access at 15% (black dashed line) but consumption only accounting for around 1% of household demand in 2005. In rural areas, we assume that access increases from 4% to 30% by 2030 while in urban areas this rises from 52% to 60%. The urban access does not increase markedly due to the rapid urbanization taking place. This is illustrated by 52% of urban population in 2005 equating to 4.1 million and 60% of the urban population in 2030 equating to 21.6%.

It is then assumed that 60% of the rural population with access use electricity as their primary energy source, while 75% do so in urban areas. This assumes that electricity is much more affordable; in 2005, the equivalent shares are 3% (rural) and 5% (urban). The assumption is that most of the electricity is from centralized generation.

Figure 11 below shows the resulting shares of electricity versus biomass taking the above assumptions into account. Essentially, biomass accounts for cooking and heating needs not met by electricity generation. **These projections are indicative for this study and provide one potential perspective on future household consumption; further work is needed to establish how these patterns compare to household consumption as modeled in the LCPDP.**

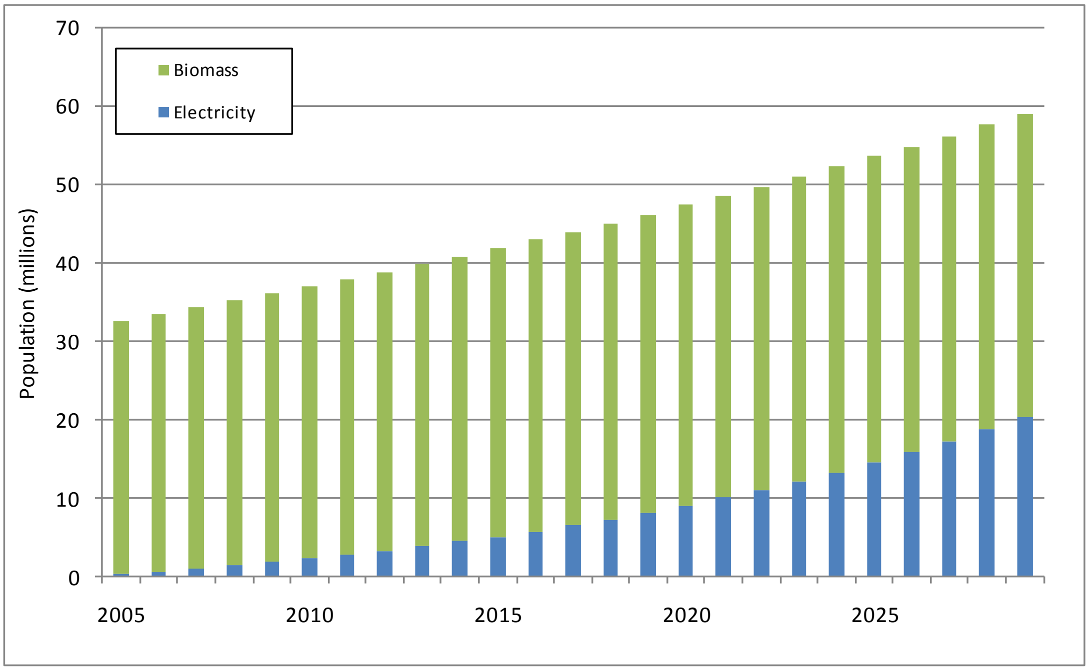
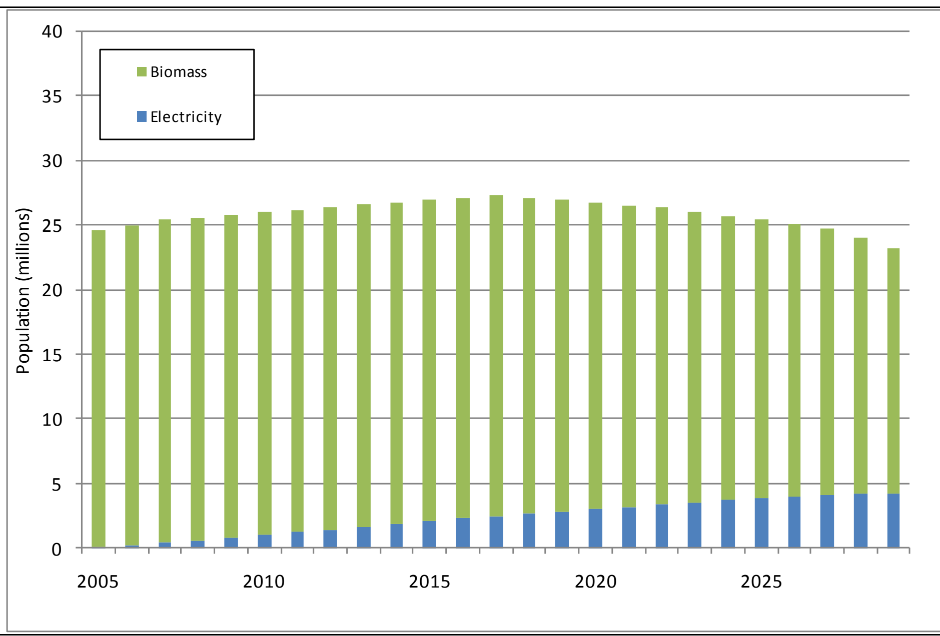


Figure 11. Population use of household energy by primary type

The urban / rural breakdown of the above figure is shown in Figure 12 below.



Rural

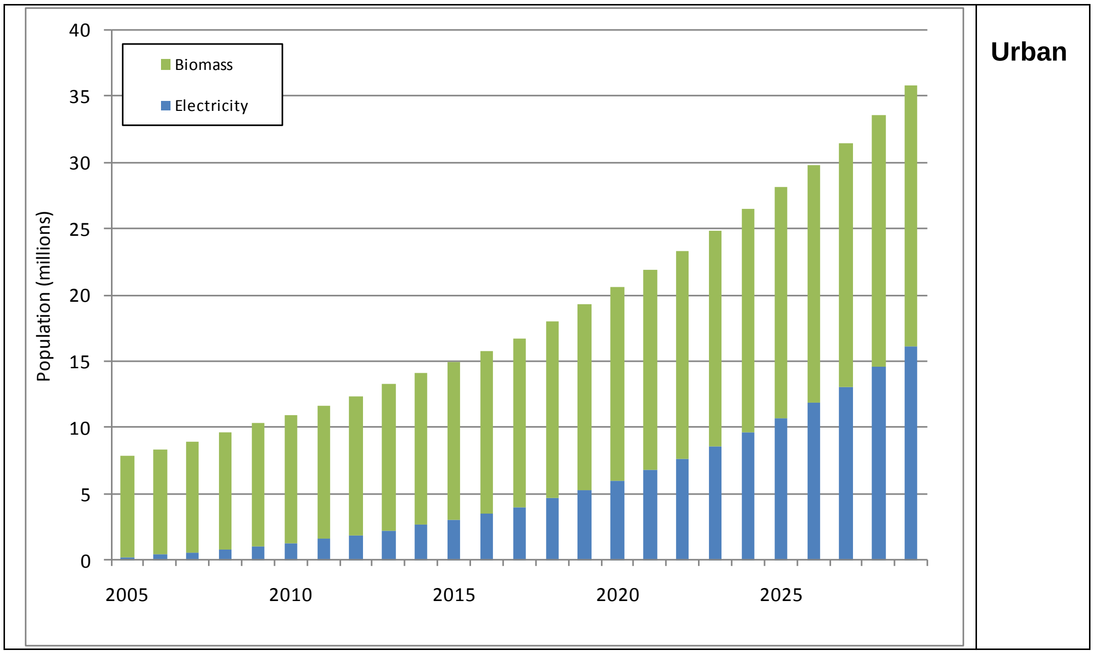


Figure 12. Rural / Urban population use of household energy by primary type

Based on the above trends, reliance on biomass (assuming the same per capita consumption) increases by 18% on 2005 in absolute terms; population is projected to increase by 82%. This suggests that even with significant expansion of modern energy services, Kenya is still going to heavily reliant on biomass energy.

Emission projections have been calculated on the basis of the same per capita use as observed in 2004 (UNEP 2006), with efficiency improvements in stove stock for biomass use, as set out in Government policy– 30% of wood burning stoves improved types. The shares between biomass types are also fixed based on 2004, assuming that the deficit in fuelwood supply is reduced by afforestation / reforestation activities. Resulting emission projections are shown in Figure 13 below. As is the current inventory practice, CO_2 emissions from biomass are not included.

Kerosene and LPG use is estimated separately, with kerosene primarily meeting the lighting needs of households without electricity, while LPG is used by middle to high income for cooking. Kerosene emissions remain at a similar level to 2005 due to limited growth in the rural population, while LPG emissions increase with urban demand increasing.

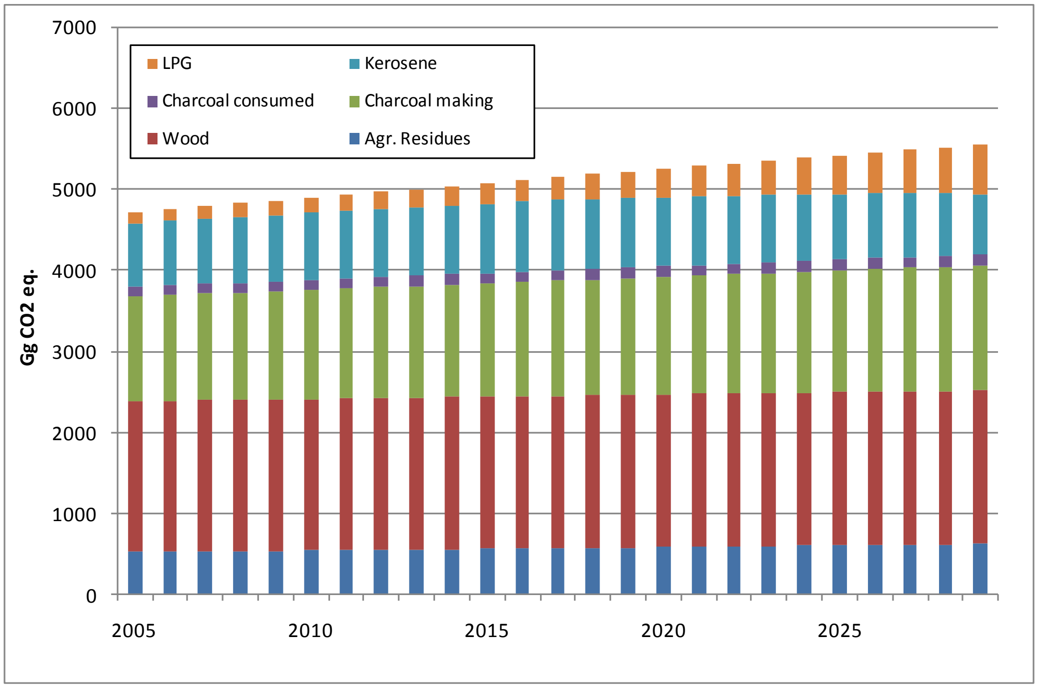


Figure 13. Projected GHG emissions (Gg CO_2 eq.) for the household sector (2008-2029)
(Note that emissions from electricity are captured in the electricity generation sector, and therefore not reported by end use sector))

There is no significant rise in emissions from this sector due to the increased use of electricity in both urban and rural populations. Note if significant expansion of access to electricity did not occur, it is likely that emissions from biomass and kerosene would be much higher. In addition, it is also assumed that the wood burning stove stock becomes much more efficient, again ensuring emissions from biomass use in 2030 remain at a similar level to that observed in 2005. Total emissions do increase by around 17% primarily due to increased uptake of LPG in the urban population.

Whilst significant uncertainties mean that emissions could be much higher than projected, based on these projections, significant potential remain to improve the efficiency of both charcoal making and wood fuel burning, further reducing emissions and reducing pressure on these biomass-based resources.

Transport

Current situation

The road transport sector accounted for nearly 50% of petroleum products consumed in Kenya in 2005, with transport as a single sector accounting for 70%.[25][26] Road transport is a rapidly growing sector, with 700,000 road vehicles in 2004 compared to 386,000 in 1992, increasing by 30,000 vehicles each year (GoK 2002, UNEP 2006).

No specific estimates of future demand for the transport sector have been made in Vision 2030; however, based on the population and GDP growth forecasts, and recent experiences both in Kenya and other developing countries, it is clear that demand, primarily for private vehicle transport, will increase significantly. This rapid expansion in future years has significant implications for energy demand, infrastructure and urban planning, and associated issues of noise, congestion, pollution etc,. It will be driven by rising incomes, rapid population growth and urbanisation. Vision 2030 (GoK 2007) states that poor urban transport systems and

[25] Kenya National Bureau of Statistics, http://www.cbs.go.ke/
[26] The majority of the remainder is consumed by the power and industry sectors

the congestion they cause in Nairobi already cost 2% of GDP (NB. Nairobi accounts for 40-50% of national GDP).

Developing projections

There are no projections for the transport sector in the Vision 2030 document. However, a published source of fuel consumption and emission projections is the UNEP (2006) assessment, which projects that petroleum demanded by the transport sector will rise from 1.9 million tonnes in 2004 to between 5.3 - 8.6 million tonnes in 2030. This is based on a lower population in 2030 than projected in Vision 2030 (55 vs. 63 million in the vision), and lower annual GDP growth (3-5% vs. 10% in the Vision). The implication is that the projections in the UNEP study are therefore likely to be at the lower end of likely future transport demand.

The estimates in this study build on this UNEP analysis, although they build in some efficiency improvements in the road vehicle stock. Overall, road vehicle numbers increase from 0.75 million in 2005 to 4.4 million in 2030. Total transport fuel use rises from 2 to 10 million tonnes of petroleum products. It is probable that the above projections could still be higher under the Vision 2030 assumptions, due to the higher economic growth and population increases assumed. If growth rates are increased by 35% post-2015, road vehicles increase to 6.5 million whilst fuel consumption increases to 14 million tonnes.

Projected emission estimates of CO_2 for the transport sector are shown below (Figure 14). This initial projection shows the emissions growth from the car sector is higher, given the large increases in demand for private cars as incomes rise. Growth by transport type is simply a function of base year vehicle splits (which are not assumed to change), vehicle specific growth rates and efficiency improvement assumptions.

The aviation sector estimates are based on energy use statistics; however, it is not clear whether this accounts for domestic aviation only or also includes the fuel consumed by international airlines (purchased in Kenya). This distinction is important from an emissions inventory context, and in thinking about future targets within an international agreement. In addition, these estimates do not necessarily include projected increases in aviation travel as the tourism sector grows. Further work is needed to better understand the future growth of aviation emissions, and the allocation of (responsibility for) domestic / international emissions from this sector.

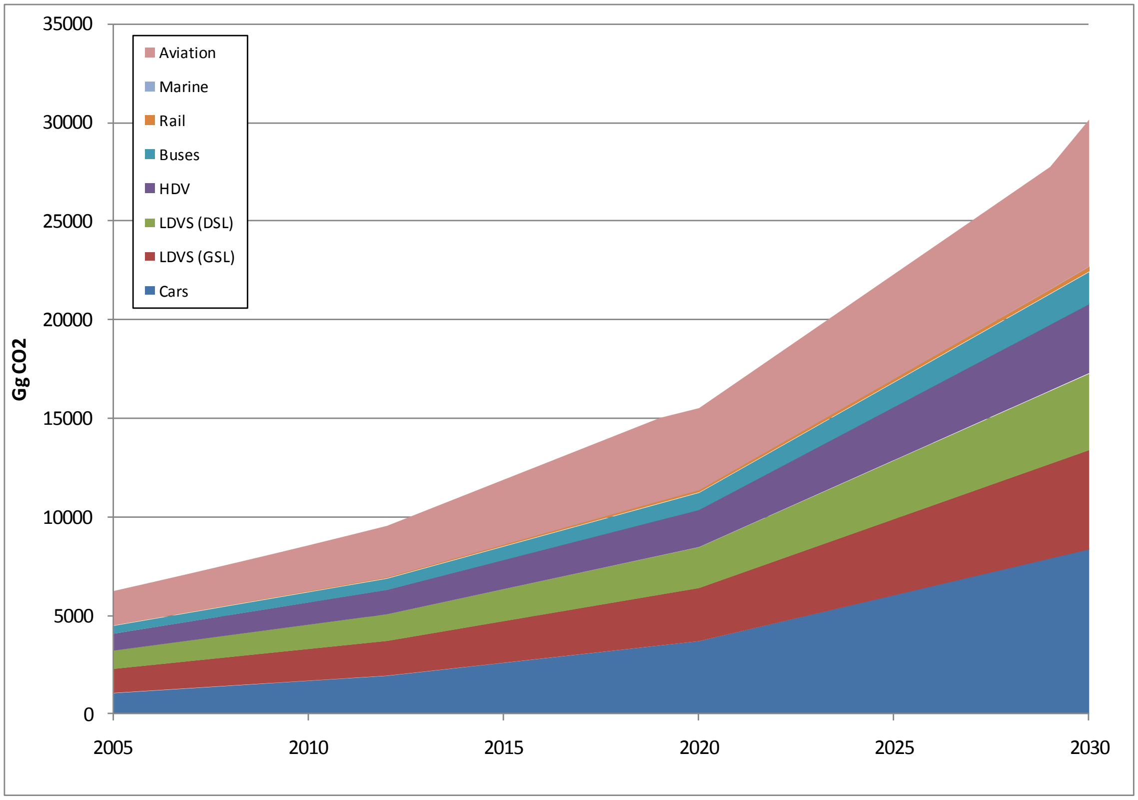


Figure 14. Projected CO_2 emissions for the transport sector, 2005-2030[27]

This is a critical sector for future emissions; whilst the above provide indicative emissions, it is important that projections are significantly developed using more robust methods, taking account of rising incomes and how that affects demand, future public transport provision, urban planning issues, transport / energy policy etc.

In conclusion, it is likely that emissions will increase significantly in future years given population growth and projected rising incomes. However, significantly more work is required to produce robust estimate on which basis policy options can be appraised.

Industry

Kenya's industrial sector is one of the largest in Sub Saharan Africa. Manufacturing accounts for 13% of the Gross Domestic Product (GDP), a share that has remained constant since 1998. The sector accounts for over 27 percent of Kenya's total export earnings (2001). By the end of 2000, the sector had nearly 700 medium sized and large-scale enterprises, and 1.3 million micro and small enterprises, employing about 300,000 people in the formal sector and 3.7 million in the informal sector (GoK 2005). The largest single sector is food, beverages and tobacco, accounting for 29% of sector GDP, and 35% employment. Textile and apparel sector is also an important sector, at 7% of sector GDP, and 25% employment. Much of the rest of the sector is fragmented, with many smaller subsectors (GoK 2007).

There is no doubt that industrial sector emissions will grow in future years, although much of the economic growth is likely to be in lower carbon intensive service sectors, based on the Vision 2030. In addition, the Vision describes an aim for a much more competitive and productive manufacturing sector, which presumably would include the adoption of more efficient technologies and practices.

In the absence of published estimates of projected fuel demand for this sector, predicted changes in industrial efficiency and sector specific growth rates are extremely challenging to develop. Indeed, it has not

[27] Emission projections do not include CH4 and N2O emissions in absence of detailed understanding of stock breakdown.

been possible to develop detailed projections. However, a scoping analysis has been undertaken to investigate the potential emissions growth, as this is potentially an important sector for low carbon options. Indicative, estimates have been made based on:

- An overall 10% growth rate, an ambition for the sector in Kenya's current Medium Term Plan (GoK 2008). Note that a lower growth rate would be expected to lead to lower emissions than outlined below. Therefore, we have also included a sensitivity case using a 7% growth rate.
- This growth rate is applied to the industrial / commercial oil consumption value for 2005, and does not take account of the use of other fossil fuels nor switching to electricity in future years.
- A reduction factor in energy consumption (linearly extrapolated) of 10% in 2020 and 15% in 2030 in the baseline is assumed, taking account of the move to less energy intensive industries. The Vision 2030 document describes the Kenyan economy moving towards a higher value, services-based economy; therefore, the reduction factors try to reflect this lower energy intensity production.

The resulting emissions projection is shown in Figure 15 below.

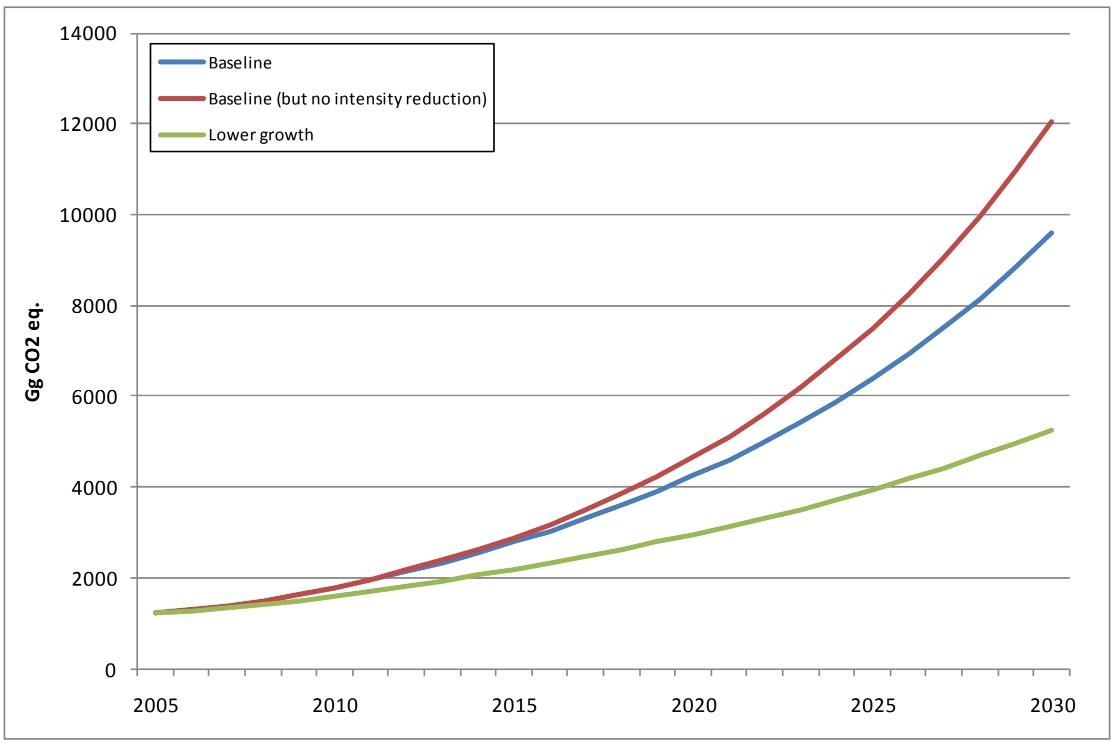


Figure 15. Projected CO_2 emissions for the industry sector, 2005-2030

Assuming lower annual industrial growth significantly reduces future emissions (as shown by the green trend line). The assumptions around energy intensity of production also have a significant effect, as shown by the difference between the blue and red line, the red line indicating no improvement.

Further information is required to develop these projections, including growth rates for different subsectors, current energy intensity of production (and therefore potential for efficiency improvements) and understanding about future energy use by type; the above projections assume continued use of petroleum products only. In addition, the structural changes to the future Kenyan economy need to be understood, including the emergence of new industries.

Agriculture

Agriculture is an important sector in the economy, contributing 24 % of GDP. Over one third of agriculture produce is exported, accounting for 65% of Kenya's exports. Horticulture and industrial crops are particularly important products for export (GoK 2007). The sector is one of the major employers in rural areas, with an estimated 3.8 million people directly employed while another 4.5 million are employed in the informal agriculture sector (GoK 2008). As stated in the 2030 Vision Medium Term Plan (MTP), as the largest sector in the economy, it is likely that it will remain the main driver for growth in the short to medium term.

Currently, about 75% of the sector is made up of smallholding farms, with low inputs (fertilisers) and yields. In the 1st National Communication (GoK 2002), there is recognition that increasing pressures on the agricultural sector from population and economic growth could lead to increasing GHG emissions and pressures on the land as the sector changes over time. Examples include the increase in fertiliser application, currently at very low levels, which could lead to increased emission of N_2O, or growth in meat demand increasing livestock numbers, and as a result CH_4.

In developing projections, there are a number of factors that are likely to lead to increased emissions:

- Increased livestock emissions due to food demands from a growing population. Livestock are an important source of methane emissions, resulting from enteric fermentation and from manure (particularly in less intensive farming)
- Increasing agricultural land area, with only 31% of high and medium potential land in use (or 5% of total land area), and increasing use of ASAL areas.
- Increasing fertiliser use to increase yields. The Kenyan government is investing in a programme which will see domestic production soon after 2010, and lead to much lower costs for the sector. Nitrogen based fertilizer use important are a significant source of N_2O emissions, but are also energy intensive to produce. Therefore additional emissions will occur due to production and application on agricultural land.

The projections methodology is very simplistic but has been undertaken to ensure completeness, and include a very important sector in assessing low carbon potential. Livestock emissions are driven by cattle number projections, increasing by nearly 40% by 2030 (provided by ILRI **-** International Livestock Research Institute). N_2O emissions are projected to grow by 20% between 2005 and 2030, driven primarily by increasing use of nitrogen based fertilizers, as productivity rates are increased. These projections do not take account of how climate impacts may affect predicted sector growth, nor the changing practices or structure of the sector in future years.

It is very difficult to make detailed projections of the potential for the export market on which Kenya is so heavily reliant, due to the global nature of this market. There is also an extremely strong potential influence on agriculture from future climate change, discussed in the main climate change impacts and adaptation of the report. Further consideration of these potential effects in light of projections is essential for future work.

Within Vision 2030, the general assumption seems to be that this export market is maintained. As well as the issues associated with climate change itself (above), there are also potential challenges in relation to the use of air transport for many goods and the issues with fuel prices, climate legislation, consumer choice, etc. This linkage between international mitigation and Kenya is another area that warrants further consideration, and this feeds though to one of the key overall study recommendations, that there is a need to re-assess Vision 2030 in light of the dual challenges of mitigation and adaptation at both domestic and international level.

There are quantitative targets for the Agriculture sector in 2012 given in Vision 2030 (GoK 2007), including: achieving an average growth rate of 7 per cent per year to 2012. It is proposed that this can be achieved by a series of measures, including productivity yield increases, land use transformation with at least 1 million additional hectares being brought into production and an extra 600,000 –1.2 million hectares being put under irrigation in arid and semi arid lands (ASALs). However, the projected longer term trends are not known. There are significant implications in relation to climate change, in terms of water availability, yields, etc in these projections. These are discussed in the main section on climate change impacts.

Agriculture is a key emitting sector currently and in future years. Developing robust current inventory estimates and projections is key to understanding future emissions and mitigation opportunities, but also for understanding a range of other issues with respect to water needs, land use change and future climate impacts, and associated adaptation needs. Currently, the future challenges for this sector are poorly understood.

Forestry

The inventory data in the 1st National Communication shows how forests play a key role in reducing CO_2 in Kenya. However, much of the forest cover is at risk from the increasing resource needs of the population (demand for land and forestry products). For example, the area of closed canopy forests has been reduced from 3% to 1.7% of the total land area since Kenyan independence. At the same time, key economic sectors, including cash and subsistence crop production, tourism and energy generation, have increasingly relied on the environmental services provided by indigenous forests (GoK 2005).

Kenya loses at least 5,000 hectares of forestland annually through excisions. This is from both plantations and indigenous forests within forest reserves but does not take into account what happens to non-gazetted forests i.e. those not surveyed, demarcated and declared forests reserves. In the last decade, of the estimated loss of gazetted forestland of 125,405ha, over 85% is indigenous forest and 15% plantations (GoK 2005).

Forest decline can be explained by a number of key pressures and issues (MEMR 2009):

- Demand for sustainable wood and fuelwood outstrips supply. With an annual per capita wood consumption of 1 m^3, the current demand stands at 37 million m^3 (or 148 million mature trees). However, the estimated sustainable wood supply is about 30 million m^3 thus creating a deficit of 7 million m^3.
- Pressure for conversion of forest land to other land uses
- Forest encroachments, illegal tree harvesting and charcoal burning
- Poverty and lack of alternative livelihoods
- Incomplete forestry policy
- Lack of adequate information on forests
- Fires due to arson or traditional management techniques
- Limited knowledge of the economic value of forests, and contribution to GDP

In Kenya's Vision 2030, protecting existing forest covers and increasing reforestation and afforestation activities are given high priority. Many of key forests are in the upper catchments of the main rivers, and therefore are critical to water catchment management, and reducing flood risk. Forests are have high biodiversity, and are therefore important for protecting for sustaining associated ecosystem services (economic production from natural systems), in particular tourism and forest products. In carbon mitigation terms, they are important sinks and help protect soils, also an important carbon store. The main section on climate impacts has a section on the role of forest ecosystem services in the Kenyan economy, and also investigates the potential effects of climate change on these.

Under its Vision, Kenya intends to achieve 10% forest cover by 2030. In the near term, the objective is to increase cover from 3% to 4% by 2012. If these objectives were realised, Kenya could in theory remain a net sink in emission terms. However, such targets are extremely challenging, with pressures on these resources projected to increase significantly due to economic and population growth. In addition, this objective requires significant investment recently estimated at KSh 578 Billion.[28]

The study has not made estimates of future projections for the forestry section, but it has discussion of the options and costs in relation to mitigation and REDD in the later sections of this report.

[28] Ministry of Environment internal estimates

Projected GHG emissions for the overall economy

The projections developed for this study are brought together in Figure 16. This shows total emissions (left hand axis) by sector. The graph also plots the per capita emissions, i.e. total emissions divided by population in that year, shown on the right hand axis. The following key points can be made:

- Total emissions in Kenya are projected to increase by 120% by 2030, largely driven by increases in the transport sector
- Per capita emissions (excl. LUCF) increase by approximately 0.5 tCO_2/ capita over the 25 year time horizon but remain significantly below a 2tCO_2 per capita level
- The growth in emissions is relatively modest considering the high population and economic growth, due to the low carbon intensity electricity, household and industry sectors
-

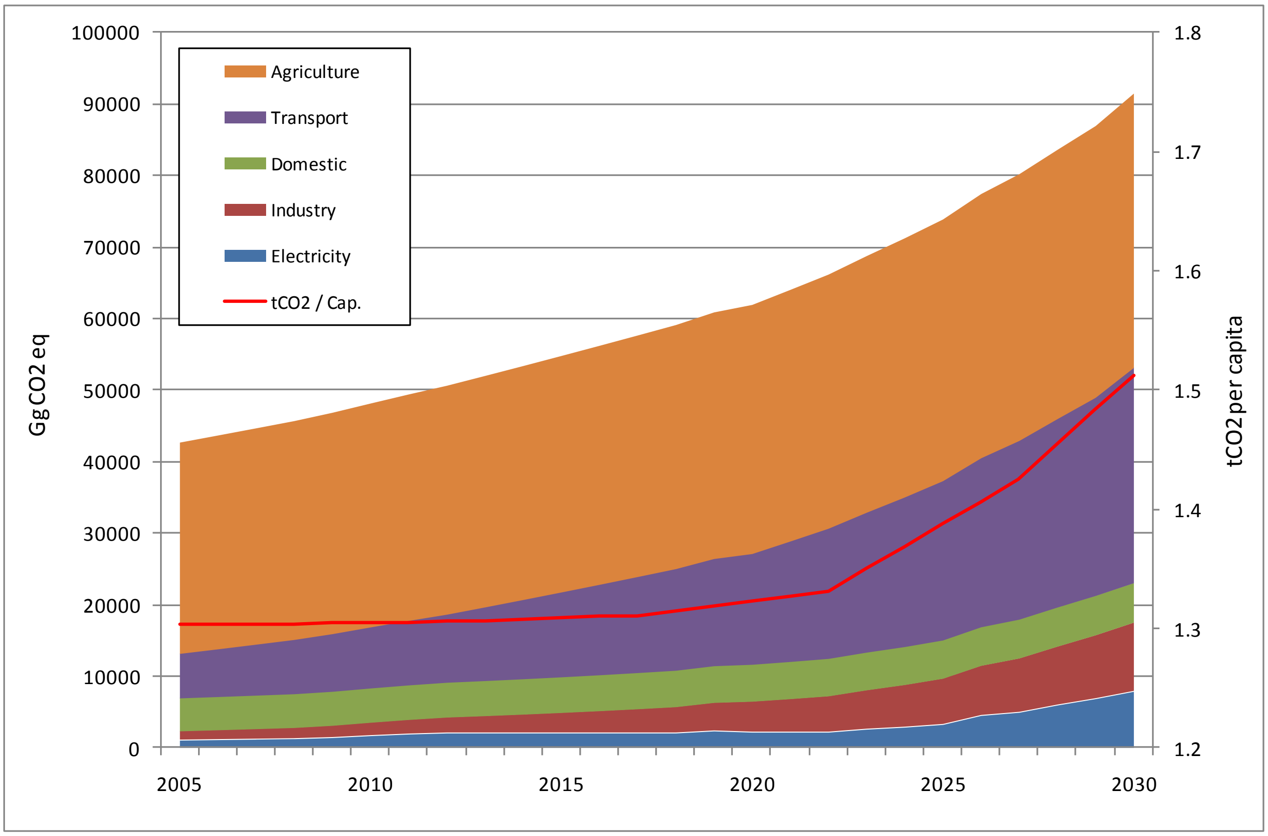


Figure 16. Projections of Kenya's GHG emissions (Gg CO2 eq.), 2005-2030

For this assessment, a very simple projections approach has been used, which attempts to reflect the economic growth and development associated with Vision 2030. It illustrates that growth in emissions will be significant, projected to increase by 120% between 2005 and 2030 (or 42 to 91 Mt CO_2 eq.). It is also estimated that Kenya's per capita emissions could increase to 1.5 tCO_2 by 2030, kept at this level by significantly increasing population growth.

As shown in the figure above, electricity generation emissions are a small proportion of future Kenya GHG emissions albeit rising in later years due to the uptake of coal (2.4% in 2005, rising to 8.6% in 2030). Therefore a much wider economy-wide view beyond electricity generation is needed to advance low carbon growth. A focus on the electricity sector alone will not move Kenya to a low carbon pathway. For this to occur, larger emitting sectors needs to be addressed, particularly transportation and agriculture.

There are a range of assumptions that if revised could change the outlook significantly. Net emissions could rise if Kenya does not maintain a low carbon electricity system (e.g. coal became more prevalent) or does not deal with deforestation rates / increase forest cover. Emissions on the other hand may be lower if the projected population or economic growth does not materialise, and energy demand, for example, remains lower.

The analysis above is based on the Vision 2030 document, but this does not take into account the effects of climate change. There is a need to assess how the projections above would be influenced by climate change, and there is a need, as highlighted in the main climate change impacts section, to introduce climate risk screening into future low carbon plans in all sectors. There is also a need to re-assess the Vision document in light of the future domestic issues with mitigation and adaptation, but also in the context of changes at the international level that would in turn affect Kenya.

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)

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.

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

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
GEF Small Grants Programme Case study (http://sgp.undp.org/)

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.

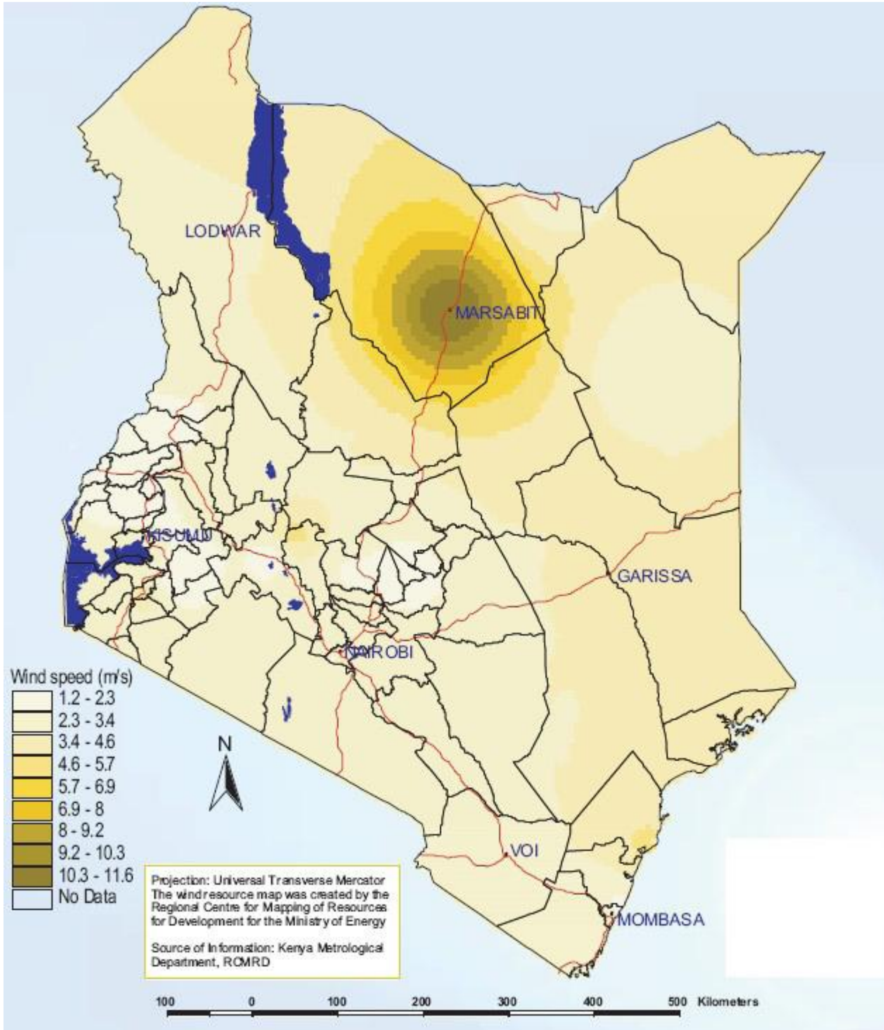


Figure 17. Wind speed map indicating potential for wind generation, particularly in Northern Kenya
(Provided by CAMCO)

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

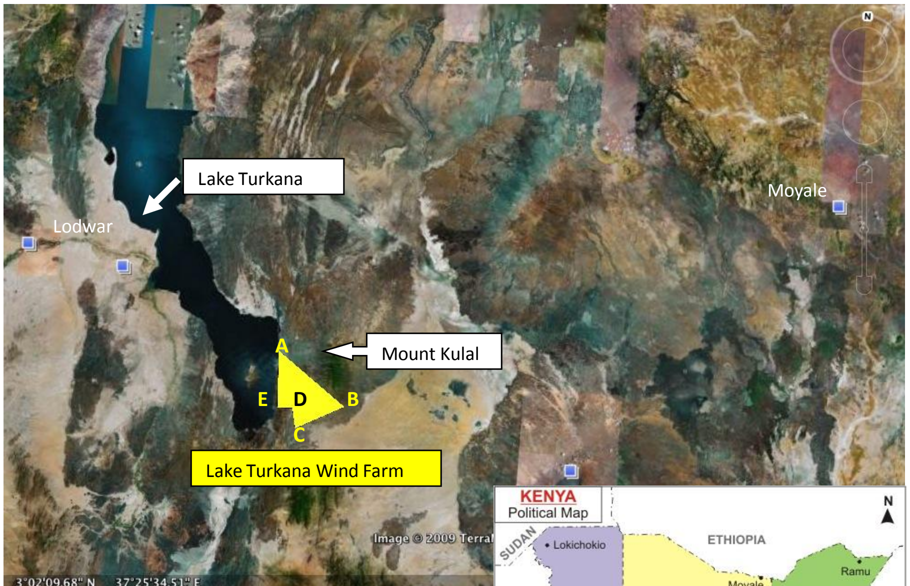
Currently, the Kenya Power and Lighting Company (KPLC) is the only licensed public electricity distributor in Kenya. The industry structure in place is therefore of the single buyer model, with KPLC undertaking transmission, dispatch, distribution and supply. KPLC buys the electricity from a power producer 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.

[30] The project has not yet entered into any Emission Reduction Purchase Agreement so the credit figure is based on the current market price.
[31] Brandtzaeg, B. and S. Hansen (2005) *Barrier to Investment in the Power Sector in Developing Countries.* ECON Analysis/Nordic Consulting Group

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.



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"

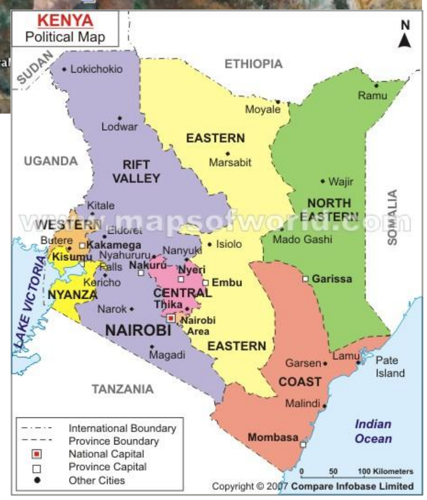


Figure 20. LTW project location and coordinates

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

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.

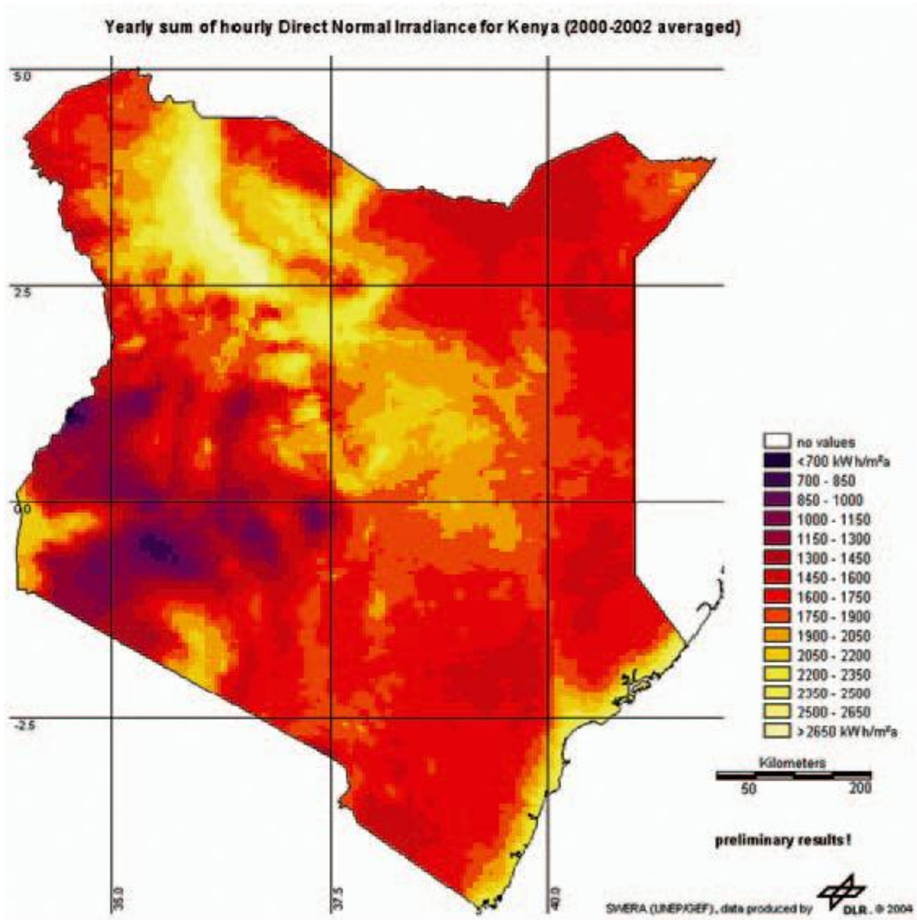


Figure 21. Irradiance levels for Kenya (2000-2002 average) (Provided by CAMCO)

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]:

- 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

[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 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.

Options appraisal for low carbon electricity generation options

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 improvements. - Reduced fuel imports - Reduced sensitivity to fuel price shocks - Greater energy diversity and security	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		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)		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 stressed resource	Lower indoor air pollution levels (health benefits) Less pressure on local forestry More convenient Slurry by-product has high nutrient content, used for fertiliser	Upfront costs Require livestock 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 (<$10/tCO_2$).

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;
- 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

[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

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.

Sector	Number using biomass	% biomass usage	Traditional stoves used	Improved stoves used
Restaurants	6,000	50%	100%	0%
Hotels, Lodgings	7,000	50%	100%	0%
Schools Primary	19,000	95%	80%	20%
Schools Secondary	4,000	95%	50%	50%
Health institutions	4,000	50%	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 benefits	Reduced deforestation and forest degradation, increased trees on farms Reduced air pollution indoors (and outdoors) Improved school / SME environments through proximity of wood-lots
Social benefits	Improved respiratory and general health of cooks Reduced eye irritation of cooks Reduced cooking times Less time spent gathering fuel, more time available for cooking Cleaner kitchens Protection for community forests
Economic benefits	Reduced fuel costs* Income generation for stove producers and tree producers Increased 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 benefits.

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.

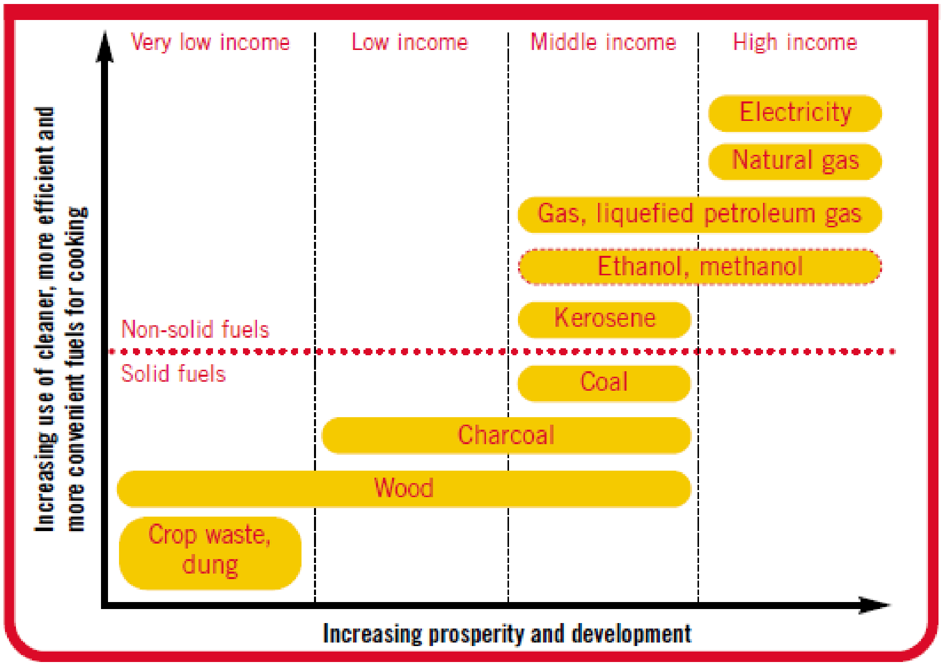


Figure 22. The energy ladder: household energy and development inextricably linked (WHO 2006)

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

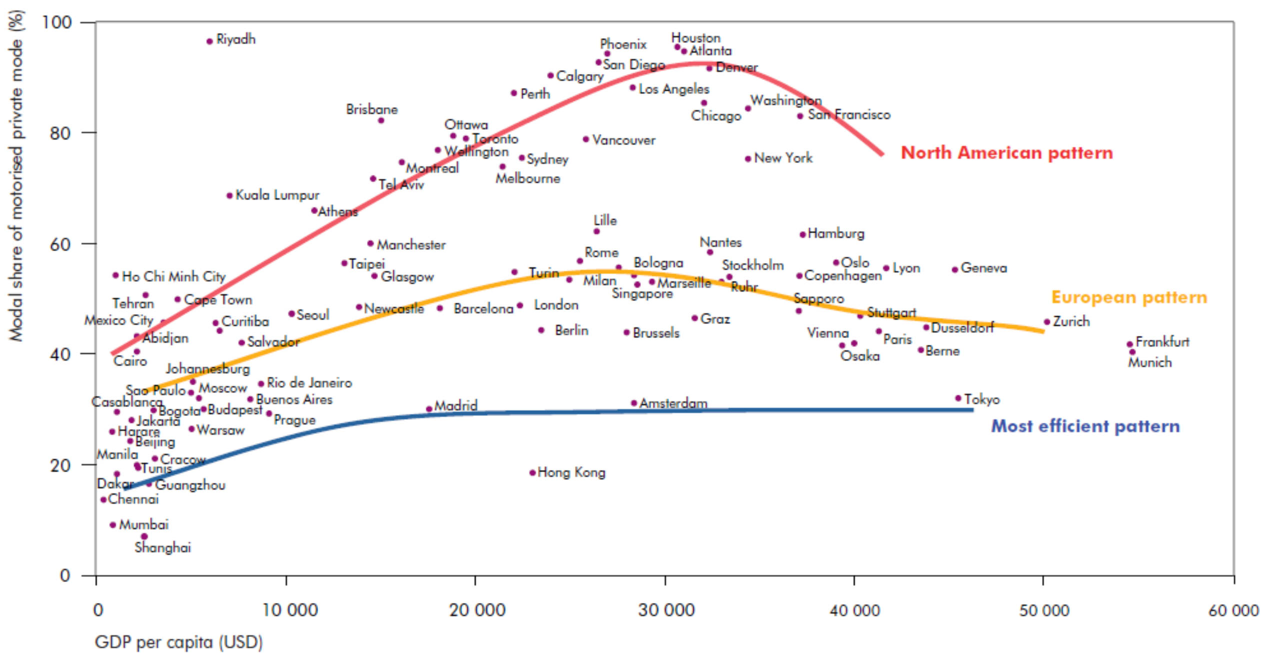
Table 5. Examples of technologies to enable fuel switching or reduce energy requirements in Kenya

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.

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).

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

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
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	

[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.

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.

Source: Mwakubo et al. (2007)

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 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]

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

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).

Challenges to energy efficiency uptake cited in Karai (2008) as:

- Energy subsidies -Non cost reflective energy tariffs
- Lack of confidence among industry on energy efficiency technologies and approaches
- Low Involvement of CEOs –perception of process as technology based or too expensive
- Energy efficiency Projects have not benefited from CDM finance
- Size of projects too small to interest banks

Sources: Kirai (2008), GoK 2005 (KAM website - http://www.kam.co.ke/ema/), Sustainable Alternatives Network (SAN), (http://www.sustainablealternatives.net), GEF (1998)

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 /tCO_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 CO2e by 2012 and 0.38 Mt CO2e 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.

5) Assessment of a low carbon pathway for Kenya

There is the potential to implement no regret (win-win) measures across many areas of economic activity in Kenya, which are available at negative cost now, and improve economic efficiency, as well as delivering low carbon and development objectives. They can also provide important benefits from reducing (fossil) energy imports, enhancing energy security, improving air quality and health, reducing pressures on natural resources, and potentially improving adaptation capability by exploiting synergies.

Low carbon options are important to ensure future growth in Kenya avoids getting ‘locked’ in to high emission pathways, and to allow maximum potential for capturing financing opportunities now and in the future. In advancing all of these areas, there is an important role for domestic policy (taxation, regulatory, incentives etc) to encourage low carbon technology development, diffusion and deployment. This also includes the reform of fossil fuel subsidies and low electricity tariffs. Curbing deforestation is also part of this low carbon pathway, and is now the subject of potential new financing flows (reducing emissions from deforestation and forest degradation in developing countries (REDD)) and also provides protection of natural habitats and ecosystem services.

In this section of the report, a number of the most promising low carbon options have been considered that could put Kenya on to a lower carbon development and growth pathway, focusing on those sectors where emissions are projected to be significant. In addition, there is also some discussion about the issues of implementation (particularly barriers) and some of the policies that may be required to ensure such options are taken up.

The key priority options include:

- Electricity sector decarbonisation, including decentralized technologies
- Reducing transport fuel consumption through improved vehicle efficiency
- Introducing efficient public transport system
- Improving the efficiency of the biomass stove stock
- Industry efficiency improvements
- Reducing agriculture emissions through livestock and cropland management
- Reducing forestry emissions through forest protection and afforestation

In assessing these measures, their marginal abatement cost (cost-effectiveness) and emission reduction potential are estimated, and the wider benefits. To do this the study has estimated:

- The indicative unit marginal abatement cost of potential measures, comparing the potential emissions reductions of a measure against the potential annual emission of carbon, thus expressing options in terms of their cost-effectiveness, or $/t$CO_2$ abated.
- Assessing the potential opportunity for the options looking at current activity levels and projections through to 2020.
- Combining these to build up an indicative marginal abatement cost curve, i.e. looking at the attractiveness of options in terms of their cost-effectiveness, and assessing the potential total reductions they could achieve through implementation.

<u>Note that the mitigation potential and costs used are indicative</u>, to demonstrate where key savings can be made. <u>The potential is derived from initial projections that we consider to require significant additional work, and marginal cost estimates are not fully Kenya specific</u>. Despite this uncertainty, the assessment can provide policy makers with some of the key options, the order of magnitude of savings and indicative investment requirements.

Framework for assessing options for a lower carbon future

As implied throughout this report, low carbon options will not be introduced to reduce emissions alone. Investment will be driven by the need to improve economic productivity and deliver growth, improve transport infrastructure and reduce inefficiency in energy and materials used. In this development and economic context, emission reductions are effectively a co-benefit of other policy drivers, and the introduction of these options is driven by self-interest, economic and development objectives. However, the introduction of carbon financing has the potential to increase the relative attractiveness of these options and to help finance their introduction.

In particular, options should:

- Further the goals of development, including poverty alleviation and economic growth
- Promote greater energy security, particularly in reducing reliance on high price fossil / electricity imports
- Enhance environmental sustainability
- Meet objectives of, or at least not conflict with, adaptation strategies
- Provide opportunities for investment through carbon financing

A range of questions to aid assessment of wider benefits are listed below.

Criteria	Assessment questions
Economic development	Are economic development objectives, as set out in the Vision document, enhanced through uptake of measure?
Poverty alleviation	Is the option going to help reduce poverty e.g. through enhancing access to energy?
Climate change adaptation	What are the linkages? Is the introduction of measure synergistic to adaptation objectives or does it involve conflicts? How climate resilient is it?
Other social benefits	Does the option increase productivity, reduce time spent on basics (water, fuel collection), provide gender opportunities, improve housing, access to education etc?
Energy security	If relevant, does the measure promote greater energy security or diversity?
Technology modernisation	Is option promoting new technology uptake / transfer?
Other environmental co-benefits	Does option protect habitats, reduce air pollution, preserve natural resources?
Financing and scaling	What are the opportunities for financing and scaling opportunity up?
Barriers to update	What are the key barriers to uptake? Are they easily overcome?

A possible framework for appraising options is shown in Figure 24, taking account of the cost-effectiveness of a given option, and the wider policy considerations (right-hand side).It is also important that cost-effectiveness numbers are also scrutinized against a number of other factors that could have a bearing on the feasibility of a given measure, or how appropriate it is:

- Capital intensity. Many options may require high upfront capital investment. Such investment may be difficult to raise, and therefore this issue needs to be considered.
- Fuel price sensitivity. The cost-effectiveness may be highly sensitive to changes in fuel prices, particularly where cost reduction is primarily based on fuel savings.
- Carbon intensity. Changing carbon intensity of electricity can drastically change the cost-effectiveness of an option. For example, options that save electricity are likely to disbenefit from reducing carbon intensity in the generation sector.
- Local experience. Previous experience of option implementation and associated expertise can affect the C-E of an option, in terms of lowering costs and ensuring robust installation and maintenance which can affect emission reduction performance.

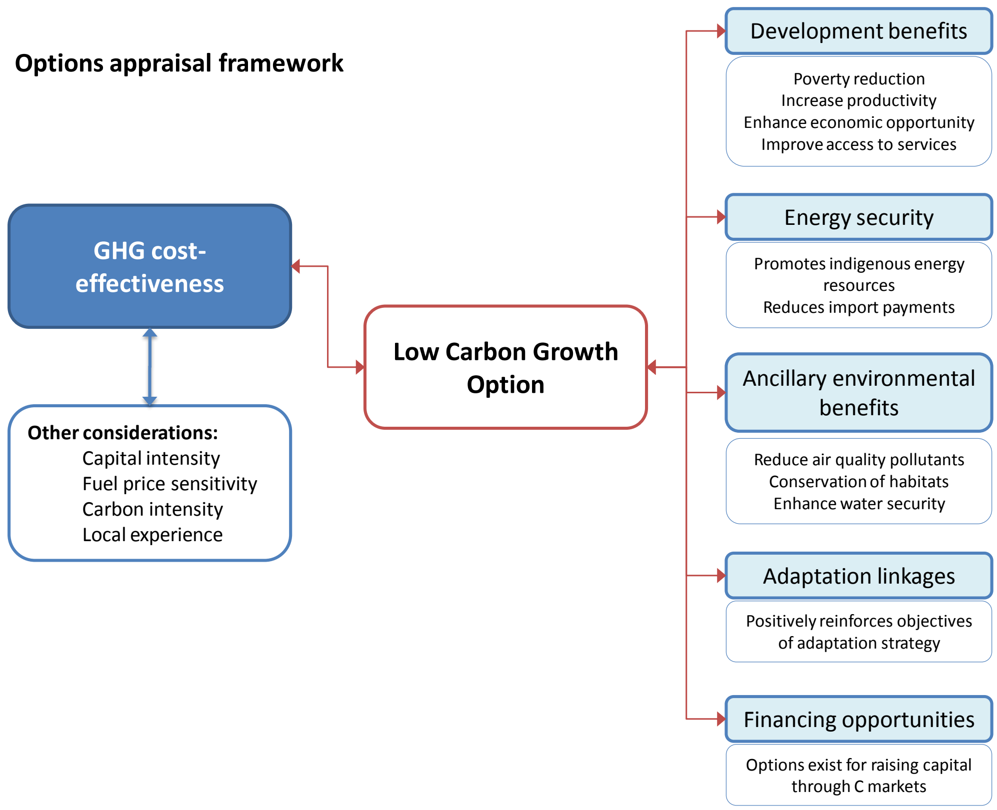
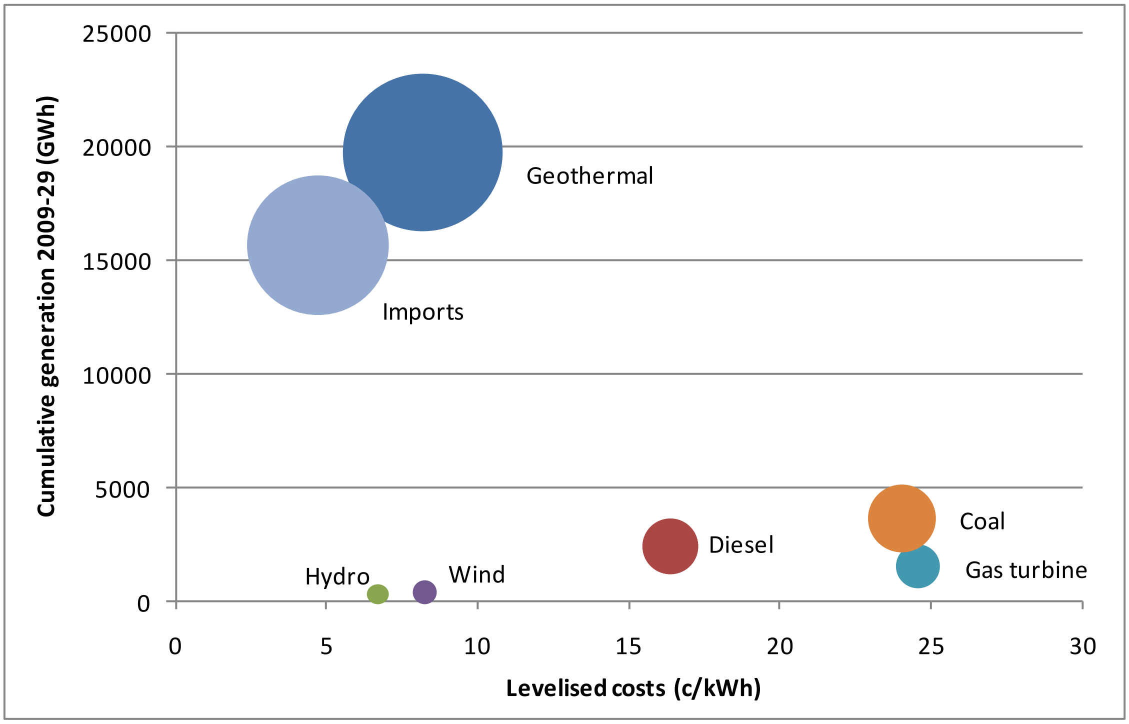


Figure 24. Options appraisal framework for low carbon growth options in LICs

Electricity generation

Kenya's electricity system is relatively low carbon. The immediate plans will lead to a further reduction in the carbon intensity, but the introduction of coal will reverse this trend by around 2020. To further reduce the intensity of the system, renewable generation could replace some of the planned future coal and diesel generation, although a proportion of this may be needed to balance the grid. There could also be some clear risks with this strategy, if any replacement concentrates the mix further towards one single technology (particularly hydro), especially in light of the potential effects from future climate change. However, clear benefits from such a policy would be a reduction in fossil imports, and potentially lower costs of generation, reduced air pollution impacts (coal in particular is a very high emitter of pollutants), and greater security of supply.

The low carbon future generation mix as projected in the LCPDP is illustrated in Figure 25 below. This shows the cumulative generation over the next 20 years from new investment versus the levelised cost of generation (not the electricity price). It shows that low carbon imports and geothermal will be the main generation types, and that these are considerably lower cost than fossil alternatives. They are also extremely cost-effective in carbon mitigation terms when compared to the average or marginal generation alternative. Due to the very high imported fossil prices and the availability of renewable generation, a low carbon future for this sector makes economic sense. It is highlighted that the costs of the fossil fuels are far to the right of the figure, i.e. they have the highest levelised costs.



* Coal operating at 20% plant utilization; hence the higher levelised costs
* Cost of capital set at 12% as per the LCPDP analysis
* Renewable generation costs derived from ESMAP (2007); thermal plant costs sourced from LCPDP and deflated to 2005 cost basis
* Base Crude Oil Price of US$100, Coal Price 135 US$/M Tonne (in LCPDP)

Figure 25. Cumulative generation (GWh) between 2009-2029 versus cost of generation (c/kWh)

Despite the obvious economic benefits, a key challenge remains the raising of investment to scale up to these levels of installed capacity, and the associated grid infrastructure and connections. Therefore, further market re-structuring may be needed to encourage private sector investment. Other important challenges remain the vulnerability to climate impacts from reliance on imported hydro generation (see main impacts study), and associated energy security issues from regionalizing supply.

The potential of options shown above does not feature significantly in the cost-curve analysis as it forms part of Government projections for the sector, informed by the central Vision 2030 growth assumptions. However, uncertainties are significant in this long term plan, as illustrated in the projection section (3), where it was demonstrated what a 30% reduction in imports might result in with respect to emissions.

Distributed or off-grid generation is not fully captured in the projections of the LCPDP. These could have an important role to play, particularly in the provision of electricity to rural areas where grid distribution is not feasible or economically viable. In 2020, the forecasts for electrification show that around 35% of households will be connected; this therefore leaves a significant potential for micro-scale generation.

The ESMAP (2007) report draws some interesting conclusions about two types of distributed provision – mini-grid and off-grid. For off-grid systems, it concludes that renewable energy is often more economical than conventional generation for off-grid (less than 5 kW) and mini-grid (5-500 kW load) applications. Technologies such as wind, mini-hydro and biomass-electric – can deliver the lowest generation costs, critically assuming availability of good renewable resources. Micro-hydro *can deliver electricity for US¢10-20/kilo watt (s) per hour (kWh), less than one-quarter of the US¢40-60/kWh for comparably-sized gasoline and diesel engine generators*. The costs of supplying electricity by a mini-grid may lead to significant increases in the overall costs of generation. This will depend on the size of the network and the power load.

Kenya has good biomass and hydro resources which could potentially be exploited for off-grid and mini-grid generation. However these generation technologies (at this scale) may be significantly more expensive than centralised plant, and investment without subsidy or grant makes purchase very difficult, particularly at the household level.

A number of options have been included in an indicative cost curve for Kenya in 2020 (see Figure 26). This cost curve is to illustrate a range of options and their potential and costs. For electricity generation, the following have been considered:

- Wind (centralised)
- Solar PV (centralised)
- Geothermal (centralised). This is 3 additional plants to what is forecast in the baseline.
- Hydro (mini-grid)
- Wind (mini-grid)
- Solar PV (mini-grid)

Table 11 provides information on the mitigation costs and potential CO_2 savings in 2020 if these options were introduced. Sector-based savings could be in the region of 80%, with these options replacing 13% of baseline generation. Renewable options tend to have lower mitigation costs as seen in other cost curve examples due to the high price of fuel in diesel generators, and the higher capacity factors of renewable options (due to very good solar / wind resources). In addition, the capital costs of renewables are not current year costs but factor in learning effects across these technologies.

Table 11. Comparison of generation costs in 2020 for centralised and decentralized electricity options and marginal abatement costs of alternative renewable technologies

Technology	No. of plant / schemes	Plant capacity	Generation cost	Mitigation cost / tonne	Total CO2 saving	Generation
		MW	*c/kWh*	*$/tCO2*	*% 2020 sector emissions*	*% 2020 baseline GWh*
Diesel plant		5	16			
Geothermal	3	70	10	-19	42.8%	6.6%
Wind (centralised)	15	10	5	-80	15.3%	2.3%
Solar PV (centralised)	30	5	24	47	11.5%	1.8%
Diesel generator		0.10	20			
Micro-hydro	500	0.10	12	-42.8	3.8%	0.6%
Micro-Wind	1000	0.10	21	2.7	5.1%	0.8%
Small PV system	3000	0.025	39	87.4	3.8%	0.6%

* All costs in USD 2005
* Current year PV capital costs have been reduced by 30% to reflect reductions by 2030.
* 10% discount rate used
Primary sources: ESMAP (2007) for mini-grid technologies; KPLC (2008) for centralised grid technologies

For decentralized technologies, the proposed numbers of schemes do not take barriers of uptake / scaling into account. Rather they are indicative of the costs and emission reduction potential of providing rural electricity generation by renewable rather than diesel generation. To put this into context, 500 micro-hydro schemes could provide electricity to over 1 million people, assuming that each scheme reaches 400 households.

Whilst micro-hydro is cost-effective, there are issues around finding suitable locations that offer relatively secure running water all year round. UNDP (2006) mentioned scale-up potential of 100 schemes, although other estimates of potential have been put much higher. Another important point is that capital costs also vary depending on location and labour costs. In a paper published on the Practical Action website *Micro-hydro power: an option for socio-economic development* (by Dr Smail Khennas and Andrew Barnett), a cost range of $655-5630 per kW (USD 1998) was suggested. PV and wind are less economic, although costs of wind could be significantly lowered where reliable and stronger wind speeds are experienced. In addition, they are more capital intensive, meaning that raising investment becomes a more significant issue.

There are options that could lead to a lower carbon system than observed in the baseline by 2020, which Kenya could implement. Post-2020, increasing renewable options could also reduce some of the coal based generation that is projected. However, more analysis would be needed to ensure that Kenya is able to maintain a balanced and reliable grid system with an increasing renewable load.

There are of course risks of a higher carbon (and more costly) system in future years if climate impacts affect hydro availability. Due to low rainfall in Kenya since mid 2008, the electricity system carbon intensity has increased due to increased use of diesel generation plus load shedding (managed reduction in supply) has become more frequent. Kenya will continue to be exposed in future years, particularly through its import of hydro-generated electricity from other countries in the region, particularly Ethiopia; domestic and imported hydropower is projected to be around 40% in 2030. A recent ECA working group report (2009) looked at this issue for Tanzania, which relies on hydropower for 50% of electricity supplied. An analysis was undertaken that assessed the additional costs of reduced supply to the economy, use of more costly alternative generation and loss of generation revenues. Under a high climate impact case, GDP losses were put at 1.7% GDP due to shortfall in electricity versus 0.1% if no climate impacts were realised. The analysis then focused on how this shortfall could be averted, suggesting that efficiency improvements across the economy could achieve this.

The above analysis illustrates the importance of building in climate resilience aspects into any low carbon pathway. The ECA analysis suggests necessary resilience in the case of Tanzania could be met through negative costs measures. However, climate variability may result in much more extreme shortfalls in one year followed by more stable climate conditions in following years. So the problem may also be one of extreme variability rather than average rainfall reductions year-on-year.

Household / commercial sector options

Biomass will remain one of the primary sources for meeting energy needs in future years. In 2030, it is projected to still provide 60% of household energy requirements. There are a number of technology-based options that could be considered for displacing or reducing reliance in solid biomass-based energy including:

- Improved stove efficiency
- Solar cookers
- Biogas digesters (particularly on smallholdings where cattle are kept)

Much of the literature suggests that improved stove efficiency could achieve up to 50% reduction in household wood fuel consumption, and between 60-70% in a large institution (commercial premises, school etc) (GTZ (2004), GEF (2005), UNDP (2006), GTZ website).

Efficient stoves are extremely cost-effective, in the sense that they save a significant amount of money where wood fuel costs are incurred. GTZ (2004) states that for households up to 30% of monthly income can be saved, and if collection is involved between 10–20 hours saved per week, allowing time particularly for women to engage in productive labour. In Kenya, a very short a payback period of two and a half months was calculated for an improved stove as compared to a service life of three years. A more recent survey showed a lifetime of 8–9 years, which would triple the amount of savings realised. As illustrated earlier in this report, significant savings can also be made at the institution level (schools, hospital etc) through introducing improved stoves.

A study by Habermehl (2007) for GTZ in Uganda calculated the economic benefits of an improved stove programme, while the institution level information is taken from a Kenya case study of improved stoves for schools (implemented by RETAP under the GEF Small Grants programme). The data used in those analyses are reproduced below, to illustrate cost-effectiveness in carbon mitigation terms of options (which are exclusive).

Table 12. Fuel and emission savings from use of improved stoves, and cost-effectiveness for mitigation

Technology	*Annual fuel saving*	*Monthly fuel saving*	*Payback period*	*Emission saving*	*C-E*
	Kg	Kg	Months	t CO2 eq	$/tCO2
Rocket Lorena Stove	22.48	1.9	2.1	0.143	-148.1
Charcoal saving	10.98	0.9	10.9	0.018	-395.2

Source: Habermehl (2007). Above data estimates are per stove, and use a 10% discount rate.

Technology	*Annual fuel saving*	*Monthly fuel saving*	*Payback period*	*Emission saving*	*C-E*
	Kg	Kg	Months	t CO2 eq	$/tCO2
Institution stove	1000	83.3	18.0	12.234	-61.8

Source: GEF Small Grants Programme, Stoves for schools in Mt Kenya region. Above data estimates are per stove, and use a 10% discount rate.

The stove options are very cost-effective and require low capital investment. Payback period is rapid due to the fuel savings (note that the above estimates for household stoves include fuel cost saving on half of the overall fuel saved, as half is assumed to be collected) meaning that this type of measure is cost-effective even without all of the other significant benefits including:

- Reduced health impacts resulting from lower levels of indoor air pollution
- Reduced cooking time
- Reduced time spent gathering fuel
- Lower burden on forests

As discussed earlier in this report, penetration of stove programmes has been successful, and the latest energy policy statement suggests strong ambitions in this area. In this analysis, potential uptake of improved woodfuel stoves is assumed for 5 million households in rural areas, and for charcoal stoves, 1 million households. Take up for 10,000 institutions is assumed. Note that these are not maximum potential numbers but rather illustrative of what could be achieved and at what cost.

These assumptions lead to savings potential of around 20% in 2020, all of which is at negative cost. Clearly, the assumed price of biomass fuels is a critical assumption here, a parameter that is likely to vary in different parts of Kenya (based on local market supply).

Transport sector

Transport emissions are going to be one of the key drivers of rising GHG emissions in future years in Kenya. This is because of significant increases in private car travel demand as incomes rise. Clearly this also has serious implications for urban spatial planning and environmental quality, especially given population and urbanisation trends.

There are two significant issues for Kenya that are considered in this analysis: - improving the fuel efficiency of the vehicle fleet (due to the very high percentage of second hand cars) and considering mass transport options in urban areas.

On fuel efficiency, Kenya has a significant second hand vehicle market. UNEP (2006) estimated over 50% of the vehicle stock of 700,000 was 15 years or older, and over 70% 10 years or older in 2004. A significant proportion, ~25%, is over 25 years. The potential for improved efficiency has been considered for HDVs, LDVs, and cars in 2020, particularly as these vehicle types account for 90+% of total vehicles (in 2004). These older cars also tend to have higher emissions of air pollution, higher noise levels, and lower safety standards. Options for hybrid vehicles have also been considered.

The above five options considered are presented in Table 13, with saving potential and cost. The first three options remove (de-register) stock that is over 15 years old.[43] The additional capital required for these options are estimated as new vehicle price minus the assumed cost of two second hand cars (70% of new vehicle price), as it is assumed that two second hand vehicles would need to be purchased within 15 years. Note these assumptions about costs of alternative second hand cars and replacement rate have a signficiant impact on cost-effectiveness. Options relating to LDVs appear more cost-effective due to the larger fuel savings based on a higher annual usage. The HDV option simply improves the efficiency of older vehicles by assuming a vehicle that is 10 years older.

Table 13. Emission and cost savings from vehicle efficiency improvements, and mitigation cost-effectiveness

Option	*Stock age*	*MAC*	*Road transport sector CO2 saving*
	Yrs	**$/tCO2**	**%**
Reduced older car stock (>15 years)	15-25	121.2	1.5%
	>25	-120.3	0.7%
Reduced older LDV (GSL) stock (>15 years)	15-25	66.6	0.4%
	>25	-189.6	4.1%
Reduced older LDV (DSL) stock (>15 years)	15-25	140.2	2.0%
	>25	-138.0	1.2%
Improve HDV efficiency	>15	-157.9	5.6%
Hybrid uptake (5% cars)		-58.2	1.8%

* 10% discount rate used
* Technology data assumptions sourced from UK MARKAL transport sector analysis

The fifth option shows 5% of new cars being purchased as hybrids rather than the conventional gasoline ICE. This measure is relatively cost effective due to the lower price differential between hybrids and ICEs by 2020, and the relative efficiency improvement versus an ICE vehicle.

A Bus Rapid Transport (BRT) option has also been considered for Kenya; although one is being planned in Nairobi, it does not feature in the baseline. This option is primarily illustrative, to indicate where it is positioned in the range of measures in terms of cost and potential. Costs have been taken from Kahn Ribeiro (2007), citing Wright and Fulton (2005), of around \$60/tCO_2. Potential is premised on an additional 10% of Nairobi's population (40% of Kenya's urban population in 2020) taking up this option, moving away from older car stock to efficient buses.

All of the options below are included in the illustrative cost curve in Figure 26. There are a range of other technologies that could improve the efficiency of the fleet (including advanced technologies, such as electric vehicles) plus other options for reducing reliance on petroleum products e.g. biofuels. It is important that all such options are fully considered, with consideration of all of the costs and benefits. A more efficient road transport fleet is likely to have the following benefits in addition to reducing carbon:

- Reducing reliance and expenditure on oil imports
- Reducing business and private costs of travel, and increasing competitiveness of the economy
- Reducing air pollution, particularly in urban areas
- Improving road safety due to an increase in newer vehicles

One potential negative impact is that legislation to reduce the availability of older vehicles may have a distributional impact on lower income groups, by impacting on the affordability of travel due to large upfront costs of vehicle purchase.

In addition to increasing efficiency, it is imperative for expanding urban areas that planned transport systems

[43] Note that we assume a 15 year old car in 2030 to have the efficiency of a vehicle in 2015.

are put in place to ensure mobility of the population can be maintained and urban environmental quality not compromised. This is very challenging and requires significant upfront costs but is critical for meeting travel demand and ensuring quality of life for a growing urban population.

Industry sector

The projections for the manufacturing sector are based on current year oil consumption, growing at a rate similar to that suggested for the economy with some autonomous energy efficiency improvements. Hence, they are relatively simplistic. The potential for energy efficiency improvement in 2020 is based on a project supported by GEF (1998) which in trying to understand how the programme could be scaled undertook some assessment of efficiency potential in SMEs. This analysis has been used to estimate potential for energy savings, and marginal abatement costs. The analysis suggests that on average there is about 16% potential savings in oil use; if this was applied to 40% consumption across all industry sectors, this would equate to over 250 Gg CO_2, or 6% of sector emissions. Marginal costs (based on a 15 year programme) are estimated to be \$20/tCO_2.

Much more work is required in this sector to understand efficiency potential in different subsectors of manufacturing. In addition, there may be a range of different technology options for larger industries that may improve productivity of the economy whilst also providing carbon benefits.

Agriculture sector

Agriculture projections are extremely uncertain, particularly because the inventory estimates (GoK 2002) are not recent and incomplete (compared to other country inventories). A simplified approach, due to high uncertainty of agriculture sector emissions, has been to use mitigation cost and reduction potential estimates for Africa from the comprehensive USEPA study (2006) on non-CO_2 mitigation options and apply them to the Kenya situation. Options for livestock management, particularly focusing on enteric fermentation, could reduce emissions by 2.1% at \$15/tCO_2 or by 0.5% at \$0/tCO_2. For cropland management, to reduce N_2O emissions in particular, we have used the following % reductions: 13.5% at \$15/tCO_2 or by 10.6% at \$0/tCO_2.

Whilst this approach is basic, it has been used provide some preliminary understanding of the extent of reduction potential at given costs for generic agriculture emission categories. At higher costs, mitigation does not increase significantly; McKinsey analysis supports this finding by estimating average abatement costs of around \$5-10 for agriculture sector in Africa (Grantham Institute 2009). On mitigation potential, it is difficult to compare the Grantham analysis with that produced by the USEPA due to different baselines and different analysis years.

Forestry sector

Kenya plans not only to preserve its forest cover but embark on a large-scale afforestation / reforestation programme. The Government has developed some initial thinking on the types of activities required, and the investment requirements. Costs are put in the region of \$385 million per annum (for 20 years), to increase forest cover from the current 3% of land area to 10%.

Therefore, we have not undertaken any additional analysis here to look at costs and potential. However, it is worth noting a number of points when considering such options from an economic perspective:

- The benefits are clear – preserving biodiversity, safeguarding tourism, improving security of fuel wood supply, improving prospects for forest based industries, retaining natural water management, and making habitats more resilient to some of the impacts of climate change.
- A potential cost is the opportunity cost lost from not using the land for another type of economic activity. Agricultural commodity prices and land rents are going to have a big impact on such costs.

- Raising the necessary investment is going to be challenging; REDD is an emerging mechanism for financing the safeguarding of existing forests. Financing will need to be found for afforestation – a current example if a project the Green Belt Movement has which is funded by the World Bank BioCarbon Fund.
- Rapid development if delivered at the projected rates would lead to significant economic pressures on the current forests but also on the land that might be designated for new forest area.

From a purely mitigation perspective, the emerging consensus is that measures to reduce forest loss and degradation, and reforestation, are relatively low cost. Cited in Nabuurs et al. (2007), Sohngen and Sedjo (2006) estimate that for 27.2 US\$/tCO_2, deforestation could potentially be virtually eliminated. Over 50 years, this could mean a net cumulative gain globally of 278,000 MtCO_2 relative to the baseline and 422 million additional hectares. At least 60% of this could be done at a carbon price near to 13 US\$/tCO_2. Relative to other regions (except South East Asia, Africa has most potential at these lower carbon prices.

Additionally, modelling results presented Nabuurs et al. (2007) suggest that 70% of mitigation potential identified could be implemented at a carbon price of between 1-20 US\$/tCO_2. Analysis by McKinsey (2009) supports the fact that forestry measures tend to be relatively low cost to those observed in other sectors.

More assessment is required for this sector to understand the costs of reducing deforestation / increasing afforestation for Kenya, particularly in the context of increasing opportunities for financing. Momentum is building in the discussions around a REDD+ mechanism prior to Copenhagen, as set out by the recent working group report on phasing funding over the next 5 years (IWG-IFR 2009); it will be important for Kenya to better understand its potential for access such financing, and how this can link in with the Government's own strategy for afforestation and forest protection.

An indicative cost curve for Kenya

An indicative cost curve for Kenya is provided below for 2020. <u>It does not represent total potential in 2020 but includes the example measures described above.</u> The primary purpose is to demonstrate that Kenya can move to a lower carbon pathway without significantly impacting on growth; in fact, many of the measures would make the economy more productive and competitive. Many lower carbon options therefore promote rather than undermine the ambitions of growth. This is particularly the case concerning energy efficiency measures, which reduce fuel costs.

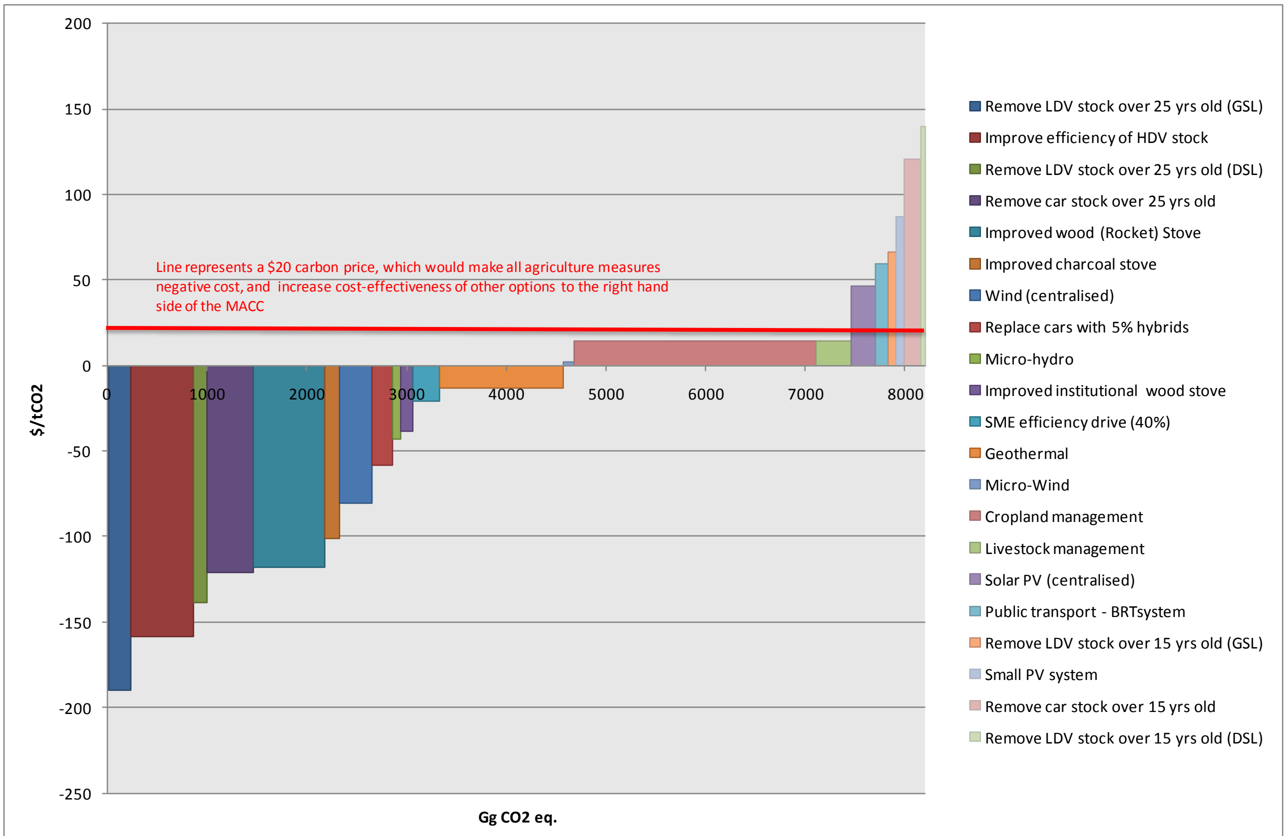


Figure 26. Indicative MAC curve of selected abatement measures for Kenya in 2020[44]

All future cost and benefits are discounted at 10%, using the net present value.[45] The first measure listed in the legend is the most cost-effective, shown as the bar further left on the MACC figure. Subsequent measures are listed in order of cost-effectiveness. The cost curve identifies that significant 'no regrets' potential is available (almost 50% of stated potential), particularly from improvements in transport vehicle efficiency, and performance of domestic stoves. The agriculture sector options are low cost (<$15 /t$CO_2$), resulting in no regrets / low cost options accounting for over 80% of stated potential.

The carbon credits that could be available for emission reductions are not included in the cost curve analysis. If they were, the negative cost potential would increase, and least cost-effective options would appear more attractive, as shown by the red line illustrating a $20 carbon price. Therefore, the above MACC represents a less optimistic situation, where additional financing is not available. This is encouraging, given the number of low or negative costs measures in the absence of a carbon price.

The emission reduction potential shown in the above MAC curve for 2020 is compared against the 2020 baseline for energy using sectors (Figure 27). These sectors have the potential to produce savings of 22% relative to the baseline. Of the potential savings, over 80% can be realised at negative or low cost.

[44] Fossil prices consistent with those presented in Kenya's LCPDP for electricity generation measures. For transport fuel prices, current petrol / diesel prices have been used.(~100 KSh / litre). Biomass prices based on those cited by Habermehl (2007)
[45] Agricultural and public transport measures use costs derived directly from literature and therefore the discount rate is not known.

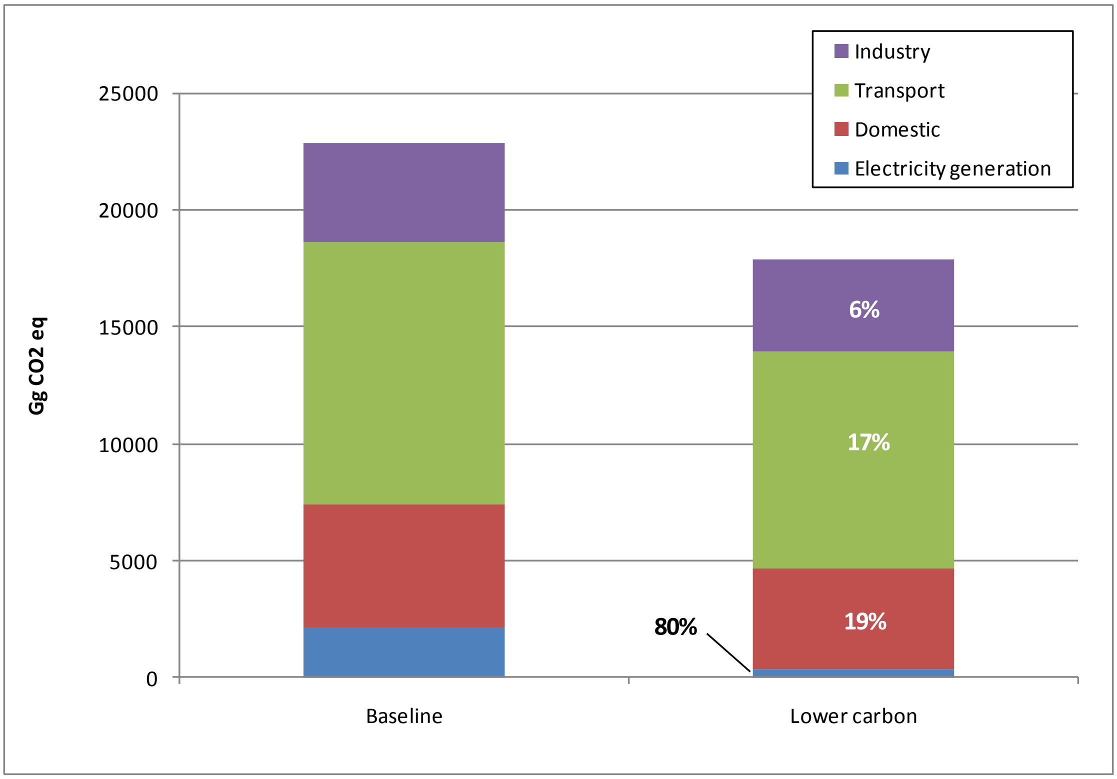


Figure 27. Kenyan emission in 2020 under the baseline and *lower carbon* case

* The % labels in the *Lower carbon* case denote % reduction by sector relative to baseline

The inclusion of agriculture sector emissions results in an overall reduction of 13%. This is lower than the 22% reported above due to the high level of the emissions from this sector.

Pertinent issues with the above MACC approach

The above MACC analysis needs to be considered in view of a number of other issues:

- **The MACC does not represent full potential**. Specific subsectors (non-road transport) and sectors (waste) have not been included. For sectors considered, only specific examples have been included. Therefore, significant additional potential is likely to be available.
- The MACC (for most measures) does not include policy / transaction costs which may be significant for implementing some of the measures listed. Project Catalyst estimate transaction costs in the region of \$1-6 /tCO_2 globally (Grantham Research Institute 2009).
- The MACC is for a single year, 2020, chosen because it represents around 10 years from current time, a period of time when progress of moving to a lower carbon pathway could be achieved. It is likely that with rising emissions post-2020, more expensive options, particularly in the transport sector, will be needed.
- Specific types of measures (which may be cost-effective) are more difficult to quantify and have therefore not been included. These include non-technical options e,g. driving behavior improvement, and issues associated with urban planning, which are very important in the context of Kenya.
- There are a number of drivers, important for Kenya, which are not included in the projections e.g. the potential effects on agricultural air freighted export markets from international emission reductions, or the effects on the long-haul tourist potential for Kenya with international emission reductions on aviation

Wider issues with the use of MACCs are outlined in the Box below.

Wider issues concerning the use of MACCs

There is no doubt that MACCs have provided an important role in helping explore mitigation options, and identifying those opportunities that are most cost-effective. However, there is both a danger of misinterpretation of and over-reliance on this approach. Misinterpretation comes because of the absence of information on underlying assumptions. Large amounts of cost-effective potential can be observed and provide an impression that this is easily attainable, without noting the many caveats and simplifications that have been made.

Over-reliance because the MACC approach is relatively simplistic. Additional analysis may often be needed to compliment the MACC approach. Indeed it is often the case that MACC are derived from more complex models, as a simplified representation. The following notes of caution need to be made for when using and interpreting MACCs:

- Static snapshots of mitigation potential in a given year. Therefore, it is of limited benefit in helping understand when investments should occur, for example, or whether additional options will be available in subsequent years. If a MACC time series is available, care is then needed to ensure that the baseline in subsequent years is adjusted to account for any additional take-up of measures.
- Limited feedback between sectors. Integrated system modellers often cite the lack of interaction between sectors as a significant problem with MACCs. In an energy system, what happens in one sector might impact on electricity demand which in turn affects the upstream sectors. None, or at least very little of this is captured in MACC analysis. Some MACC analyses do account for changes in electricity sector intensity.
- An associated issue is the interaction between measures. Introducing one measure first could have an impact on the cost-effectiveness of the second measure and so on. This may be particularly true of building measures.
- Few MACCs integrated the full cost of the measure in the analysis. Hidden and missing costs (e.g. implementation, transaction costs) are often omitted but can have a significant bearing on a given measure. In other words, full costing of measures could also lead to a better representation of the barriers to uptake. [46] As MACCs tend to represent technical measures, significant costs associated with implementation are usually overlooked.
- MACCs often take account of overlaps between the range of alternative options but not always. A MACC may list three power plant options; however, if one is introduced it may be the case that the other two are not needed. Therefore simply aggregating options in a MACC to get total potential is not always correct.

An additional sensitivity has been undertaken to highlight the importance of the discount rate chosen. While the above MACC estimates are based on a 10%, the impact of a higher commercial discount rate and lower societal based rate (as used in the UK) are provided for illustrative purposes below. Note that the agriculture measures have been removed, as they have not been calculated but rather derived directly from literature review.

The lower discount rate (commonly used in McKinsey work represents a ‘societal view’ of costs and benefits, highlighting the measures that will be in the public interest to implement. A private sector perspective can be quite different, with investment decisions factoring in much higher rates. Higher rates make options with high upfront costs and future streams of benefits (e.g. many energy efficiency investments) appear less attractive. This moves the MACC upwards, and changes the order of options on the basis of cost-effectiveness. Conversely, a low rate will make such options more attractive. This is reflected in Figure 28.

[46] Some economic analysis (although not found in the review) also use higher cost of capital (or CRF) known as a hurdle rates to reflect the barriers to uptake of perceived higher costs, consumer choice or the quick payback period that consumers expect.

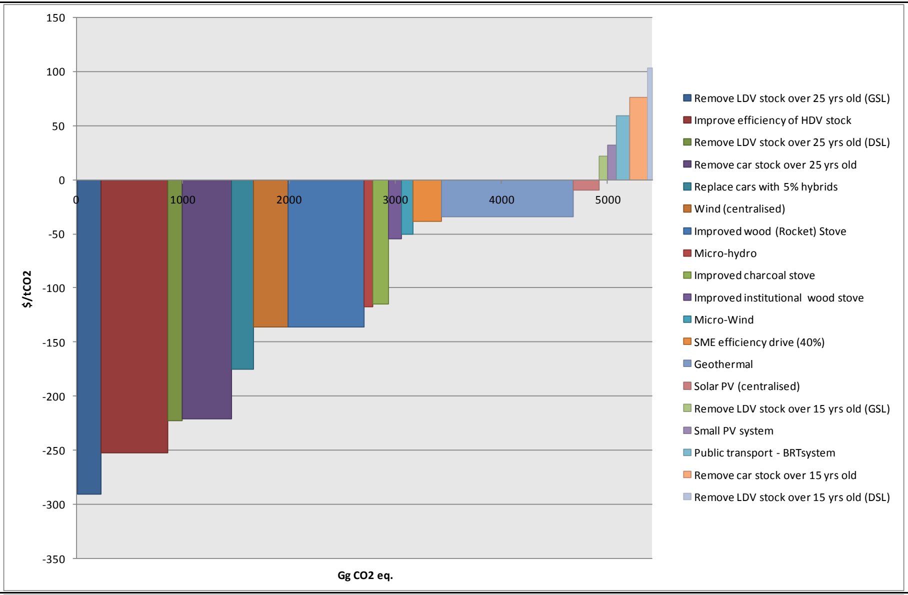
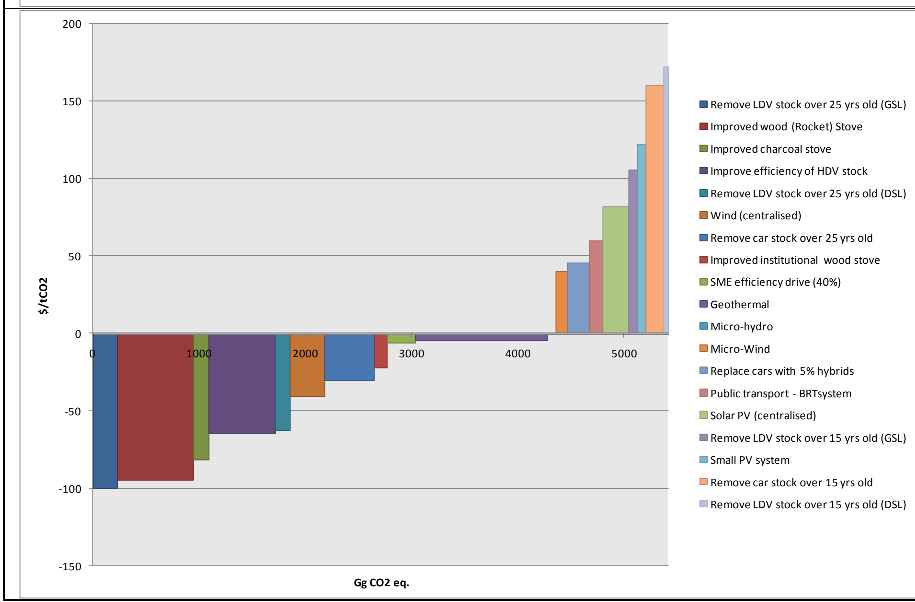
	**4% discount rate**
	**20% discount rate**

Figure 28. Indicative MAC curves of selected abatement measures for Kenya in 2020 using alternative discount rate assumptions

Carbon financing requirements

Kenya is going to need to invest heavily in infrastructure and technologies if it is to grow to the extent set out in the Vision 2030. There are emerging opportunities that will enable financing of such investments where the carbon benefit can be demonstrated.

CDM as has been the primary carbon financing mechanism that the developing world has had access to. However, the benefits of this scheme have not been realised for African countries. Africa holds less than 3% of CDM projects; of these, most are in South Africa (APF 2009). Barriers to this mechanism include high transaction costs, low institutional and technical capacity and small sized projects. Institutional capacity needs to be strengthened in order that other aspects of CDM, that allow for small-scale projects or programmes (multiple projects) to be included under the mechanism. There is also a need of course for Kenya to suggest changes to current carbon financing under the CDM so that any emerging scheme is as beneficial as possible. A number of different mechanisms are being discussed and therefore it is vital that Kenya and associate countries look at what might be most beneficial for raising finances.

The potential for carbon financing under non-UNFCCC administered funds also needs to be realised, such as World Bank Climate Investment Funds, plus the emerging REDD / REDD+ schemes that may be important for Kenya in financing forest protection measures and afforestation plans. Again, it is vital that Kenya positions itself to fully inform the ongoing discussions about how mechanisms might work, and strengthens the institutional capacity to ensure that opportunities are taken.

Grantham Research Institute (2009) describes a range of barriers that may need to be overcome in Africa to access potential mitigation financing. These include limited capabilities to efficiently deploy funding, limited capacity / capability to meet MRV requirements, and the perceived investment climate for internal and external investors. They also highlight that for certain measures (e.g., fuel efficient stoves or REDD) financial support will need to go to a wide range of communities and individuals to have an impact, and policies and institutions will be needed to support such distribution.

The same report discusses how to enable access to carbon markets for Africa, including *tailoring market mechanisms to Africa's opportunities; and designing a phased approach to market access to allow Africa build its capabilities*. In particular, market mechanisms should include *specific opportunities such as REDD; accommodate small scale projects; and guarantee further capability building*. The report notes that financing will initially be done through public financing routes such as mitigation funds, but could then shift to private funding through offset markets in the longer term.

Summary

This analysis shows that there are significant opportunities for further reducing GHGs while promoting and ensuring growth rates are maintained. Whilst these have been assessed, it is important to stress that more work is required to understand the potential of such options, due to the uncertainties in the projected baseline.

The measures shown in the above cost curve are listed below, showing what might be the policy driver for introducing a given option, and the co-benefits of the measure if indeed the measure was being appraised for carbon mitigation.

Option	***Policy driver***	***Co-benefits (as a GHG mitigation measure)***
Expanding use of renewables (centralised)	Expanding capacity to meet future needs based on strong resource base	Reduce reliance on / payments for foreign fossil imports More cost-effective across many types Leverage carbon finance to fund investment Potential to build regional expertise, and export No air quality pollution
Decentralised generation from renewables	Rural electrification	Lower cost than alternative fossil generation Limit requirements for expensive grid expansion Sustainable energy for local economic growth No air quality pollution
Introducing improved stoves	Reduce biomass demand	Reduce indoor air pollution, and therefore health impacts Reduce fuel costs Protecting fuel Saving economic / leisure time (wood collection)
Improving efficiency of road transport fleet	Reducing reliance on fossil fuel imports	Reduce reliance on / payments for foreign fossil imports Reduce costs of vehicle use Reduce air pollution Reduce road traffic accidents (due to newer cars)
Planned public transport scheme for Nairobi	Meeting urban transport demand	Reduce congestion Reduce air and noise pollution levels Save travel time / enhance productivity Reduce road traffic accidents
Tackling energy inefficiency in SMEs	Reducing industry fuel costs, increasing competitiveness	Reduce fuel costs, enhance competitiveness Enhance energy security Reduce air pollution
Improve livestock and cropland management	Improve agriculture productivity and reduce land degradation	Protect / enhance arable land quality Safeguard rural livelihoods Increase economic productivity of sector
REDD / Afforestation	Protect forestry-dependent economy and energy supply security	Protect biodiversity, and dependent sectors Ensure security of wood fuel supply

It demonstrates that many of the options are important and consistent with objectives of sustainable economic growth. The costs analysis suggests that many of the above measures are also cost-effective, and can save money for the economy rather than add significant additional financial burden. Further work is required to develop other options and provide a more comprehensive picture of the different opportunities, building on this emerging picture of a lower carbon future.

6) A Low Carbon Growth Strategy

In many sectors, Kenya is already on a low carbon pathway because of the significant renewable resources it has. This is particularly demonstrated in the low carbon intensity of the electricity generation system, the dissemination of renewable decentralised technologies (solar PV systems for homes), the widespread use of biomass and the significant forest resources (holding carbon stocks). This suggests that to a certain extent it is very much in the interest of Kenya to be low carbon e.g. due to the prevalence of renewable resources, this type of energy is more cost-effective than fossil-based alternatives.

Whilst Kenya has a relatively low carbon intensive economy, very high projected rates of economic and population growth may see carbon intensity increase. The question is whether it is in the interest of Kenya to push for lower carbon growth; clearly there will be global benefit due to lower future emissions. Fundamentally, this is likely to be based on whether the additional costs of an alternative low carbon growth path outweigh the benefits. In addition, there is also the question of whether the low carbon growth path is also as resilient to future climate impacts predicted, including extreme weather events (droughts and flooding) which appear to be more frequent even in recent years.

The apparent benefits of a low carbon growth path are firstly economic. This is demonstrated in the electricity sector, which is projected to remain relatively low carbon under the baseline because of the abundance of cost-effective renewable generation potential, both in-country (geothermal) and in neighbouring countries (hydro, particularly in Ethiopia). There are however concerns that a significant future reliance on hydro may leave the system vulnerable to shortages (due to reduced rainfall or water scarcity due to demand elsewhere), and a move to more reliable fossil generation. Therefore, the issue of climate resilience is key. The low carbon generation system will also provide low carbon electricity to a rapidly expanding consumer base, displacing biomass and kerosene in the household sector. This change in consumption and a continuing significant contribution from biomass means that this sector will remain relatively low carbon in future years.

Secondly, a move to a lower carbon pathway can also mean technology improvements; economic modernisation may well push technology advancement forward, realising this important synergy. Thirdly, lower carbon growth opens the door to carbon financing; while access to such financing needs to improve for lower income countries like Kenya, it is clear that a range of financing options are being discussed that could make lower carbon options more economically attractive. Fourthly, many lower carbon options offer a range of co-benefits to social welfare, health, energy security and wider environmental quality.

Finally, as Kenya develops and meets its objectives of becoming a modern economy with increased quality of life (as set out in the Vision 2030), it may be treated differently as a developed nation under any future climate agreement. This could include setting carbon reduction targets; therefore, the carbon footprint of large-scale investments (e.g. power plant, transport systems) in the next 10-20 years should include assessment of the risks of *lock*-in to higher carbon technologies, particularly for investments that last 40-50+ years. Such investments once made are sunk and very expensive to stop operating in a lower carbon world.

Recognising the benefits as outlined above, in particular that a lower carbon pathway does not necessarily lower growth and require significant additional financing, this and subsequent analyses should focus the mind of policy makers on the opportunities for low carbon growth, particularly as the 2nd implementation plan for the Vision 2030 is developed. Importantly, it also supports many of the policy objectives that need to be met for sustainable development as discussed.

Whilst the opportunities have been stressed, there are however significant challenges. One of the most significant is population growth and rapid urbanisation, which will put additional pressure on planning (including spatial planning) for a lower carbon future. These drivers will increase demand on energy, food and water, leading to increases in emissions. This means that opportunities for implementing lower carbon alternatives needs to be an integral element of the planning and policy making system. This would in effect remove the need to balance climate objectives (adaptation / mitigation) against economic growth consideration because they would be inextricably linked.

Challenges of rapid urbanisation

High urbanisation rates now and in future years provides an important context for assessment of a lower carbon pathway. By 2030, most of the population are predicted to be living in urban areas, which means that any strategy to move to a lower carbon pathway also needs to reflect this demographic shift. In addition, this needs to be strongly linked with adaptation measures.

Developing urban transport systems that allow for urban growth whilst reducing carbon emissions will be critical. This includes public transport systems that can be developed to accommodate growing populations but also reflect how urban areas are foreseen to grown. Spatial and transport planning need to be wholly joined up. Lower emission vehicles and alternative transport fuels (CNG / biofuels) may also be part of a more sustainable urban transport system. There are also considerable co-benefits to be realised through this approach, including lower air pollution, less congestion and potentially safer roads.

Housing planning should also integrate lower carbon objectives, such as promoting build that requires less cooling, and increasing green areas to reduce urban heat island effects. The needs of adaptation should also be considered e.g. built to enhance water collection (to reduce pressures on public systems). Effective planning and creative urban design are going to be key to ensure climate proof, low energy buildings. This of course extends to other urban infrastructure. Affordability will also be key, in addition to policies that will ensure poorer communities (e.g. slum dwellers) can also benefit from such sustainable urban growth.

Further work is required to better understand the urban aspects of a lower carbon pathway, and is an important recommendation of this study.

There are also barriers that need to be overcome to increase uptake of low carbon technologies. These are summarised by Grantham Research Institute (2009), and include (in order of most stated by countries surveyed):

- Economic / market barriers (e.g. no finance, poor commercial case)
- Low levels of information / awareness
- Policy / regulatory framework
- Technical problems of use in-country
- Lack of skills / know-how
- Limited institutional capacity

Identifying, acknowledging and overcoming such barriers is crucial in promoting and delivering a lower carbon strategy.

In conclusion, because of its location, availability of resources, and socio-economic conditions, the study concludes that there are significant economic benefits for Kenya in following a low carbon development path, as well as large environmental and social benefits. A low carbon pathway is strongly in Kenya’s self interest, and would also provide potential extra investment from carbon financing. This is also important given the goal to become a middle income country by 2030, as countries of this development level will need to be reducing GHG emissions from the planned baseline level, if the global target to limit global temperature change to 2 degrees is to be achieved.

Study recommendations

Specific recommendations from the study are as follows:

- In this initial study, emissions projections, consistent with Vision 2030 as far as possible, suggest significant increases in emissions in future years, particularly in the agriculture sector but also in a rapidly growing transport sector. There are, however, large uncertainties around Kenya's national emissions and growth path. Whilst the broad conclusions of large increases in emissions are relatively robust, further work is needed to improve these initial estimates and to give a degree of confidence in the analysis and this is a priority research areas.

- In many areas, Kenya is already initiating measures and policies that are consistent with low carbon development. This includes the electricity sector power emissions. However, the current plans do not maximise the economic potential that could be gained. In many sectors, the current plans are likely to 'lock-in' Kenya to a higher emission pathway, which will reduce future economic opportunities and are also likely to reduce future economic growth. An example already existing in the electricity sector with the planned implementation of coal fired generation. These need to be identified and ideally, alternatives considered.

- The study has outlined an alternative low carbon path for Kenya. This initial analysis projects very real economic, environmental and social benefits from adopting a low carbon development path. These include both direct economic benefits (no regret opportunities), additional economic benefits from carbon financing, and wider economic benefits from ancillary benefits of these policies, including reduced imports, improved air quality, improved energy security, reduced pressure on natural resources. The key aim for Kenya is to continue this switch to a lower carbon pathway, to further realise these benefits, and to maximise the potential for the flow of carbon credits under existing and future mechanisms. Further assessment of how far Kenya goes down the low carbon pathway is needed, to robustly assess the full costs and benefits.

- Unlike other countries, power generation is a very low proportion of total emissions, and will continue to be so in the future under the baseline Vision 2030 projections. It is therefore a priority to tackle these other sectors, because in contrast to the power sector, emissions from these sectors are already increasing, and are projected to rise dramatically in the future along the development pathway towards a middle income country. These must also be addressed to achieve low carbon growth – and we emphasize that addressing the electricity sector is only a small part of the overall story. A key conclusion and recommendation is for the need for Kenya to move beyond the narrow interpretation of low carbon in just the electricity sector, and progress at an economy wide level.

- While the electricity generation sector plans project a low carbon future, there are some risks, and therefore more work should be undertaken to consider the following:
    - Exposure to climate impacts. Kenya will be very exposed to regional variability in rainfall due to domestic and imported reliance on hydropower. There is a need to build climate risk screening into future low carbon plans across all sectors
    - Exposure to system reliability problems. A high renewable system can carry risks if specific resources do not achieve projected generation, hydro being the obvious example. Kenya maybe reducing exposure in future years by maintaining fossil based generation
    - Energy security concerns. Future reliance on imports are premised on large infrastructure projects being completed, and political stability in the region

- Agriculture and transport remain the large emission growth sectors. For transport, while efficiency gains offer significant opportunities, the demand for private transport is going to increase significantly. This is a much harder to problem to solve but will require a robust strategy that considers improved public transport, demand management, and urban planning. Key barriers include large upfront costs associated with transport schemes, and costs to private individuals to purchase newer efficient vehicles, or more advanced technologies. The transport strategy that accompanies the Vision 2030 needs to be more robust in firstly assessing how the growth in transport demand will be met, taking account of sustainability issues. For agriculture, although low carbon options appear low cost, they are difficult to implement due to many small holdings and fragmentation of the land; therefore high transaction costs could be envisaged.

- The domestic sector remains a large consumer of biomass due to population growth, but has a much lower per capita usage. This is largely due to large-scale access to electricity, enabled by increasing urbanisation but also efforts to expand rural electrification. More research is needed to establish alternative pathways that do not see large scale electrification.

- The strategy for the forestry sector is also very important; large scale afforestation is planned as is the need to protect existing cover. New financing schemes such as REDD / REDD+ will be critical in ensuring that this happens due to the significant investment required. Kenya needs to be well positioned to take advantage of the schemes that may emerge post-Copenhagen.

- To realise the many low carbon opportunities requires the mainstreaming of mitigation policy across all part of the economy and across all of Government. Following from the points above, it would be extremely beneficial for Kenya to undertake a detailed assessment of a low carbon strategy including a detailed investment and financial flow analysis. This would identify no regret and low cost options that are justified on the basis of ancillary benefits. It would also be advisable for Kenya to strengthen its capacity to develop and implement proposals for any future schemes (programme CDM, NAMAs, REDD, etc). This would also require significant development of projections, which form the basis of understanding cost-effective potential. In combination, there is also a need to investigate the potential for further funding by exploiting synergies with adaptation.

- Related to this there is a need to re-assess the Vision 2030 document in light of the potential for low carbon growth and opportunities for growth, but also potential barriers to growth that might arise from the future global carbon market, particularly in relation to key growth sectors that have high carbon intensity or international links.

Research priorities

There are a number of research priorities emerging from this work:

- Establishing robust and up-to-date base year emissions, including for the LUCF sector. This is presumably happening as part of the 2nd National Communication activities.
- Development of robust projections, taking detailed account of different drivers in sectors, and likely structural change in the economy. This is fundamental to being able to understand what future year emissions may look like, and the potential reductions.
- Sensitivity analysis around the different projections, for example if Vision 2030 assumptions on growth are much lower. In addition, incorporation of changes resulting from climate impacts / adaptation.
- Investment and financial flow analysis for mitigation (as part of a joint mitigation-adaptation analysis). This should follow the recent guidance from UNDP on IFF analysis.
- More comprehensive view of mitigation potential, building on the MACC analysis already developed, and consideration of wider economic impacts through macro economic analysis and modelling. There would also be considerable benefit in extending the analysis time horizon out to 2030 and perhaps even to 2050. Also, there should be additional focus on implementation, including the capital intensity of projects (measuring upfront capital requirements) and other barriers (feasibility, scale-up etc)
- More quantification of the co-benefits of low carbon pathway; for example, estimates of reduced energy security risks, or lower air pollution in urban areas / households. In addition, more consideration needs to be given to equity issues and distributional impacts of a lower carbon pathway e.g. does it benefit certain groups while disadvantaging others?
- Increasing focus on urban issues in the context of lower carbon growth due to rapid urbanisation in future years
- Further development of the analysis of linkages between adaptation and mitigation, exploring the synergies but also potential conflicts

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Appendix 1. Key low carbon projects and organisations working in the energy sector

Project	Period		Contribution
MOE Installation of Solar PV Systems in schools and health facilities in ASAL areas. 134 Institutions already benefited	2005	2012	460 million Kenya shillings
MOE Installation of Solar PV Systems in schools and health facilities in ASAL areas, 54 institutions benefited in this period	2008		130 million Kenya shillings
SIDA, Swedish Energy Agency (STEM),Programme on Capacity Building for CDM (East Africa). The project focus is on training DNAs of the three countries Kenya, Tanzania and Uganda	August 2007 –	November 2009	
UNDP Renewable Energy Technology Assistance Programme (RETAP). Market transformation for highly efficient biomass stoves for institutions and medium scale enterprises in Kenya.	2007	2010	USD 975,000
World Bank Capacity Building and Bio Carbon Fund Pilot Implementation	2006	2008	USD 462,250
French Development Agency Funding of Kipevu Combined Cycle - KenGen CDM pipeline	2008	2010	USD 90 Million
French Development Agency Re-forestation of the Aberdare -- Purchase Agreement signed with Bio Carbon Fund in 2006. 300 ha of AFD sites are part of the agreement			USD 49 Million
French Development Agency Olkaria II 3rd Unit (Geothermal Plant) KenGen CDM pipeline	2008	2010	EUR 1.3 Million
Kenya Energy Sector Environment Programme (KEEP) MOE - sponsored programme to conserve water for HEP generation, wood fuel production, pole treatment of electricity transmission, carbon sink and (liquid) biofuels production	Ongoing		30 million Kenya shillings
Bamburi Cement (Lafarge East Africa) Development of 2 to 3 CDM projects through fuel switching from fossil fuel to sustainable biomass	2008	2010	USD 20 million
Enegry Efficiency & Conservation	Ongoing		
KAM Energy efficiency & Conservation Support for manufacturing industry in improving energy efficiency			20 million/year
East Africa Portland Cement (EAPC) Energy Efficiency leading to Reduction of the more expensive clinker, main raw material in the making of cement, leading to lower consumption of fuel in the firing process.			

Organization and address	Field of Interest
JP Morgan Climate Care. Eden Square Business Center, Westlands P.O. Box, 856, 00606, Nairobi	Climate Care wants to tackle climate change today by providing carbon offsets by helping people have an impact, lowering business emissions and individual carbon footprints through carefully sourced carbon reduction

Tel: +254 (0) 20 367 3183 Fax: +254 (0) 20 367 3183 Email: jpcc.projects@jpmorganclimatecare.com	projects
Carbon Positive has offices in Netherlands, Brazil, Kenya, China, Brazil, UK and Australia www.carbonpositive.net	Carbon Positive arranges and manages sustainable energy and reforestation projects to cut greenhouse emissions and generate tradable carbon assets that customers can sell for cash. The projects are in developing countries and benefit local communities as well as global climate. Carbon Positive has offices in The Netherlands, Australia, Kenya and Brazil and is run by business professionals dedicated to sustainable development, allied with like-minded companies and charities.
Camco Advisory Services (K) Limited Muringa Road off Elgeyo Marakwet Road PO Box 76406-00508 Nairobi Kenya Tel: +254 20 387 5902 Fax: +254 20 387 5902	Camco is a leading climate change and sustainable development company. It provides world class strategic, technical and financial solutions for all carbon related issues. Camco is able to provide solutions for the public and private sectors, in the developing and developed world and across all the stages of the carbon management process.
UNDP SGP KENYA UNDP, P.O. Box 30218, Nairobi, 00100 Phone: (254-20) 7624474 Fax: (254-20) 7621076 Email: nancy.chege@undp.org	GEF projects in climate change help developing countries and economies in transition to contribute to the overall objective of the UNFCCC. Climate change could have devastating effects on the well-being of people already living on the edge of poverty - with limited financial and technical capacity, yet dependent on climate sensitive sectors for their life and livelihoods, communities must rely on their own ability to adapt and survive in constantly changing conditions. Projects are implemented according following GEF Operational Programmes OP11- Promoting environmentally sustainable transport OP5 – Removal of Barriers to Energy efficiency and Energy Conservation OP6 – Promoting the adoption of Renewable Energy by Removing Barriers and Reducing Implementation Costs
Practical Action - Eastern Africa (formerly ITDG)AAYMCA Building (Second Floor) Along State House Crescent P.O. Box 39493, Nairobi, Kenya Tel: +254 20 715293 / 719313 / 719413 Fax: +254 20 710083 E-mail: ITDGEA@...	Practical Action - Eastern Africa aims to build technical skills of poor people and enabling them to improve the quality of their lives and those of future generations. The programme sectors include - Energy, Rural Agriculture and Pastoralism, Transport and Manufacturing, Fund-raising and Marketing, Building Materials and Shelter Programmes.
GTZ Office Nairobi P.O.Box 41607 00100 GPO Nairobi Kenia	GTZ operates on themes such as promotion of renewable energy and efficiency, rural development, good governance, economic development and employment, social development among others
African Center for Technology Studies (ACTS) Gigiri Court, Off United Nations Crescent, P.O.Box 45917 - 00100, Nairobi, Kenya. Tel: +254-20 712 6889/90/94/95 Fax: +254-20 233 9093 Email: info@acts.or.ke Web: **http://www.acts.or.ke**	ACTS is a Nairobi-based international intergovernmental science, technology and environmental policy think-tank that generates and disseminates new knowledge through policy analysis, capacity building and outreach. Its programmes include Biodiversity and Environmental Governance, Energy and water security, Agriculture and food security, Science and technology literacy.
Green Africa Foundation, Kenyatta International Conference Centre (KICC), Lower Ground floor, room13	Kenyan organization founded in 2000 to support ecological and environmental conservation with a particular focus in arid and semi arid lands of Kenya where poverty is most prevalent. The Foundation focuses on capacity

Post Office Box 9164-00200 Nairobi, Kenya Telephone: +254 20 224 8768/9 +254 20 224 8846 Fax no. +254 20 224 8768 Email: info@greenafricafoundation.org	development of poor communities through a partnership approach that integrates environmental conservation and community livelihoods. Their main focus is on Biodiesel production projects (from Jatropha), environmental conservation through sports, among others
Vanilla Jatropha Development Foundation (VJDF) P.O Box 13828 GPO 00100 Nairobi Kenya Phone: +254-20-608456	To enhance the productivity, profitability and sustainability of Vanilla-Jatropha production-consumption value chain in eastern Africa sub-region based on an integrated / efficient Vanilla-Jatropha production system
Kenya Industrial Research Institute (KIRDI). P.O. Box 30650. Tel: 254-20-603842/609440. FAX: +254-20-607023 Email: dir@kirdi.go.ke, info@kirdi.go.ke	This is a national research institute established in 1979 under the Ministry of Trade and Industry and mandated to undertake multidisciplinary research and development in industrial and allied technologies. The major R&D departments are the engineering, energy and environment, ICT, leather and textiles, and food technology divisions. KIRDI has developed over 40 technologies in these fields.
Kenya Electricity Generation (KenGen) Stima Plaza, Phase III, Kolobot Road, Parklands P.O. Box 47936 – 00100 GPO, Nairobi, Kenya Tel: +254 20 3666000 Fax: +254 20 248848	Kenya Electricity Generating Company Limited, KenGen is the leading electric power generation company in Kenya, producing about 80 percent of electricity consumed in the country. The company utilizes various sources to generate electricity ranging from hydro, geothermal, thermal and wind. Hydro is the leading source, with an installed capacity of 677.3MW, which is 72.3 per cent of the company's installed capacity.
Appropriate Technology Centre Kenyatta University, P.O. Box 43844, Nairobi	Renewable energy technologies, post harvest & food preservation technology, energy saving wood and charcoal cookstoves, water storage.
Renewable Energy Technology Assistance Programme (RETAP). P.O. Box 28201, 00200 Nairobi, Kenya. Westlands, Waumini 1 st Floor Tel/Fax +254 20 3002344, 2033867 E-mail: info@retap-africa.org	The programme 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.
Kenya Power and Lighting Company (KPLC) P.O Box 30177, Nairobi	It owns and operates Kenya's interconnected power transmission and distribution network.
AFREPREN AFREPREN/FWD House, Elgeyo Marakwet Close P.O. Box 30979 GPO 00100 Nairobi, Kenya Telephone +254-722509804 +254-720973610 +254-020-2535266 afrepren@africaonline.co.ke	Energy, Environment and Development Network for Africa is a registered Non-Governmental Organization based in Nairobi, Kenya, with vast expertise on energy in East and Southern Africa and some experience in West and North Africa. Among their activities include examining initiatives for providing least-cost clean energy services to urban and rural poor households and small scale enterprises.
Renewable Energy Engineering Contractors (REECON) Ngong road, Nairobi, Kenya Telephone: 045-40557	Consultants and retailers of wood burning stoves and furnaces, biomass energy systems, composting systems, energy efficient homes and buildings, hydro energy system components (small), solar cooking systems, Biogas plant, waste water, incineration, energy efficiency.

Photovoltaic Market Transformation Initiative (PVMTI) Bandari Plaza, 2nd Floor Woodvalle Groove, Westlands P.O. BOX 11463, 00606-Sarit Centre NARIOBI, KENYA Tel: ++254 (20) 4452593 Fax: +254 (20) 4452594	PVMTI is an initiative of the International Finance Corporation (IFC) and the Global Environment Facility (GEF) with the aim of accelerating the sustainable commercialization and financial viability of PV technology in the developing world and to provide successful examples of sustainable and replicable business models that can be financed on a commercial, basis.
Think Solar Technics P.O. Box 64057-00620, Nairobi. Tel: +254 20 3567916. FAX: 3567916	Consulting, design, installation, education and training services, contractor services, maintenance and repair services
Appropriate Technologies for Enterprise Creation: ApproTEC - KENYA P O Box 64142 Nairobi, Kenya Tel / Fax: 787380/1, 783046, 796278 e-mail: ApproTEC@ApproTEC.org website: www.ApproTEC.org	Their aim it to promote sustainable economic growth and employment creation in Kenya and other countries, by developing and promoting technologies which can be used by dynamic entrepreneurs to establish and run profitable small scale enterprises
Sahar Auto Fitters Konza Road, Machakos, Eastern Kenya 90100 Telephone: 044-24083	Wood burning stoves and furnaces
Solar World Ea Ltd P.O Box 78516 00507, Ring Road Parklands and General Mathenge Rd Junction, Westlands, Nairobi, Kenya	Consulting, design, installation, engineering, contractor services, maintenance and repair services of solar electric power systems, backup power systems, batteries lead acid deep-cycle, solar water heating components, photovoltaic module components, led lighting, solar torches, solar lanterns, solar caps, radios, solar mobile chargers, wind turbines.
Craftskills East Africa Limited. Telephone: (+254) 20 2394414, 20 2390848, 733 649401, 724 324273	Manufacturer and retailer of Wind Power Turbines, Wind Power water pumps. Batteries. DC and AC LED Lights. Solar Panels Inverters