Kenya's Climate Change Action Plan:

Mitigation

Chapter 7: Transportation

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Table of Contents

Abbreviations

B10	10 percent of biodiesel
BAU	business as usual
BRT	bus rapid transit
CDM	Clean Development Mechanism
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
E10	ten percent ethanol
GHG	greenhouse gas
GIZ	German Development Cooperation Agency
HDV	heavy duty vehicle
IPCC	Intergovernmental Panel on Climate Change
ITDP	Institute for Transport and Development Policy
KRC	Kenya Railways Corporation
Kton	kilotonne
LRT	light rail transit
MRTS	mass rapid transit system
Mt	million tonnes
NAMA	nationally appropriate mitigation action
NMT	non-motorized transport
PHPDT	Peak Hour Peak Direction Traffic
REDD+	reducing emissions from deforestation and forest degradation plus the role of conservation, sustainable management of forests and enhancement of forest carbon stocks
RVR	Rift Valley Railways
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change

7.1 Introduction

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

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

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

7.2 Transportation Sector: Background

7.2.1 Sector context

Four broad sub-sectors can be identified within the transport sector in Kenya:

- Road - served largely through a growing number of trucks, buses, motorcycles, minibuses and private passenger vehicles;
- Water - consists of coastal and inland sectors;
- Rail - the existing rail network is in a state of disrepair and in need of refurbishment and extension; and
- Air - served by three international airports and around 300 other, mostly unpaved, airfields.[1]

The focus of this low-carbon scenario analysis is the road sector, which is estimated in this report to account for 99 percent of non-aviation transport GHG emissions in Kenya (see Section 7.4). The smaller size of the water and rail transport sub-sectors makes them less attractive from the point of view of identifying mitigation options. Rail is, however, considered within the analysis as a mitigation option to replace some forms of road transport. International aviation is not counted as part of national emissions, and domestic aviation is not considered in the low-carbon analysis because of limited mitigation options and low associated development benefits.

Kenya had roughly 1.4 million registered vehicles and 400,000 motorcycles in 2011, with approximately 60 percent of these vehicles used in and around Nairobi. Private vehicles carry 22 percent of travelers but account for 64 percent of traffic volume.[2] New registrations of vehicles were approximately 200,000 in 2010, an increase of more than 20 percent over 2009[3]. Kenya relies largely on imports for vehicles, which are predominately (approximately 80 percent) second-hand vehicles from overseas markets.

Of new vehicles registered each year, Kenya's complete knock-down vehicle assembly industry accounts for approximately one third. Planned new complete knock-down assembly plants for vehicle manufacturers from China and India may increase the proportion of new vehicle sales. Traffic conditions in Nairobi and other major cities are characterized by congested and unsafe roadways, and unreliable vehicles.[4] In major cities, especially in Nairobi, severe traffic congestion, especially during the extended peak hours, contributes to local air pollution but also leads to significant economic losses as much time and fuel is spent in traffic congestion.

The majority of individual trips in cities are on foot (Table 7.1), as public transport services are comparably expensive or inadequate to meet demand, and private cars are out of financial reach for the majority of Kenyans. That being said, passenger cars represent a significant and rapidly growing segment of the transport sector. Also, not shown in Table 1, is the large stock of heavy-duty vehicles (HDVs) that deliver the majority of freight in Kenya given the run-down state of the railway system across much of the country.

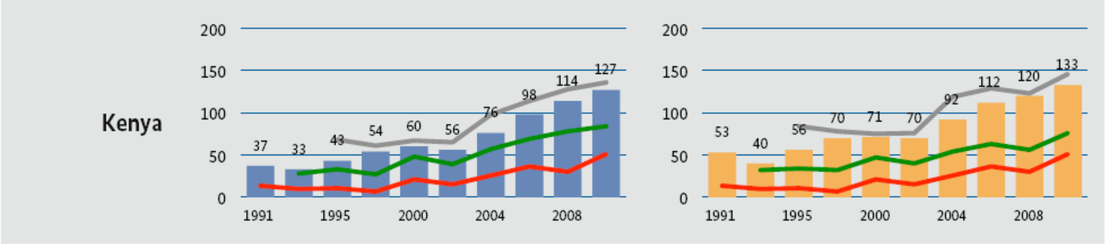
Table 7.1: Transport all purpose modal split (number of trips) in Nairobi excluding motorcycles

Mode	Walking	Cycling	Private car	Matatu / mini-bus	Bus	Train	Institution bus	Other
Modal split	47%	1.2%	15.3%	29%	3.7%	0.4%	3.2%	0.2%

Source: Omwenga, M. 2011. Integrated Transport System for Liveable City Environment: A Case Study of Nairobi, Kenya. 47th Congress of the International Society of City and Regional Planners.

Kenya relies entirely on imported petroleum products, which accounted for KSh 72.6 billion in 2010; 7.6 percent of the country's import bill.[5] Fuel prices in Kenya are comparable to neighbouring non-subsidised countries based on the most recent comprehensive study of global fuel prices (see Figure 7.1).

Figure 7.1: Time series of fuel prices in Kenya, 1991 – 2010



▬ **Grey Benchmark Line:** Retail price of gasoline and diesel of Romania/Luxembourg. In November 2010, gasoline (diesel) prices in Romania (Luxembourg) were the lowest in Europe. Prices in EU countries are subject to VAT, specific fuel taxes as well as other country specific duties and taxes.

▬ **Green Benchmark Line:** Retail price of gasoline and diesel in the United States. Cost-covering retail prices incl. industry margin, VAT and incl. approx. US 10 cents for 2 road funds (federal and state). This fuel price being without other specific fuel taxes may be considered as the international minimum benchmark for a non-subsidised road transport policy.

▬ **Red Benchmark Line:** Price of crude oil on world market.

Source: German International Cooperation Agency. 2012. International fuel prices 2010/2011. *7th Edition. Accessed 11th July 2012 at: http://www.giz.de/Themen/en/SID-9FFE0FD5-8DD57DBF/29957.htm.*

The sector consumes approximately two thirds of the total net domestic sales of petroleum products, with the overall amount of petroleum demanded by the transport sector projected to rise from 1.9 million tonnes in 2004 to between 5.3 and 8.6 million tonnes by 2030 depending on different demand scenarios.[6]

7.2.2 Structure

The institutional structure governing the transport sector in Kenya is fragmented and responsibilities are spread across many institutions, which fall under the mandate of a number of ministries. As the central actor, the Ministry of Transport's mandate is to formulate transport policies to guide in the development of the sector, develop the regulatory framework for the transport sector and supervise transport service delivery.

The regulatory framework is enforced through four main regulatory bodies:

1. Transport Licensing Board;
2. Kenya Civil Aviation Authority;
3. Kenya Maritime Authority; and
4. Kenya Railway Corporation (KRC).

The Kenya National Highways Authority, the Kenya Rural Roads Authority and the Kenya Urban Roads Authority are responsible for the development, and maintenance of international classified roads, urban roads and rural roads, respectively. The Kenya Roads Board is responsible for financing the maintenance of roads and undertaking technical audits.[7]

Regulatory functions in the petroleum sector are shared among various players including the Ministry of Energy, provincial administrations, local authorities, Kenya Bureau of Standards and Petroleum Institute of East Africa.

The Energy Regulatory Commission is responsible for issuance of licenses and permits for all undertakings and activities in the development and use of biofuel. In 2006, the Ministry of Energy established the National Biofuels Committee to coordinate the activities of all stakeholders in the biofuel sector. The Kenya Biodiesel Development Association is a government-registered body under the Ministry of Energy that has been put in place to research institutions, planting materials, suppliers, growers, processors, marketers and distributors[8].

The supply of road public transport services, as well as vehicle licensing, is controlled by the Transport Licensing Board in Kenya, which falls under the Kenya Revenue Agency. The licensing board has the right to specify and approve the route on which a vehicle operates.[9] In practice, however, this may not always be effective.[10]

The Kenya Railway Corporation manages the country's single-track railway system, which has been managed since 2006 by a private consortium, Rift Valley Railways.

7.2.3 Policy

The transport sector is governed by numerous statutes affecting either all sectors of the economy or sector-specific legislation. Many of the sector-specific laws are outdated and require review to facilitate the effective operations of the entities they govern and to enhance harmony in the transport sector.[11]

The Integrated National Transport Policy is the key policy document that seeks to improve the institutional and legal framework in Kenya, and has been in preparation for the better part of a decade. A further draft[12] and a sessional paper[13] of the policy were published in 2009 and 2010, respectively. These documents highlight a number of critical challenges relating to infrastructure, regional linkages, environmental impact, policies and integration, and institutional capacity and structure.

The main elements of the Transport Policy, when complete, are expected to be:

- Establishment of the Department of Transport;

- Consolidation of transport functions under one Ministry, and separation of policy making, regulatory and service provision functions (the GoK would continue to reduce its direct involvement in operations and services);
- Consolidation of urban public transport;
- A focus on user- and polluter-pays models of revenue gathering to fund sectoral development; and
- Promotion and integration of non-motorized and intermediate means of transport (including walking, animal-drawn carts and bicycles) into the transport systems.

The country does not have vehicle fuel economy standards or vehicle emission standards for light duty vehicles. Inspection certification is only required for public service and commercial vehicles which results in less than 20 percent of vehicles being subject to inspection.[14] However, fuel standards did lead to the elimination of leaded petrol in 2006.

Vehicles imported into Kenya are required to be no older than eight years from year of manufacture. In mid-2011 Kenya's Ministry of Finance announced an exemption of import duty for "battery operated vehicles." However, it is unclear if this will include hybrid electric vehicles or other types of low emission vehicles.[15]

7.2.4 Summary

Kenyan has experienced high rates of urbanisation, city growth and development; but transport systems and infrastructure have not kept pace. Transport services can be characterised as poorly integrated, over burdened and inaccessible to many Kenyans.

Kenya can be expected to have continued high growth in the transport sector. Private vehicle ownership will continue to grow alongside economic development. In addition, Kenya is strategically positioned to act as a trade hub for much of central and eastern Africa, which is expected to see large growth in the coming decades.[16]

Improvements in the transport sector are needed, providing low-carbon opportunities. Numerous studies have demonstrated that the transport sector, and in particular road transport, offers opportunities for savings on imported fuels through improved efficiency, alternate modes of transport and fuel substitution.[17]

7.3 Development Priorities of the Government of Kenya

The mobility of people, goods, and services is essential for economic growth, poverty alleviation and human development. The Government of Kenya recognises the transport sector as one of the critical enablers in achieving Vision 2030 and has identified at least two broad strategies that relate to transport:

- Developing and maintaining an integrated, safe and efficient transport network; and
- Implementing infrastructure projects that will stimulate demand in hitherto neglected areas targeting increased connectivity and reduced transport and other infrastructure costs.

In order to achieve these strategies, Vision 2030 references a number of flagship projects that focus on the transport sector, including:

- A 50-Year Integrated National Transport Master Plan – that aims for consistency of transport infrastructure with other public policies and the establishment of Kenya as the leading transport hub in the East and Central African region.

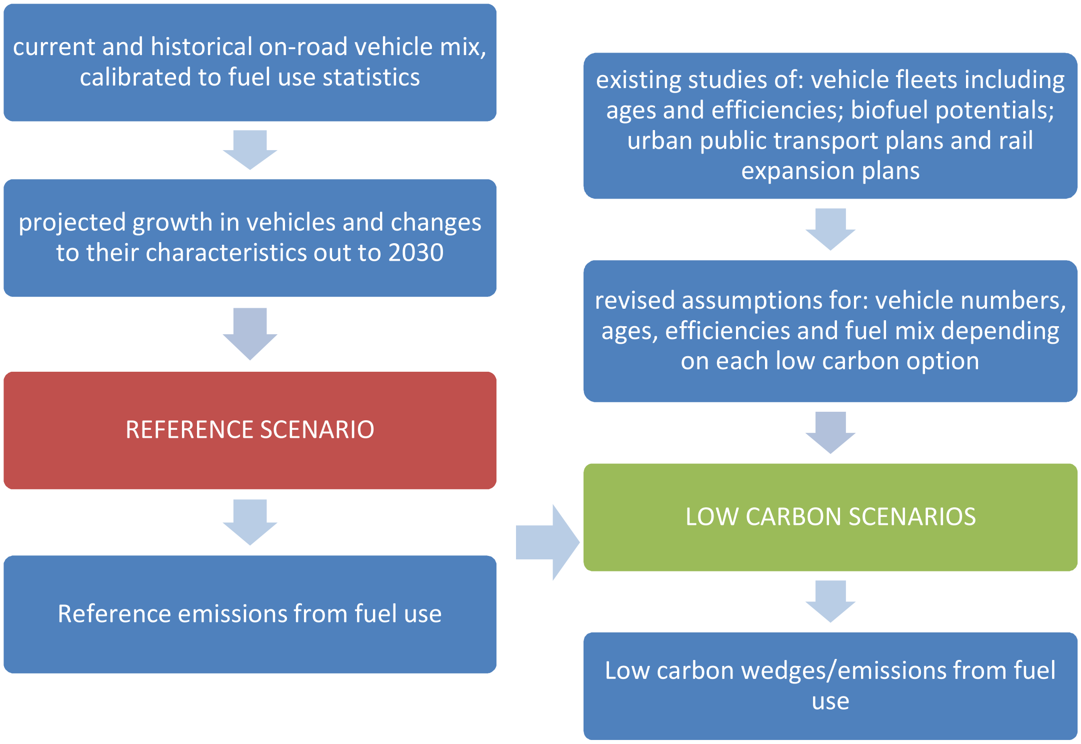
- Development of light rail for Nairobi and its suburbs – stretching from the Nairobi station to the international airport, that will serve at least 150,000 passengers daily, which is 5 per cent of the future public transport demand in the Nairobi metropolitan area.
- Development of a new transport corridor to Southern Sudan and Ethiopia – comprising a new road network, railway line, oil refinery at Lamu, oil pipeline, Lamu airport and free port (with favourable customs regulations) at Lamu.
- National road safety programme – to fast track implementation of the National Road Safety Action Plan to achieve the targets of reduced incidence of road crashes.

Mass rapid transport systems, such as light rail and rapid bus, are also a key component of the pending Nairobi Metro 2030 plan.

7.4 GHG Reference Case

This section briefly discusses the methodology, data and assumptions that were used to generate the GHG emissions reference case for the transportation sector between the years 2000 and 2030. This is followed by a discussion of data availability and quality; and development of the reference case, against which to measure abatement potential. Figure 7.2 illustrates the methodology used to develop the reference case and low-carbon scenario (discussed in Section 7.5).

Figure 7.2: Approach for determining mitigation potentials of low-carbon development options in the transport sector



7.4.1 Reference case methodology

The development of the emissions reference case is aligned with the major sectors and categories of the Intergovernmental Panel on Climate Change (IPCC). Transportation is a sub-sector of the IPCC energy sector, which also includes electricity supply and the household, commercial and industry energy demand sectors.

The transportation sector comprises GHG emissions from on-road vehicles, domestic aviation, marine and rail vehicles. Creating an inventory for these transportation modes is relatively straightforward as sufficient data is available in Kenya to determine the amount of petroleum fuels that are used by each mode. Developing a more detailed inventory that separates emissions into different vehicle types such as personal passenger, freight and buses presents a greater challenge. Data availability on the fuel consumption and energy demand for these different vehicle types is limited in Kenya as fuel sales data is not disaggregated and registration data for all vehicles is incomplete. This results in relatively high uncertainty for the analysis of the various mitigation options, predominantly in regards to the calculated mitigation potentials and costs.

The methodologies, data and assumptions used to generate the greenhouse gas emissions reference case for transportation are presented in detail in Chapter 2, Preliminary Greenhouse Gas Emissions Inventory.

7.4.2 Data availability and quality

Uncertainty in the overall fuel demand and emission from the transportation sector is fairly low as these estimates are based on total reported fuel usage from petroleum fuels sales data and national statistics. However, the allocation of fuels between different vehicle types has a much higher degree of uncertainty. The split in fuel demand between on-road personal passenger, freight and buses was determined from incomplete registration data and an examination of data on the number of vehicles, the fuel type and average fuel efficiency available for newly registered vehicles.

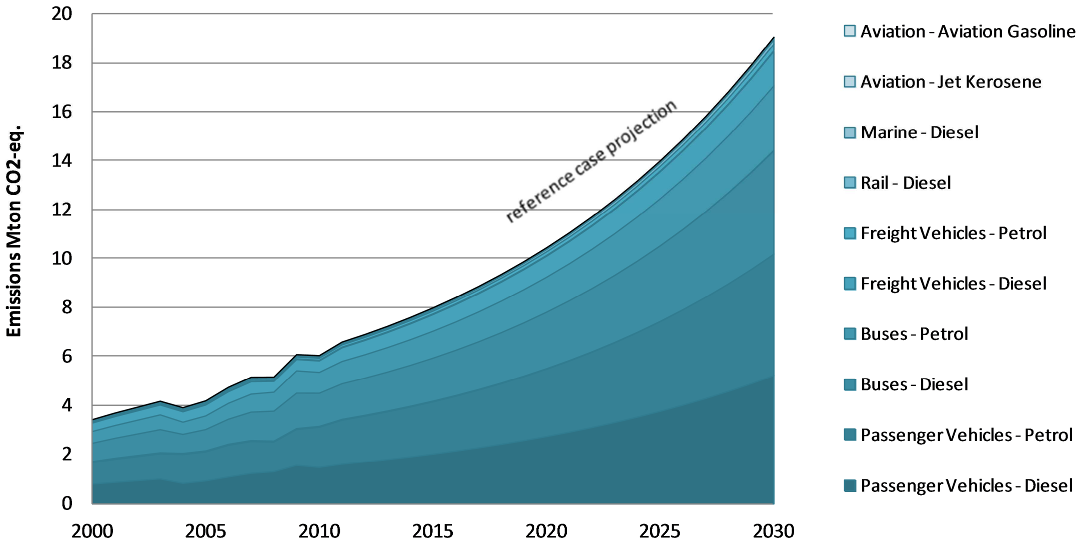
However, data on the fuel efficiency of freight vehicles or the demand for freight (that is, tonnes of kilometres travelled or vehicle kilometres travelled) in Kenya was not available and it was necessary to make some crude assumptions and develop a simple model to balance total fuel demand between these different types of vehicles. In particular, assumptions regarding the average number of kilometres travelled, the future growth rate in the stock of vehicles and changes in future fuel efficiency have a high degree of uncertainty because there were no Kenyan projections available.

For the domestic aviation sector, estimates of the fuel demand were based on a crude approximation of the fuel demand between international bunker fuels for international aviation flights, which are not included in the domestic GHG inventory, and domestic usage. This split in fuel consumption could be improved if flight data for the entire country was available.

7.4.3 Greenhouse gas emissions reference case

The emissions reference case for transportation is summarized in Figure 7.3. Total emissions are likely to rise from approximately 6 million tonnes (Mt) in 2010 to almost 19 Mt in 2030. Figure 7.3 also indicates that over 91 percent of total transportation emissions between 2010 and 2030 are related to on-road vehicles. Aviation jet kerosene accounts for another eight percent of emissions, while rail, marine and aviation gasoline account for only one percent of emissions.

Figure 7.3: Transportation emissions by fuel and vehicle type ($MtCO_2e$)



The projected number of vehicles in the reference case is indicated in Figure 7.4, which are the major driver of transport emissions. Passenger vehicles running both petrol and diesel show the largest gains over time.

Figure 7.4: Total vehicle population in baseline emissions reference case

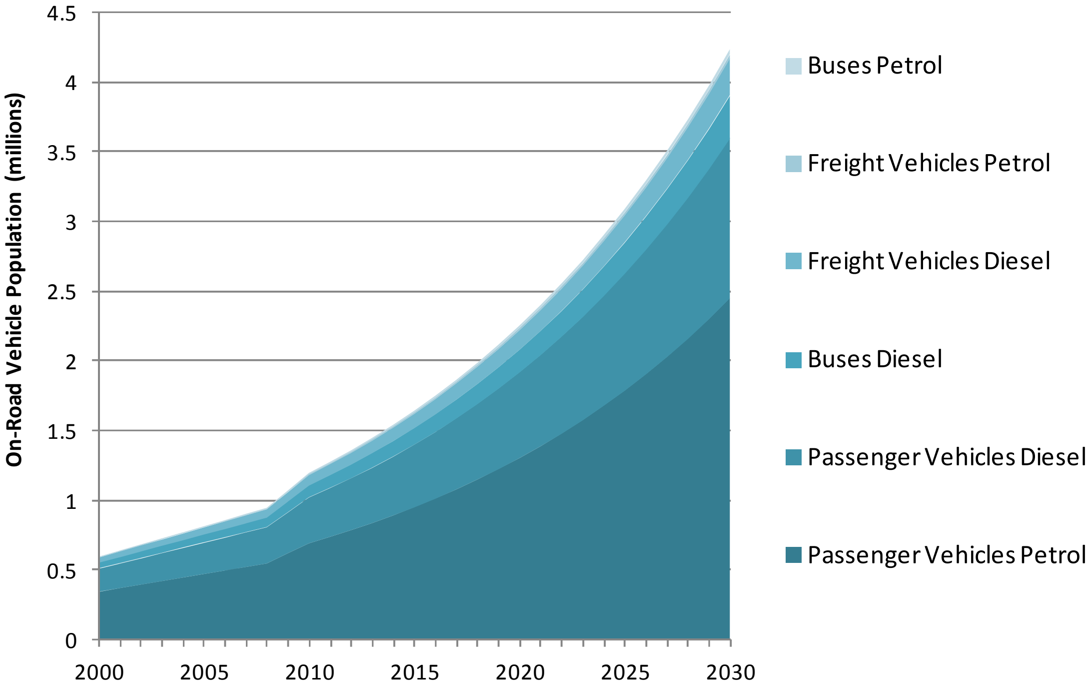
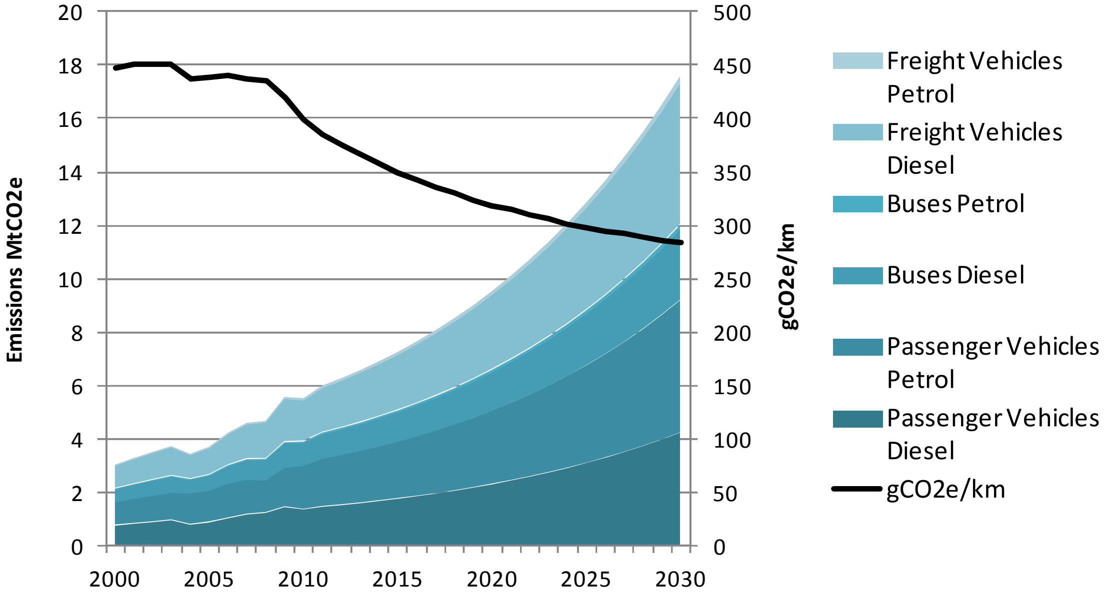


Figure 7.5 indicates the emissions related only to on-road transportation. This figure illustrates that passenger petrol, passenger diesel, and freight diesel vehicle types each account for approximately one quarter of total on-road emissions. The average fleet economy of all on-road vehicles is also plotted on the graph and we can see that between 2010 and 2030 it is expected to decline by 30 percent.

Figure 7.5: On-road transportation emissions by vehicle type and average fleet fuel economy ($MtCO_2e$)



7.5 Low-carbon Scenario Analysis

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

7.5.1 Identification of abatement options

The identification of low-carbon options for further analysis followed a participatory multi-step approach that is described in Chapter 1. The current state of transport services in Kenya and the large expected growth in demand presents a wide range of possible low-carbon development options in the transport sector. Based on a detailed screening exercise, seven options were selected for in-depth analyse:

- Improved passenger vehicle stock efficiency;
- Improved heavy duty vehicle (HDV) stock efficiency;
- Bioethanol use;
- Biodiesel use;
- Bus rapid transit (BRT) system implementation in Nairobi;

- Light rail transit (LRT) system implementation in Nairobi; and
- Shift of freight from road to rail.

These options and the results were presented at local validation meetings in March and June 2012 for review by and input from Kenyan experts. Box 7.1 discusses options that were suggested by Kenyan experts and the rationale for not including in the low-carbon scenario.

Box 7.1: Low-carbon options in the transportation sector not considered in the analysis

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

Promotion of non-motorized transport (NMT) – Improving conditions for pedestrians and bicyclists are an important component of the Integrated National Transport Policy and Vision 2030. However, this option was not included in this analysis for two main reasons. First, a very high percentage of journeys are undertaken by walking, primarily because of lack of capacity in public transport and unaffordable costs of motorized transport. Improved conditions for NMT are important, but levels will decrease over the coming decades if the government meets its development targets. Second, there is a significant overlap with the options for mass rapid transit systems. If designed and priced well, the improved access to transport services and reduced transport inefficiencies resulting from improved transit systems will greatly reduce the number of journeys undertaken by foot. The opportunities to improve NMT conditions are assumed to be part of any plans for BRT or LRT systems because the large infrastructure requirements for such systems offer ample opportunities for NMT infrastructure to be included in their planning.

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

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

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

7.5.2 Calculation of abatement potentials

The abatement potential of the various low-carbon options are calculated using bottom up assumptions on the vehicle mix and characteristics for each of the options to determine the amount of fuel saved or substituted, which in turn allows the total GHG emissions for different vehicle types to be calculated. Compared to the reference scenario, which uses topdown data on fuel use to determine emissions, abatement potentials for individual options need more detailed data. That said, some of the uncertainties of the emission projections are less important as the mitigation potentials are determined using relative changes in transport systems, and rely less on absolute overall figures. Different low-carbon options are assumed to either shift transport from one mode to another (for example, to mass transit systems such as BRT or LRT), improve the average efficiency of vehicles on the road (for example by removing older vehicles from the on-road stock) or by directly reducing the amount of non-renewable fuel that is used (for example through substitutions with biofuels). (See figure 7.1.)

The only two options for which the mitigation potential was estimated in a different way were BRT and LRT systems. It is difficult to determine the net emissions impact that a public transport system has, because it not only changes the ownership patterns of private vehicles, but also their usage habits. At the same time a large reduction in traffic within the Nairobi metropolitan area could also have fuel efficiency benefits for the remaining vehicles due to reductions in congestion. Estimating the total emissions impact becomes a complex task, beyond the scope of this analysis. Fortunately a 2008 study of a large-scale public transport system for Nairobi is available and mitigation impacts for the BRT and LRT systems were estimated based on the data provided in that study. [18]

7.5.3 Calculation of abatement costs

Abatement costs in the transport sector are highly variable, both in terms of their magnitude and the reliability and ease with which they can be calculated. While options in the electricity sector have a convenient metric through which they can be compared (the cost per unit electricity supplied over a plant lifetime), this is not true of transport services.

The most appropriate way of representing costs is also dependent on the perspective taken; for example calculating the marginal abatement cost of a public transport system gives an indication of its mitigation cost efficiency – in terms of cost per unit of abatement – and may be of interest to potential international supporters. However, this is often of little relevance to national policy makers who must plan the significant upfront capital expenditure of such a system. Equally, upfront financing is of little importance to individual users who are interested in their own ability to pay for the completed public transport system.

Some of the options in this analysis lend themselves to the calculation of marginal abatement costs, while for others this could not be determined with any reasonable level of accuracy within the scope of this analysis. Specifically:

- **Improving the efficiency of passenger vehicles stocks** – Marginal abatement costs were calculated by comparing purchase costs and discounted[19] fuel costs[20] over a vehicle lifetime for older inefficient vehicles with newer more efficient models. Much older second-hand vehicles were assumed to be in the order of 25 percent of the cost of newer (yet still second-hand) vehicles based on observed sale prices in the market. The final marginal-abatement costs presented in Section 7.6.4 are highly sensitive to this assumption of vehicle costs.
- **Improving the efficiency of HDV stocks** – In this instance marginal abatement costs were calculated on the basis of incremental costs that would be incurred to improve vehicle efficiency by regulating for improved vehicle systems such as low-rolling resistance tyres or tyre pressure monitoring. As for the option "Improving the efficiency of passenger vehicle stocks" discounted fuel costs over the lifetime of the vehicles are used for the calculation. A cost calculation approach similar to passenger vehicles – looking at the removal of older vehicles – could also have been taken, but in light of the potential ease with which improved efficiency systems could be introduced into the commercial trucking sector (assuming that costs are favourable,

companies should in theory be willing to adopt such measures) an incremental improvement approach was adopted.

- **Adoption of biofuels** – Marginal abatement costs were calculated on the basis of previous studies of biofuel production costs in Kenya[21] and current conventional fuel costs. It was assumed that there are no retrofit costs associated with using low percentages of biofuels in the low-carbon scenarios.
- **BRT and LRT mass transit systems** – Marginal abatement costs for such systems are very challenging to calculate. While it is relatively straightforward to give estimates of the infrastructure and operational costs of BRT and LRT systems, it is much more difficult to estimate the total reference costs that are incurred by private vehicle owners for the business as usual scenario, especially when considering congestion effects. For this reason, broad estimates of capital and operational costs are provided for BRT and LRT systems for Nairobi based on a recent external study along with indicative marginal abatement costs calculated for similar mass rapid transit systems installed elsewhere.
- **Shift of freight from road to rail** – It was not possible within the scope of this assignment to collect detailed information on the freight costs of current road transport services, nor to estimate rail freight costs for a hypothetical improved rail system. Comparisons of road and rail costs are highly dependent on system operational characteristics, types of freight and distance amongst other aspects. However, if railways are well designed and managed, they can, for a wide range of commodities, deliver both higher capacity and lower costs of operation than road freight, at lower external costs to the community[22]. As a result, the same approach is taken for a shift of freight from road to rail as with the mass transit systems: estimates of capital expenditure requirements are given based on recent studies.

7.5.4 Data availability and uncertainties

With regards to data availability for low-carbon options, the situation is similar to challenges in data availability experienced in establishing the transport sector baseline.

There is little reliable data available about vehicle fleet sizes, usage patterns and fuel use characteristics. This makes it difficult to establish the current average fuel economy of different types of vehicle or different ages of vehicle. A 2011 study by the United Nations Environment Programme (UNEP) collected detailed data on vehicle type and performance (and even then, not on usage patterns), but this study only covered newly registered vehicles in certain years.[23] The data does not provide any information about older vehicles that are already on the road and there is little way of knowing how many older vehicles are still active as there is no system in place to register this or deregister vehicles that are no longer in use.

Assumptions were made as to the relative fuel economy of older vehicles to compare with newly imported vehicles (for which data was available), as well as on the split of vehicles of different ages. Although older vehicles can be observed in abundance in Kenya and are undoubtedly responsible for a large proportion of airborne emissions, their total GHG emissions impact is based on a number of assumptions that introduce additional uncertainty.

The biofuels data on potential production volumes is drawn from a single 2008 study that considers different feedstocks for both bioethanol and biodiesel, as well as different scenarios depending on: 1) whether existing land or additional land is cultivated, 2) whether or not there is competition with food production, and 3) whether or not improved farming practices are adopted.[24] While this seems to be a relatively robust study, there were no other comparable sources of data for Kenya with which to compare the data, which makes it difficult to draw strong conclusions about the capacity of Kenya to produce large volumes of biofuels without impacting food security.

One detailed study on mass transit systems was available for Nairobi, which focused on LRT with a small BRT component.[25] This study was used as a starting point for estimating investment costs and mitigation impacts for both types of mass rapid transit systems, complemented by studies from other cities. Overall, uncertainty in mitigation potentials for these low-carbon options is thus very high because the study did not provide any methodology for determining mitigation impacts and these could not be verified by other means. Investment and operations cost figures are arguably more reliable but are only relevant for the specific extensive transit system considered in that study.

Government statistics for freight transport are available for rail freight volumes in previous years,[26] but no detailed data is available for road freight. Estimates of mitigation impacts were made on the basis of a single study that considered potential growth in rail transport out to 2030 as well as assumptions on the relative GHG emissions intensity of rail-based versus road-based freight transport .[27]

7.6 Low-carbon Development Options

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

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

7.6.1 Context

Improving passenger vehicle and HDV stock efficiency

Within the current passenger vehicle and HDV fleets in Kenya, there is a prevalence of old vehicles with poor fuel efficiencies. The number of older second-hand vehicles on Kenyan roads is partly due to economic policy reforms in the early 1990s, which liberalized many aspects of international trade. For instance, between 1992 and 2001, vehicle population in Kenya grew by 46 per cent, on the back of mostly reconditioned vehicles.[28]

Recent tests of vehicles in Nairobi showed that a significant proportion of vehicles on the road were relatively old and had been used for high mileage; with roughly 70 percent of vehicles failing Kenyan air quality control standards. While fuel efficiency data is not available for these vehicles, it could be anticipated that their performance would be poor, in accordance with their emissions, due to a combination of age and state of repair.[29] Kenya has comparatively lower octane petrol[30] and high sulphur content diesel.[31] This lower fuel quality severely limits the performance of the Kenyan vehicle fleet as well as the ability to adopt new vehicle engine technologies.

At present, there is a large influx of “new” vehicles into Kenya each year, with new registrations rising by more than 30 percent between 2009 and 2010. These vehicles are required to be less than eight years old in accordance with government regulations and act to bring the average fuel economy down. However, with no vehicle retirement programme in place, the current fleet of older vehicles is expected to remain in use until conditions remove them from the broader pool of vehicles.

Bioethanol

Ethanol is a liquid fuel that can be produced from a variety of sugars and starch-containing crops. Examples include cassava, sweet sorghum, maize, sugar beet, sugarcane and wheat. Ethanol can also be used for alcoholic beverages and various pharmaceutical, medical and industrial uses. Kenya has been producing ethanol for over twenty years in relatively modest quantities and, for a period in the 1980's, was blending it into the petrol mix as a 10 percent blend known as "gasohol." This programme has now ceased. However Kenya still produces ethanol for other industries with a capacity of approximately 125,000 litres per day (as of 2008).[32]

Road vehicles can generally use blends of up to 10 percent ethanol (so called E10) in petrol without modifications or engine damage. Recently an E10 requirement was reintroduced in Kenya as pilot programme in Kisumu and Nakuru. However a lack of initial supply of bioethanol has meant that this target can only be realised through significantly increased sugar production in the region. In addition, the high demand for ethanol in the production of alcoholic beverages in the region has raised ethanol prices, making it difficult to achieve blended ethanol targets cost effectively.

Estimates of available resources for bioethanol production range from approximately 49 million litres per year (under a status quo assumption based on actual production in 2006) using sugarcane to more than 23,000 million litres per year using only new farmland (current food crop areas are not included) with improved farming practices and additional feedstock sources such as cassava and sorghum.[33]

Biodiesel

Biodiesel is a liquid substitute for petroleum-based diesel fuel made from vegetable oil derived from a wide variety of oil-bearing plants such as castor, coconut, croton, jatropha, rapeseed (canola) and sunflower. Unlike ethanol, which has several markets aside from energy, biodiesel's only use is as an alternative source of fuel for transport and stationary power. The vast majority of biodiesel projects being planned or underway in Kenya involve the use of jatropha as a feedstock, however other feedstocks are being discussed. To date there have been a number of poor experience with jatropha crops.

Nearly all diesel-powered equipment can use blends of up to 20 percent biodiesel, and many engines can use higher-level blends or even pure biodiesel with little or no modification. Biodiesel has the added advantage of being free of sulphur. Therefore blending biodiesel will reduce the sulphur content of the diesel in direct proportion with the blend ratio.

A draft biofuels strategy aims at increasing accessibility to energy (through biofuel production) and reducing dependence on imported petroleum products by 25 percent (in volume) by 2030.[34] Estimates of available resources for biodiesel production range from less than 2 million litres per year (under a status quo assumption based on actual production in 2006) using castor and sunflower feedstock to more than 18,000 million litres per year using existing farmland with improved practices.[35]

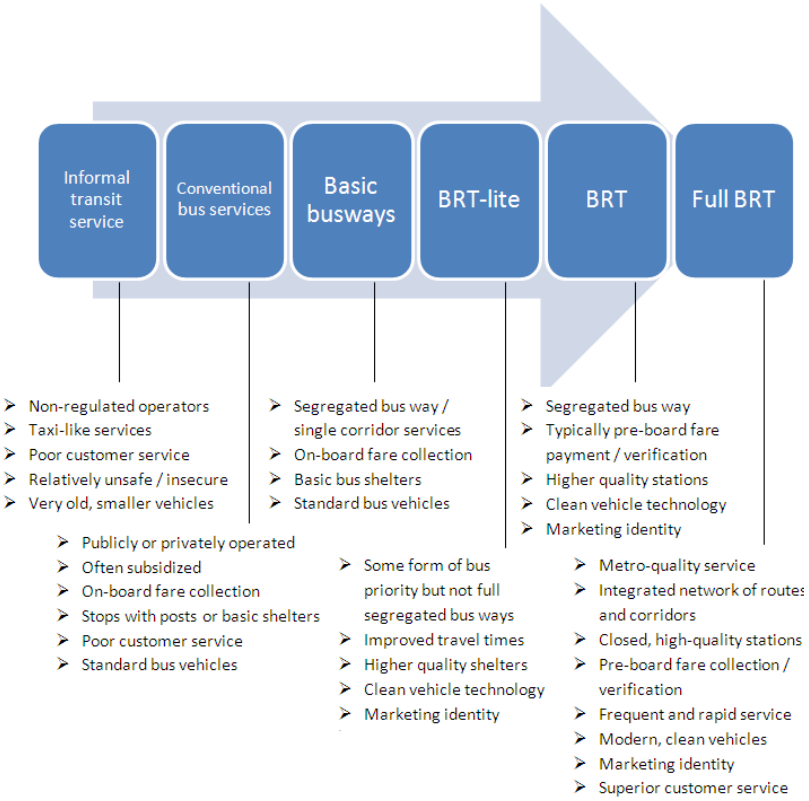
BRT and LRT systems

Public transport in Kenya, especially in urban areas, is dominated by matatus (or minibuses). As the role of the Kenyan Bus Service, which was once Kenya's largest bus company, declined, matatus grew in numbers to an estimated 40,000 in 2004[36] of which some 15,000 operate in or around Nairobi.[37] This growth in matatu numbers has occurred alongside, and contributed to, increased urban congestion, particularly in Nairobi. While matatus may well have an important role to play in Kenya in the future, the deteriorating transport conditions mean that improved mass transit systems are a priority in meeting the future transportation demands.[38]

Bus rapid transit systems are increasingly being implemented in developing cities across the world. As of 2010, over a hundred BRTs were under construction in Latin America, Africa and Asia.[39] BRTs are generally seen as an option with considerable potential in cities in the developing world. They can change the trend of modal shifts to private vehicles towards public transportation, thereby bringing about a range of benefits including reduced congestion, air pollution and greenhouse gases, and better service to poor people. Its main drawback compared to other urban transport systems is its demand for urban space.[40]

If designed well, a BRT system can deliver metro-quality service at a significantly lower capital cost. The Institute for Transport and Development Policy (ITDP) defines bus rapid transit as "a high-quality bus-based transit system that delivers fast, comfortable, and cost-effective urban mobility through the provision of segregated right-of-way infrastructure, rapid and frequent operations, and excellence in marketing and customer service."[41] While BRT systems can be designed in different ways depending on the needs of a city (see Figure 7.6), they typically involve segregated lanes with exclusive right-of-way and modernized bus technology. They are also characterized by efficient fare collection, rapid boarding and alighting, cleaner technologies, and an integrated modal system at main terminals and stations.

Figure 7.6: Quality spectrum of public bus transport



Source: ITDP. 2007. Bus Rapid Transit Planning Guide. *New York: ITDP.*

Light-rail based public transport systems can be used as an alternative to bus-based services. LRT is often refers to rail systems that use electric rolling stock operating in lanes or on rails separated from other traffic. They generally have a lower capacity, speed and capital cost than metro systems, but higher capacity and higher speed than traditional tram systems. In general the upfront capital costs of LRT systems (in terms of infrastructure and vehicle stock) are higher than for BRT systems, although the passenger carrying capacity may be higher and pay this back over time.

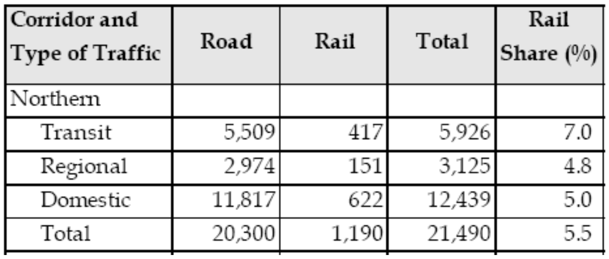
A recent study of mass rapid transit options in Nairobi concluded that a predominantly LRT based system would be the most cost effective. However, Kenyan experts expressed the view that the lower upfront costs of BRT and potentially faster implementation times is likely to make it the preferred choice of Government of Kenya (although LRT would still have a role to play). Current efforts indeed seem to be focussed on BRT systems and the Sustran project coordinated by UN-Habitat is collaborating with the Government of Kenya to plan a BRT corridor for Nairobi. The Ministry of Transportation had previously announced plans for nine Mass Rapid Transit corridors incorporating BRT and LRT. Out of these nine, there are five BRT corridors, including Ruiru to Thika Town via Thika Road, Airport Road Junction to Machakos via Mombasa Road, and Westlands to Kikuyu via Waiyaki Way.[42] The World Bank has also approved funding for an additional BRT route on an elevated Uhuru Highway overpass.

The necessary construction efforts for a BRT or LRT can also provide a starting point for investment in NMT infrastructure, which may be developed in parallel with the mass transit system infrastructure.

Shift of freight from road to rail

Kenya Railways Corporation (KRC) is the national railway of Kenya, but since 2006 much of the track and rolling stock has been allocated to a private operating company, Rift Valley Railways (RVR), on a 25-year concession basis.[43] Although there are rail links between Kenya, Uganda and Tanzania, the track has fallen into a state of disrepair with limited capacity and very slow movement. As a result, the majority of freight in the region is carried via road (Figure 7.7), which in turn has led to worsening of congestion, air quality and road condition.[44]

Figure 7.7: Base case traffic for the “northern corridor” (i.e. Kenyan overland freight to and from Mombasa) and mode 2009 (000 tons)



Corridor and Type of Traffic	Road	Rail	Total	Rail Share (%)
Northern				
Transit	5,509	417	5,926	7.0
Regional	2,974	151	3,125	4.8
Domestic	11,817	622	12,439	5.0
Total	20,300	1,190	21,490	5.5

Source: Nathan Associates. 2011. Corridor diagnostic study of the northern and central corridors of East Africa. *Arlington: Nathan Associates Inc.*

In terms of cargo volume, Kenya's railway system has been at a standstill or in decline in the past few years. Freight volumes are estimated to be in the order of 1,572 kilotonnes (ktons) in 2010, a decrease of roughly 300 ktons since RVR took over the railways concession in 2006.[45] To give a sense of what fraction this represents of freight in Kenya, total freight volumes are estimated to be in the order of 28,000 ktons. This is a conservative figure, as it only includes trade with overseas partners that passed through the Port of Mombasa (it does not include overseas trade that used the Central Corridor). Moreover, freight is expected to grow rapidly over the coming decades, increasing almost six-fold by 2030.[46]

Since taking over its concession, RVR traffic volumes and income have fallen below that required for sustainable operations. It has been estimated that RVR traffic and income levels would have to increase threefold in order to achieve financially viable and sustainable operations.[47] While a revival of the rail sector could be expected in Kenya, it would require long term investment and results, and greater freight movements would not be seen until after 2015.[48] An initial study suggests that rail's share of transit freight in Kenya could increase to more than 30 percent by 2020.[49]

Railway transportation is about four times more fuel-efficient than road transportation.[50] It could therefore offer significant mitigation opportunities for Kenya, as well as reduce fuel imports, congestion and road damage.

7.6.2 Scenarios

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

Improving passenger vehicle stock efficiency – This option results in total fuel efficiency improvements of seven percent versus the reference case by 2030 for petrol and diesel cars through restricting import of second hand vehicles and removing older (15+ year), low-efficiency vehicles. The relevant factsheet in Annex 1 provides more detail on how this equates to total vehicles retired.

Improving HDV stock efficiency – The option assumes fuel efficiency improvements of up to 10 percent in 2030 through improved rolling resistance of tyres, tyre pressure monitoring and on-road testing of emissions regulations for all heavy duty vehicles. (Other options for achieving efficiency improvements include eco-driving training, regular maintenance, tracking and route planning with global positioning systems, and real-time engine and driver telemetry.) The relevant factsheet in Annex 1 provides more detail on the assumptions for improvements over time and rate of adoption.

Bioethanol – The government is piloting an E10 blend in Kisumu and Nakuru, an initiative that will require significant increases in bioethanol supply (initial estimates put the shortfall at approximately 60 percent of demand). Given the financial and efficiency issues that have dogged the predominantly government-owned sugar industry,[51] it is assumed in the reference case that bioethanol use does not reach widespread adoption across Kenya. Under the low-carbon development scenario, 10 percent of regular petrol is replaced by bioethanol by 2020, which is equal to the introduction of an E10 blending requirement. This requires a substantial increase in bioethanol production capacity and feedstock availability. The relevant factsheet in Annex 1 provides more detail on total volumes of ethanol required over time.

Biodiesel – Under the low-carbon development scenario, 10 percent of regular diesel is replaced by biodiesel by 2020, which is equal to the introduction of a B10 (10 percent of biodiesel) blending requirement. Introduction is staggered, with a two percent biodiesel target established for 2015. This requires a very large increase in bioethanol production capacity and feedstock availability. The relevant factsheet in Annex 1 provides more detail on total volumes of biodiesel required over time.

BRT system implementation in Nairobi – A significant shift of private transport in Nairobi to BRT assumes that the mass transit system from a recent feasibility study[52] is implemented, but with BRT as the dominant mode of public transport complimented by some minimal use of LRT services (see below). The low-carbon scenario assumes a more moderate level of level of BRT infrastructure in place by 2015 than the ambitious schedule in the feasibility study; that is, approximately one-third of the trips initially planned for 2015 could actually be serviced by a BRT system in that year. (The feasibility study anticipates that the majority of a very comprehensive operational mass transit system will be in place by 2015.) Rough estimates of the approximate Peak Hour Peak Direction Traffic (PHPDT) that would be achieved are given in the relevant factsheets in Annex 1. It should be noted that the shift to BRT from private vehicles and taxis would probably be a smaller fraction (in the order of 10 to 20 percent) of its ridership; the rest would come from matatus and buses (which still give an efficiency gain) and NMT (which does not realise any emissions reduction.

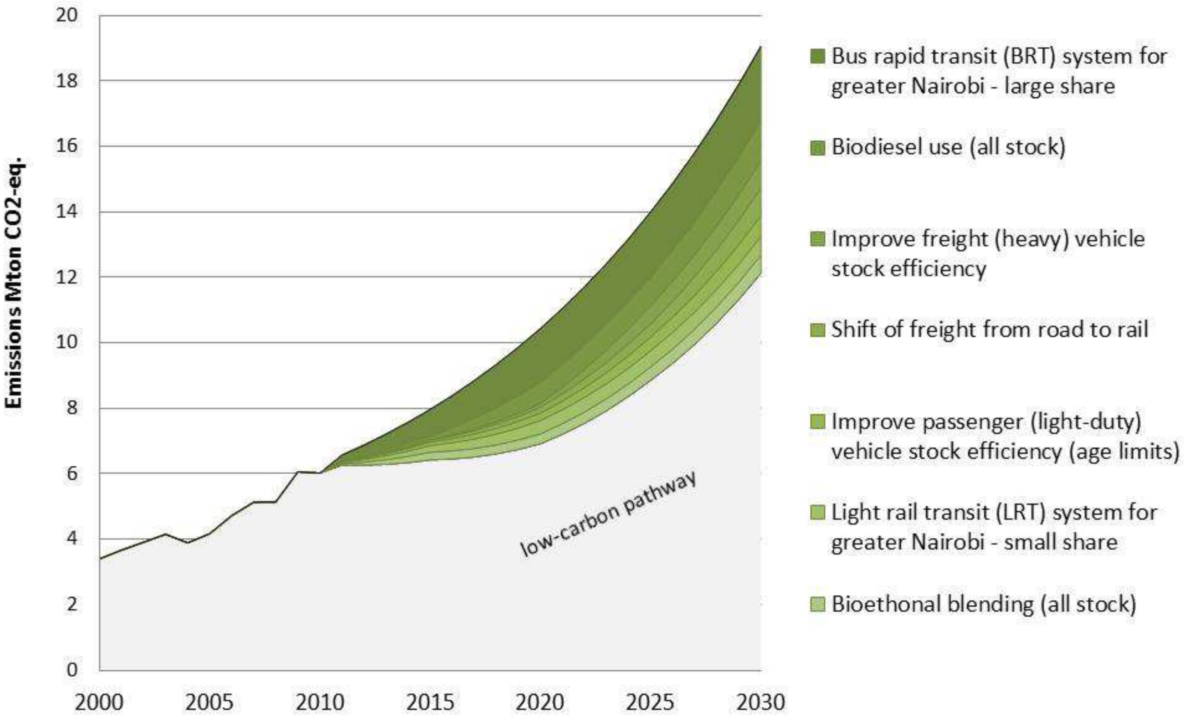
LRT system implementation in Nairobi – The low-carbon scenario assumes a moderate shift of private transport (as well as other modes such as matatus) in Nairobi to LRT (noting that each of the two low-carbon options assumes a mix of LRT and BRT are being implemented). The scenario assumes that the mass transit system from a recent feasibility study[53] is implemented, but with BRT as the dominant mode of public transport complimented by some minimal use of LRT. Like the BRT scenario, the somewhat ambitious schedule in the feasibility study is assumed to be delayed by five years, but with a moderate level of LRT infrastructure in place by 2015 (although even this assumption may be optimistic given the timeframes necessary to construct the required infrastructure). Rough estimates of the approximate PHPDT that would be achieved are given in the relevant factsheet in Annex 1.

Shift of freight from road to rail – A large majority of freight movements currently are undertaken by road transport due to various issues with the available rail freight service. This scenario assumes that approximately 30 percent of transit freight is moved to rail transport by 2030 in line with the forecasts made for an improved Kenyan rail system.[54]

7.6.3 Mitigation potentials

Figure 7.8 shows the low carbon mitigation wedges in the transport sector. As discussed in Section 7.5 on the methodology for the low-carbon assessment, the results are based on bottom-up calculation of emissions for most options, except for BRT and LRT systems where surrogate data has been used from a recent feasibility study in Nairobi. Mitigation potentials for each five-year period out until 2030 are given in the factsheets in Annex 1.

Figure 7.8: Low-carbon option mitigation wedges in the transport sector – interaction between options not considered



The development of an extensive mass transit system for greater Nairobi, in the form of BRT corridors and limited LRT corridors, has the largest abatement potential in 2030, with approximately 2.8 $MtCO_2e$ per year in total,[55] followed by a 10 percent biodiesel blending with a potential of 1.2 $MtCO_2e$ per year. The abatement potentials for the other technologies vary between 0.5 and 0.8 $MtCO_2e$ per year.

It is important to note that Figure 7.8 does not consider any interaction or overlap between different mitigation wedges. Each wedge is calculated independently from the others. When displayed as total cumulative emissions as in Figure 7.8, the total emissions reduction that could be achieved is overestimated. This can be illustrated by considering two options that can have a direct interaction. On the one hand the bioethanol low-carbon option is calculated based on an estimate of the total number of petrol vehicles and their usage and technical characteristics in Nairobi in 2030. However, the calculated mitigation potential for a BRT system assumes that a large number of private vehicles in and around Nairobi would be used significantly less, because people would switch to bus transport instead.

Should both options be implemented, either the total mitigation impact of the bioethanol option would be less than is calculated here, because vehicles are used less; or the mitigation impact of the BRT option would be less because the trips in private vehicles which are replaced are undertaken in a less GHG intensive manner as the vehicles use some bioethanol. Thus the resulting wedges need to be interpreted with caution and are best viewed individually, as represented in the factsheets in Annex 1. This is acceptable for this type of analysis because not all options will be taken forward in the short to medium term. But when more detailed analysis is being performed on a subset of priority actions, interactions will need to be taken into account.

Even when putting aside this issue of overlap and interaction and depicting the wedges as a simple addition of mitigation potentials, as done in Figure 7.8, it can be seen that the total cumulative impact of the wedges on GHG emissions is offset by the large anticipated growth in on-road vehicles in Kenya. This is expected in a country such as Kenya that anticipates rapid economic expansion in the coming two decades with corresponding large increases in private car ownership and freight movement. The dispersed nature of transport emissions and the limited cost-effective technology options for reducing emissions make it challenging for any country to achieve a large decarbonisation in the transport sector.

7.6.4 Costs

The costs presented are in several formats because of the wide variety of options in the transport sector and the inherent challenges in determining costs for most transport options due to their complex dynamics. Marginal abatement costs were calculated in this low-carbon analysis for four of the options (see Table 7.2). The cost discussion for the other low-carbon options is based on results from a number of studies.

According to these calculations, the improvement of HDV stock efficiency and bioethanol blending are negative cost options, implying that these options should be cost-effective to implement for vehicle owners. Cost effective interventions to reduce abatement costs can also be considered, such as discounting customs duty for imported new and used vehicles with low CO_2 emissions ratings will reduce abatement costs. Similarly reducing taxes on locally blended biofuels will improve their costs.

It should be noted that the assumptions for the costs for technology replacement and improvement for the options improving passenger vehicle and HDV stock have a very large impact on the resulting marginal abatement costs. For this reason, the uncertainty around the costs quoted here is very high.

Previous estimates of the marginal abatement costs for removing older passenger vehicles from the road deviate by a large degree from the figures in this low-carbon analysis, with

Table 7.2: Marginal abatement costs in 2012 for selected options in the transport sector

	Marginal abatement cost (USD/tCO$_2$)
Improved passenger vehicle stock efficiency[1]	128
Improved HDV stock efficiency[2]	-35
Bioethanol blending[3]	-15
Biodiesel blending[4]	66

Notes:
[1] Based on current costs, no attempt made to estimate future vehicle costs or fuel prices.
[2] Based on current costs, 3 percent improvement assumed by 2020 and 10 percent technology improvement in 2030.
[3] Based on current costs, not estimated separately for 2020 and 2030 due to lack of information on future production costs.
[4] As per bioethanol.

large negative marginal abatement costs reported, in the range of US$ -140 to -190 per ton of CO$_2$.[56] This illustrates the difficulty in estimating costs in this sector. In addition it is important to also focus on additional social and environmental benefits of such options, rather than mitigation costs alone.

For HDV vehicles, a study for the United Kingdom that found large negative marginal abatement costs for HDV technology improvements such as improved rolling resistance tyres broadly supports this analysis of marginal abatement costs for that option.[57]

Although marginal abatement costs for biofuels can be calculated based on current fuel costs (and existing studies of production costs for biofuels), how these will change in the future is highly dependent on external oil prices and developments in Kenya in regards to oil extraction. Information on the current oil exploration in Kenya is limited and cannot be used, but it is important to note that this may greatly affect the marginal abatement costs for biofuels. A study of marginal abatement costs of biofuel use for passenger vehicles in Europe showed that for every dollar of variation in the per barrel oil price, the marginal abatement cost changed by almost four dollars.[58]

Estimates for investment cost for BRT and LRT systems vary widely. Depending on the required capacity, urban context and complexity of the project, BRT systems can be delivered for US$1 to 15 million per kilometre,[59] with most existing BRTs in developing countries in the lower part of this range.[60] These figures are substantially lower than those for rail-based systems, which cost approximately USD$50 million per kilometre.[61,62] The marginal abatement costs of implementing BRTs in China have been estimated at US$ 2.6 per ton of CO$_2$.[63] For Latin American cities, costs for BRTs were estimated to be US$ 14-66 per ton of CO$_2$, depending on the policy package involved.[64]

For freight, rail is often competitive with road-based transport on a per tonne-km basis, and net benefits for society accrue in terms of health, environment, reduced road damage and improved congestion conditions. However, no marginal abatement costs for modal shifts from road- to rail-based freight transport are available in the environmental economic literature, and no marginal abatement cost curve that includes this option was found.[65] A small scale Clean Development Mechanism (CDM) project in India for a shift of road to rail transport (for a cement factory) gives an investment cost per of carbon of US$ 81 per ton of CO$_2$[66], but this is not a marginal abatement cost as it does not take into account the full Net-

Present Value of the project and does not compare the costs of the alternative road transport option.

While marginal abatement costs (for the improved vehicle stock and biofuel options) give an indication of the cost-effectiveness of different low-carbon options, their results should be interpreted with a high-level of caution. The resulting costs are highly dependent on the underlying assumptions and don't give an indication on the capital intensity of the options nor the ability of consumers to pay should they be implemented. Marginal abatement costs also don't reflect other barriers to the deployment of technologies and generally don't include transaction costs required for project development. Finally, marginal abatement cost curves say nothing about the development benefits of various options, and thus can only provide one input into a more comprehensive process of selecting mitigation options to pursue.

7.6.5 Development impacts

Development impacts are qualitatively described in the study and tested with stakeholders at local validation meetings and individual interviews. **Table 7.3** provides an overview of development benefits of the low-carbon options in the transport sector (see also the factsheets in Annex 1).

Table 7.3: Overview of development benefits of low-carbon options in the transport sector

● High Positive ◓ Positive ▬ Neutral / Minor impact ◡ Negative ◓◡ Uncertain	Climate			Development			
	Abatement potential ($MtCO_2$)	Adaptation impact	Congestion and road quality	Road safety	Air quality	Energy security	Food security
Improved passenger stock	0.6	▬	▬	◓	◓	◓	▬
Improved HDV stock	0.8	▬	▬	◓	◓	◓	▬
Bioethanol	0.55	◡	▬	▬	◓	◓	◓◡
Biodiesel	1.2	◡	▬	▬	◓	●	◓◡
BRT system for Nairobi	2.3	▬	●	●	●	●	▬
LRT system for Nairobi	0.6	▬	◓	◓	◓	◓	▬
Shift of freight to rail	0.8	▬	●	◓	◓	◓	▬

A brief introduction to some of the health, economic and environmental issues related to the road transport in Kenya is a good starting point for understanding the potential development benefits of the low-carbon options described in this study:

- **Congestion** – It was estimated that 50 million vehicle hours were lost in 2002 in Nairobi because of congestion at peak hours, wasting an estimated 63 million litres of fuel worth US$25 million.[67] The economic value of the person hours lost is much higher than this. While recent estimates are not available it is highly likely that this figure has become worse.
- **Road safety** – Kenya, and specifically Nairobi, has a poor road accidents and safety record. Road transport is responsible for approximately 68 deaths per 1,000 registered vehicles, which is 30-40 times greater than in highly motorized countries. Road traffic accidents are the third leading cause of death after malaria and HIV/AIDS and present a major public health problem in terms of morbidity, disability and associated health care costs.[68] The resulting cost of accidents is very high, estimated at between two and five percent of GNP.[69,70]
- **Air quality** – Road transport is a major, and growing, source of air pollution in urban areas, especially particulate matter. Air pollution in Nairobi is high with mean daytime concentrations of fine particles ranging from 10.7 micrograms per cubic metre at the rural edge of the city to 98.1 micrograms per cubic metre on a sidewalk in the central business district. This implies that there are very high levels of suspended particulate matter within the inhalable range, up to five times global standards.[71] These can be attributed to vehicular exhausts and many of the leading disease complaints in Nairobi relate to vehicle exhaust fumes.[72]
- **Road quality** – The high volumes of traffic, and in particular the high volume of HDVs, rapidly deteriorate many Kenyan roads. The life expectancy of roads in Kenya is approximately eight years, far shorter than roads in Europe where a life expectancy could be expected to be in the order of 40 years.[73]

Development impacts related to public transport options

Effective mass transit systems, which act to remove vehicles from the road, could have positive impacts on congestion, road safety, air quality and road quality – resulting in high development benefits. In addition, affordable high-quality mass rapid transit has the potential to help improve social equality and reduce poverty.

Development impacts related to shifting freight transport to rail

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

Development impacts related to improving vehicle efficiency

Options related to older vehicle retirement would have positive safety and air quality impacts. Old vehicles are inefficient in their consumption of fuel and management of exhaust gases, and emit more airborne pollutants per litre of fuel than newer models. Improving vehicle efficiency is one of the most cost-effective interventions to reduce transport-related emissions.[74]

Development impacts related to biofuel options

The biofuel options have potential benefits and risks not linked to congestion, road safety, air quality and road quality. Rural development is an often-argued benefit of biofuel production, through job creation or improved small-hold farmer incomes. However, a significant body of literature suggests that industrial-scale biofuel production often does not benefit the rural poor.[75] The potential impacts of a biofuel policy need to be carefully considered and, where possible, include a focus on pro-poor rural development.

The impact of biofuels production on food security is a major concern that was frequently raised at stakeholder consultations. There is a widespread perception that biofuels, and in particular biodiesel, could be high-risk options to pursue because of their potential to compete with food production on existing and new cropland. Food security is a priority of the Government of Kenya.

A 2008 study by Endelevu Energy and ESD, which was used in this low-carbon analysis, suggests that biofuels could have a role to play without impacting food security. The 2008 study estimates that biodiesel resources range from less than 2,000 to 17,000,000 cubic metres per year, and bioethanol resources range from approximately 49,000 to 23,000,000 cubic metres per year. The lower end of the range represents status quo assumptions and is based on actual production in 2006 without food competition. The upper end of the range assumes that existing farmland cannot be used and that only new farmland is used. This upper figure is roughly two orders of magnitude higher than the biofuel volumes required in 2030 to meet the low-carbon scenario of this analysis. However, it remains unclear to which extent the Endelevu Energy and ESD study took into account the fact that most land in Kenya which is currently not used for crop cultivation has some other use, including cattle grazing.[76]

In this low-carbon analysis, total biodiesel use in 2030 for the low-carbon scenario (a B10 blend) is in the order of 415,000 cubic meteres per year, while total bioethanol use would be approximately 200,000 cubic meters per year (for an E10 blend). These figures are at the low end of the ranges in the Endelevu Energy and ESD study, implying a limited impact on food security. Larger-scale use of biofuels could pose potential sustainable development risks. Consideration of large-scale biofuels implementation will need to study associated impacts in an integrated way to account for future food needs, land use by local communities, biomass demands from other sectors such as electricity generation and government plans for reforestation.

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

7.6.6 Climate resilience impacts of low-carbon options

Most of the options described in this chapter are not expected to be impacted by climate change. Bioethanol and biodiesel could be vulnerable to climate change as weather conditions and rainfall could directly impact crop yields and availability of irrigation. It is important to promote energy crops that are suited for the local climactic conditions in Kenya and, where possible, have been developed or chosen for resilience to future climate impacts.

Road and rail infrastructure can be vulnerable to climate change impacts; for example, roads can be severely impacted by flash floods, but in this sense, the low-carbon options are comparable to the reference case in terms of resilience. However, a shift to public transport is not expected to directly impact the climate resilience of Kenya's transport infrastructure.

7.6.7 Feasibility of implementation

The German Development Cooperation Agency (GIZ), which is supporting low-carbon transport programmes in many countries, note that:

> What makes transport so special – and difficult to tackle – is that emissions stem from millions and millions of small decentralized mobile sources; that emission levels are the result of the transport choice that billions of people make every day; that the scope for technical improvements is limited in the

> short run; and that transport volumes are closely linked to economic growth. Cutting carbon dioxide emissions in the transport sector is thus particularly difficult.[77]

General barriers and issues for the mitigation in the (urban) transport sector include:

- Infrastructure-related measures often have high up-front capital requirements, which can be a barrier even if the costs are paid back over the lifetime of the investment.
- GHG emissions are only a minor issue for (local) transport policy makers, particularly in developing countries. The focus, therefore, should be on sustainable transport, which will bring down GHG emissions as a side benefit.
- Transport systems are very complex, built up over decades, and have strong interactions with urban planning.
- Transport systems are determined by the decision of millions of end-users, and changing behaviour has proven difficult in many cases.
- Because of the vested interests of the automobile industry and labor and consumer organizations, a strong political commitment is needed to implement drastic, successful changes in urban transport systems.
- Estimating the impact of individual policy measures requires complex models and a large data input.[78,79]

Some specific barriers can be identified in the Kenyan context for the low-carbon options considered in this analysis.

- The belief that new crops, such as jatropha, would be immediately commercially productive on marginal land, has been shown to be incorrect.[80] A significant barrier for action on biodiesel is the poor experience with jatropha, combined with widespread concern about potential negative impacts on food security.
- An important barrier is the ability of customers to pay for improved public transport services. Matatu fare of Ksh 50 or Ksh 100 at peak hours, depending on destination, is high considering that minimum wage is about Ksh 200 to 300 per day.[81] Public transport services will need to consider ability to pay.
- Previous efforts to reform public transport services have met strong resistance from matatu unions, and they can be expected to resist future actions that impact their services.

7.7 Potential Policy Measures and Instruments

Several policy measures and instruments are available to reduce GHG emissions from the transport sector. Table 7.4 demonstrates the three fundamental strategies to reduce GHG emissions from transportation:

- Avoid travel by motorised means;
- Shift to cleaner and environmentally friendly modes; and
- Improve the efficiency of existing transport systems and technology.

Implementation of the low-carbon options discussed in this chapter would require a combination of the instruments suggested in Table 7.4.

Potential policy measures and instruments to support public transport options

BRT and LRT systems may require planning, economic support and awareness raising initiatives. Furthermore, public transport systems can also be complemented by transport

Table 7.4: Examples of different types of policy instruments (planning, economic, regulatory, and 'soft') for avoid (A), shift (S) and improve (I) strategies as well as a combination of the three (ASI)[82]

	Planning	Economic	Regulatory	Soft
A	Mixed-high density planning	Road pricing / congestion charge	Closing districts to vehicles	Campaigning for locally produced goods
S	Mass transit/NMT infrastructure	Incentives for mass transit/NMT	Enforcing right-of-way and exclusive lanes for mass rapid transit vehicles and NMT	Awareness raising for mass transit/NMT/car-pooling
I		Incentives for efficient/low-carbon vehicles and fuels	Fuel economy standards for low carbon fuels (e.g. biofuels) and vehicles	Eco-driving training campaigns and new vehicle carbon emission rankings to inform customers
ASI	Integrated transport planning	Fuel/carbon tax	Sectoral emissions target	Institutional restructuring in support of integrated transport planning

Source: Bakker, S. and Huizenga, C. 2010. "Making climate instruments work for sustainable transport in developing countries." Natural Resources Forum*, 34: 314–326.*

demand management measures, which attempt to influence how and when people travel and, in particular, discourage the use of private motor vehicles. These measures can includes aspects such as congestion pricing, fuel taxes and parking control, each of which have certain advantages or disadvantages depending on city or country context. In order to promote public transport, a smart combination of push and pull policies is required.

Potential policy measures and instruments to support biofuels

Biofuels often use regulations that require a certain percentage blend of biodiesel or bioethanol in a country's fuel supply, but these can be complemented by tax reductions on biofuels, direct subsidies for production or conversion and guaranteed prices for producers, amongst others.[83] More specific interventions can also be made by governments, such as: 1) allocation or leasing of large tracts of previously public, community owned, trust, or private land to encourage foreign or local investment; 2) development of national biofuel standards and certification requirements; and 3) public investment into coordinated national research and development programmes on feedstock development and distribution to farmers.[84] Biofuel policies have additional challenges to integrate with agricultural policy and to ensure that the complex issue of 'food versus fuel' is adequately dealt with. While international trade is a key driving force in setting commodity prices, flexibility in biofuel policies domestically, as well as vigilance from policy makers, can allow governments to try and mitigate impacts on food security. Finally, as noted earlier, there is a need to try to include a focus on pro-poor rural development in biofuel policy, as large-scale biofuels production may not always achieve this. Options include clustering of small-hold farmers to reach critical masses; encouraging contract farming; incorporating biofuel production into a national guaranteed rural employment programme in biofuels development; supporting extraction of bio-oil at village level and encouraging development of rural energy centres with biodiesel powered generators for agricultural services, battery charging and public lighting.[85]

Potential policy measures and instruments to improve vehicle efficiency

A number of policy options are available to improve on-road fuel economy. They typically focus around regulatory measures but can also include direct incentives and awareness campaigns. These include standards for vehicle fuel economy, standards for vehicle emissions, vehicle inspections, taxation and pricing measures for vehicle performance, inclusion of emissions standards in warranties, car labelling, fuel price reform (taxation/reduction of subsidies), incentives to get older vehicles off the roads (also called car scrapping schemes), standards for fuel quality and driver education.[86]

Finally, in addition to the above described planning, economic, regulatory and soft measures, there is a strong need to improve the quality of data available in the transport sector. In order to track trends in national transport emissions, policymakers should establish a starting point from which to measure and monitor emissions. Reliable data needs to be made available that covers usage patterns, current infrastructure and vehicle stock characteristics.[87] For example, there is currently no comprehensive Kenyan fuel economy data, nor reliable data on the number of vehicles on the roads and their characteristics. Improving data availability is important to:

- Provide a basis for tracking progress, such as improvements in fuel economy;
- Provide evidence for policy making and development of appropriate guidelines in the transport sector, and
- Make baseline estimates more reliable, so that mitigation actions in the transport sector are more attractive to various sources of climate finance.

7.8 Conclusion

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

In terms of priorities, the introduction of an extensive mass transit system for greater Nairobi in the form of BRT corridors - potentially complemented by some LRT corridors - stands out as a potential priority action due to its significant benefits in terms of relieving traffic congestion, improving local air pollution and increasing road safety. It would also be in line with government priorities as the Government of Kenya has already started to secure funding for these investments. After initial experience has been collected in Nairobi, such a system could be replicated in other large urban areas in the country. The shift of freight transport to rail in combination with a modernization and extension of the existing rail network would facilitate regional trade, as well as improve road safety and road quality. By decreasing wear and tear of roads through heavy traffic, this option would also increase climate resilience. While the use of biofuels would not only lower GHG emissions, but also the need for fossil fuel imports, large-scale production of biofuels in Kenya could compete with food production and should only be pursued in a well regulated manner.

Annex 1: Low-Carbon Development Option Fact Sheets

Improved Passenger Vehicle Stock Efficiency

This mitigation option focuses on improving the efficiency of vehicles by restricting and removing low efficiency vehicles in the market, or subsidizing or regulating for higher efficiency vehicles.

Current situation: Relatively high proportion of older, less efficient vehicles and significant numbers of imported second-hand vehicles are in use.

Low-carbon scenario: Assumes that the import of second hand vehicles is regulated to achieve a 2 percent improvement per year in average new vehicle efficiency and the removal of older low efficiency vehicles through incentives or regulation. Results in an overall fleet fuel efficiency improvement of 7 percent versus reference case by 2030 for petrol and diesel cars.

Development benefits and priorities

Development benefits:

- Reduced fuel costs for users.
- Improved energy security through lower oil imports.
- Improved urban air quality (less emissions per vehicle).
- Reduced accidents due to more modern vehicles.

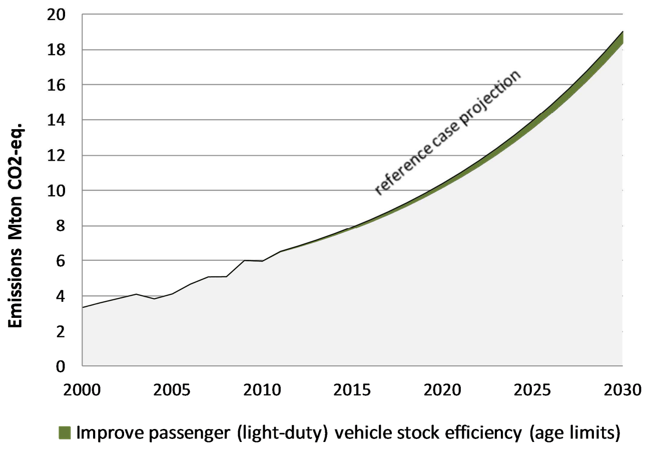
Alignment with Government of Kenya priorities: The transport sector is one of the critical enablers in achieving Vision 2030 and aims at developing and maintaining an integrated, safe and efficient transport network. A *National road safety programme* is one of Vision 2030's flagship projects.

Links to adaptation: no significant link to adaptation / climate resilience.

Abatement potential and costs

Greenhouse gas abatement: These efficiency improvements amount to an abatement potential of 639 $ktCO_2$/year in 2030, or approximately 3.6 percent of total transport emissions. Similar studies that considered removing (de-registering) stock that is over 15 years old, reported a similar abatement potential of 1.5 percent of total road transport sector emissions from vehicles aged 15 to 25 years and 0.7 percent from vehicles over 25 years of age.[88]

Costs: The marginal abatement cost in this study is in the order of US$ 60 to 130 /tCO_2 based on current fuel prices and vehicle costs (which mitigation costs are highly dependent on). These costs are likely to change because of on going oil exploration in Kenya.



Scenario	2010	2015	2020	2025	2030
Number of 15 year+ old cars removed from the road	-	63,000	135,000	254,000	385,000
Abatement potential ($ktCO_2e$)	-	103	222	418	639

Feasibility of implementation

Scrapping old vehicles for a payment is expensive, thus likely to be feasible only for very old cars if at all. There is potential to introduce tax incentives but existing regulations need to be enforced. The use of modern high efficiency vehicles requires strict control on fuel quality regulations.

Improved Heavy-Duty Vehicle Stock Efficiency

The current HDV fleet in Kenya has a relatively high proportion of older, less efficient vehicles and many imported second-hand vehicles.

Current situation: Relatively high proportion of older, less efficient vehicles and a lot of imported second-hand vehicles.

Low-carbon scenario: Assumes a phased (penetration increases over time) average per vehicle fuel efficiency improvement of three percent in 2020 and 10% in 2030 through various actions such as improved rolling resistance of tyres, tyre pressure monitoring and enforcement of emissions regulations for all heavy duty vehicles (see table below).

Development benefits and priorities

Development benefits:

- Reduced fuel costs.
- Energy security benefits.
- Improved urban air quality (less emissions per vehicle).
- Reduced accidents due to more modern vehicles.

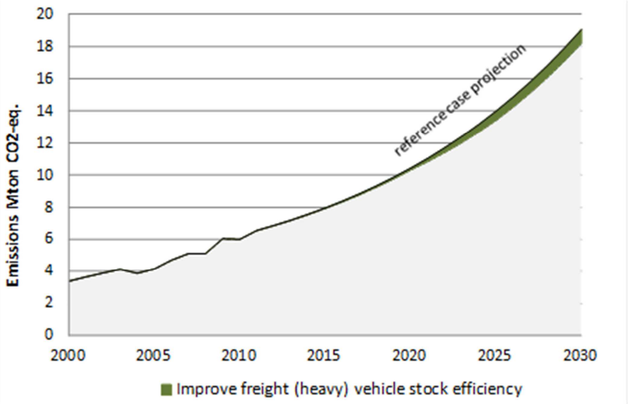
Alignment with Government of Kenya priorities: The Government of Kenya recognizes the transport sector as one of the critical enablers in achieving Vision 2030 and aims at developing and maintaining an integrated, safe and efficient transport network. A *National road safety programme* is one of Vision 2030's flagship projects.

Links to adaptation: no significant link to adaptation / climate resilience.

Abatement potential and costs

Greenhouse gas abatement: The efficiency improvements amount to an abatement potential of 473 kilotons of CO_2 per year in 2030, or approximately 4.8 percent of total transport emissions. Similar studies that considered removing (de-registering) stock that is over 15 years old reported an abatement potential of 2.4 percent of total road transport sector emissions from HDV vehicles aged 15 to 25 years and 5.3 percent from HDV vehicles over 25 years of age.[89]

Costs: For this study the marginal abatement cost is found to be very favourable, in the order of US$ -150 per tonne of CO_2 in 2030 based on current fuel prices and vehicle improvement cost estimates (which mitigation costs are highly dependent on). These costs are likely to change because of on going oil exploration in Kenya.



Scenario	2010	2015	2020	2025	2030
Efficiency improvement for HDVs (%)	-	3%	3%	10%	10%
Improved HDVs on road (%)	-	25%	80%	90%	100%
Abatement potential (ktCO_2e)	-	25	108	549	841

Feasibility of implementation

Achieving the efficiency improvements under the low-carbon scenario through regulation requires setting of quality standards for the import and use of HDV tyres and enforcement of the regulation, which may be challenging (especially in informal garages). Customers may not react to incentives to purchase tires with lower rolling resistance as replacement tyres because of their payback period, lack of clear information and limited market availability. If new vehicles are regulated to meet certain fuel economy standards then this use of modern high efficiency vehicles requires strict control on fuel quality regulations.

Biodiesel

Biodiesel is a liquid substitute for petroleum-based diesel, made using vegetable oil derived from a wide variety of oil-bearing plants such as castor, coconut, croton, jatropha, rapeseed (canola) and sunflower. Unlike ethanol, which has several markets aside from energy, biodiesel's only use is as an alternative source of fuel for transport and stationary power. The vast majority of biodiesel projects being planned or underway involve the use of Jatropha as feedstock, however other types of feedstocks are being discussed.

Available estimates of resources range from less than 2 million litres per year (under a status quo assumption based on actual production in 2006) using castor and sunflower feedstock to more than 40,000 million litres per year using existing farmland with improved practices.[90]

Current situation: Biodiesel production in Kenya is at a nascent stage, and production levels are negligible. Several government, private sector and NGO initiatives are in place to boost production levels.

Low-carbon scenario: 10 percent of regular diesel replaced by biodiesel by 2020; that is, introduction of a B10 blend requirement.

Development benefits and priorities

Development benefits:

- Energy security benefit due to less petroleum use and imports.
- Potential for job creation for local processing and harvesting.
- Potential for improved land-use practice.
- Production of co-products such as glycerol and fertiliser.

Potential risks:

- Biofuel production may lead to conflicts over land use and compete with food production.

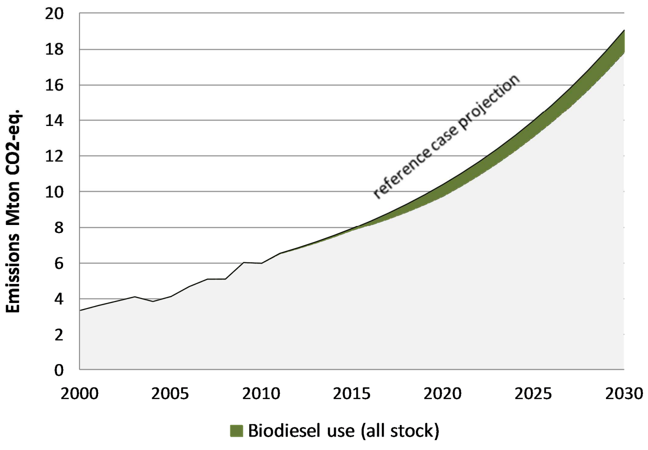
Alignment with Government of Kenya priorities: According to Vision 2030, Kenya aims to increase the reliance on national energy resources over imports. Biofuel production can contribute to this goal.

Links to adaptation: Agricultural productivity may be affected by climate impacts.

Abatement potential and costs

Greenhouse gas abatement: The use of 415 million litres per year of biodiesel amounts to an abatement potential of 1,212 kilotons CO_2 per year in 2030. This is less than the estimated potential that can be achieved if additional land is cultivated with improved practices.

Costs: Marginal abatement costs are estimated to be US$ 66 /tCO_2 based on slightly higher biodiesel costs versus traditional diesel (at 2012 prices). However this could change and according to other reports, Kenya could save US$ 71 million per year by substituting 12 percent (10 percent of gasoline and 2 percent of diesel) of its imports with locally produced biofuels by 2013.[91] These costs are likely to change depending on the oil exploration in Kenya.



Scenario	2010	2015	2020	2025	2030
Percentage of biodiesel in supply	0%	2%	10%	10%	10%
Diesel usage – biodiesel (m^3/year)	-	33,000	223,000	303,000	415,000
Abatement potential ($ktCO_2e$)	-	98	652	883	1,212

Feasibility of implementation
Current efforts in biodiesel production, especially those based on jatropha have not been very successful. This has reduced the willingness to pursue biodiesel in Kenya. Large-scale production as assumed under the low-carbon scenario would require significant use of new land and improved farming practices. In addition, strong oversight is required to ensure that biodiesel production does not compete for land with food crops.

Bioethanol

Ethanol is a liquid fuel that can be produced from a variety of sugars and starch containing crops. Examples include cassava, sweet sorghum, maize, sugar beet, sugarcane and wheat. Ethanol can also be used for alcoholic beverages and various pharmaceutical, medical and industrial uses. Kenya has been producing ethanol for over twenty years in relatively modest quantities and, for a period in the 1980's, was blending it into the petrol mix as a 10 percent blend known as gasohol. This programme has now ceased; however Kenya still produces approximately 125,000 litres per day (as of 2008) of ethanol for other industries.

Estimates of resources range from approximately 49 million litres per year (under a status quo assumption based on actual production in 2006) using sugarcane to more than 45,000 million litres per year using existing farmland with improved practices and additional sources such as cassava and sorghum.[92]

Current situation: Ethanol production in Kenya, while an established market, does note produce significant volumes for the transport sector.

Low-carbon scenario: 10 percent of regular petrol replaced by bioethanol by 2020; that is an introduction of an E10 blend requirement.

Development benefits and priorities

Development benefits:

- Energy security benefit due to less petroleum use and imports.
- Potential job creation from local processing and harvesting.
- Potential for improvements in land use practice.

Potential risks:

- Biofuel production may lead to conflicts over land use because of competition with food production.

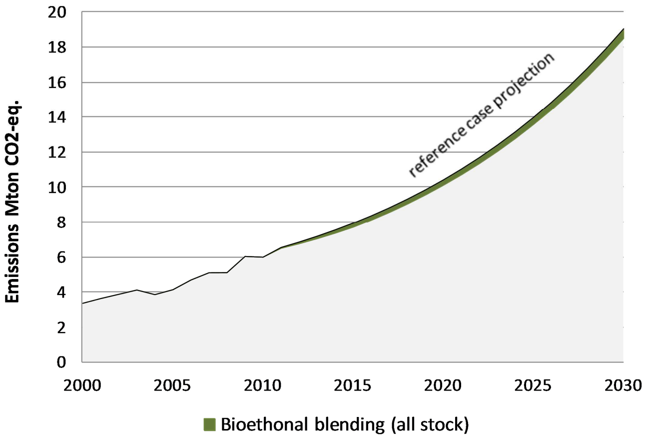
Alignment with Government of Kenya priorities: As stated in Vision 2030, Kenya aims to increase the reliance on national energy resources over imports. Biofuels production can contribute to this goal.

Links to adaptation: Agricultural productivity may be affected by climate impacts.

Abatement potential and costs

Greenhouse gas abatement: The use of 196 million litres per year of bioethanol amounts to an abatement potential of 547 $ktCO_2$/year in 2030. This is less than the estimated potential that can be achieved if additional land is cultivated with improved practices.

Costs: Marginal abatement costs are estimated to be US$ -15 per tonne of CO_2 based on a bioethanol price of KSh 56.5 including taxes. This assumes sugarcane is used as feedstock.[93] These costs are likely to change depending on the ongoing oil exploration in Kenya.



Scenario	2010	2015	2020	2025	2030
Percentage of bioethanol in supply	0%	10%	10%	10%	10%
Usage – bioethanol (m^3 per year)	-	84,000	108, 000	144, 000	196, 000
Abatement potential ($ktCO_2e$)	-	234	303	404	547

Feasibility of implementation

The introduction of large-scale biofuels programs requires consideration of:

- Potential conflict with food crop production;
- Significant new areas of land for cultivation;
- Need for improved farming practices;
- Areas with insecure land tenure, where the poor may be dispossessed of land; and
- Competition for ethanol with other industries that have historically been able to pay more than the pre-tax fuel price.

Bus Rapid Transit System - Nairobi

A Mass Rapid Transit System (MRTS) for Nairobi is likely to consist of a Bus Rapid Transit (BRT) System and a Light Rail Transit (LRT) System. It An MRTS is needed to provide services for a rapidly expanding Nairobi including significant growth in satellite towns and areas outside the city proper[94].

Current situation: Public transport in Nairobi relies mainly on matatus and taxis; traffic congestion poses large costs to the economy.

Low-carbon scenario: Significant shift of private transport in Nairobi to MRTS, with BRT as the dominant component of a MRTS and LRT playing a smaller complimentary role for certain high thoroughfare corridors.

Development benefits and priorities

Development benefits:

- Congestion reduction: time and economic savings.
- Improved air quality and reduced health costs.
- Increase in energy efficiency per passenger-kilometre.
- Noise reduction.
- Improved road safety (if implemented properly).
- Potentially lower land grab per passenger-kilometre.

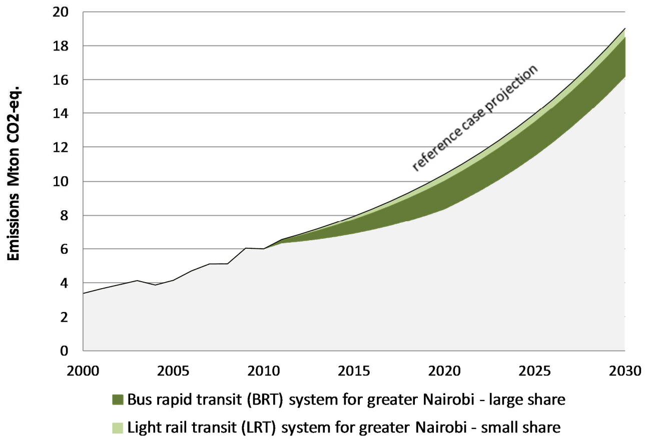
Alignment with Government of Kenya priorities: The Vision 2030 document does not explicitly mention BRT, but states that the light rail system would carry 150,000 people per day to meet 5 percent of the future public transport demand. Mass rapid transport is also a key component of the pending Nairobi Metro 2030 plan.

Links to adaptation: No significant links.

Abatement potential and costs

Greenhouse gas abatement: A recent feasibility study[95] indicated reductions of between 4,832 to 5,696 ktCO$_2$e per year for a MRTS system in Nairobi depending on the design (for example, how it deals with existing traffic).[96] This study takes a more conservative assumption on implementation timing, estimating emissions reductions from a BRT in 2030 to be in the order of 2,280 ktCO$_2$e per year for greater Nairobi.

Costs: Preliminary feasibility studies have put the costs for a BRT system (when implemented in combination with a light-rail system) at KSh 82.9 billion (approximately US$ 1 billion) for an 84-kilometre system. Total passengers served by a combined BRT and light-rail system are estimated to be between 3.2 and 4.5 million depending on growth rates and city planning.[97]



Scenario	2010	2015	2020	2025	2030
Approximate Peak Hour Peak Direction Traffic for total BRT + LRT system (PHPDT; ‘000 passengers)	-	55	111	129	148
Abatement potential (ktCO$_2$e)	-	821	1,641	1,983	2,280

Feasibility of implementation

Barriers include the current lack of a coordinated urban transport policy and its enforcement and high capital investment. A BRT system is likely to affect space available for cars. In addition, a change in the status quo, if not managed very carefully could be met with resistance from bus and matatu owners and operators.

Light Rail Transit System - Nairobi

A Mass Rapid Transit System (MRTS) for Nairobi is likely to consist of a Bus Rapid Transit (BRT) System and a Light Rail Transit (LRT) System. An MRTS is needed to provide services for a rapidly expanding Nairobi including significant growth in satellite towns and areas outside the city proper.[98]

Current situation: Public transport in Nairobi is mostly reliant on matatus and taxis; traffic congestion poses large costs to the economy.

Low-carbon scenario: Significant shift of private transport in Nairobi to MRTS, with BRT as the dominant component of a MRTS and LRT playing a smaller complimentary role for certain high thoroughfare corridors.

Development benefits and priorities

Development benefits:

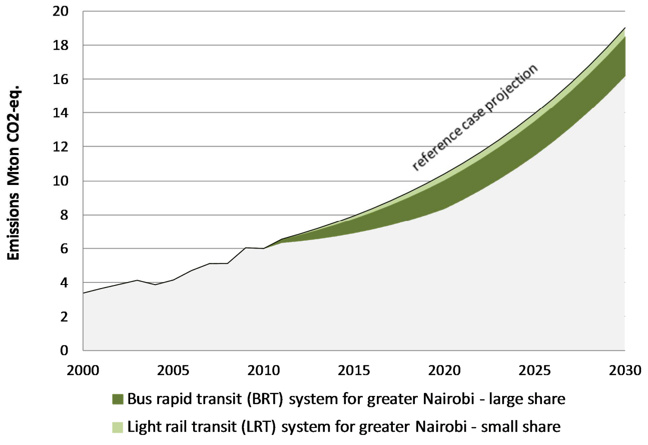
- Congestion reduction: time and economic savings.
- Improved air quality and reduced health costs.
- Increase in energy efficiency per passenger-kilometre.
- Noise reduction.
- Improved road safety (if implemented properly).

Alignment with Government of Kenya priorities: The Vision 2030 document states that the light rail system would carry 150,000 people per day to meet five percent of the future public transport demand. Mass rapid transport is also a key component of the pending Nairobi Metro 2030 plan.

Links to adaptation: no significant links.

Abatement potential and costs

Greenhouse gas abatement: A recent feasibility study indicated reductions of 6,020 ktCO$_2$e per year for an LRS in Nairobi.[99] This study takes a more conservative assumption on implementation timing, estimating emissions reductions from an LRT in 2030 to be in the order of 2,280 ktCO$_2$e per year for greater Nairobi. However, it is likely that a predominantly BRT system will be taken forward in Nairobi, with only a small LRT component; these reduced potentials are shown below and at right.



Costs: Preliminary feasibility studies have put the costs for a single line on the light rail system from the airport to city centre around US$ 190 million. Other studies have indicated costs for a more extensive LRS (when implemented in combination with a BRT system) at Kshs 326.5 billion or approximately US$ 4.1 billion.[100] Total passengers served by a combined BRT and LRT are estimated to be between 3.2 and 4.5 million depending on growth rates and city planning.

Scenario	2010	2015	2020	2025	2030
Approximate Peak Hour Peak Direction Traffic for total BRT + LRT system (PHPDT; ‘000 passengers)	-	55	111	129	148
Abatement potential (ktCO$_2$e)	-	205	410	496	570

Feasibility of implementation

Barriers include are the lack of a coordinated urban transport policy and its enforcement, and very high capital investment. An LRT system might affect space available for cars. As an LRT system is more expensive to build and operate than a BRT system it may be challenging to offer fares that are affordable to a large part of the population.

Shift of Freight from Road to Rail

Current situation: Large majority of freight movements are with road transport due to various issues with the available rail freight service.

Low-carbon scenario: Approximately 30 percent of transit freight is moved to rail transport by 2030.

Development benefits and priorities

Development benefits:

- Reductions in congestion from heavy-freight vehicles.
- Improved energy security through lower oil imports.
- Improved local air quality.
- Reduced accidents.
- Reduced degradation of road systems.

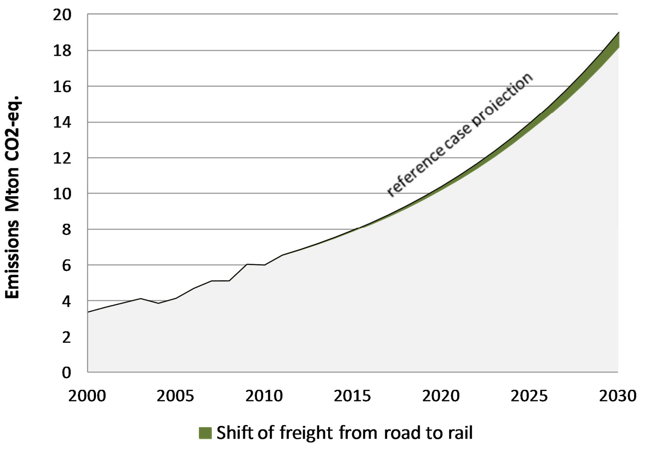
Alignment with Government of Kenya priorities: The government recognizes the transport sector as one of the critical enablers in achieving Vision 2030. The Government aims to develop and maintain an integrated, safe and efficient transport network, and implement infrastructure projects that will stimulate demand in neglected areas which will target increased connectivity and reduce transport and other infrastructure costs. One of the Vision 2030 flagship projects is *Development of a new transport corridor to Southern Sudan and Ethiopia*, which comprises of a new road network and railway line.

Links to adaptation: No significant links.

Abatement potential and costs

Greenhouse gas abatement: to the shift from freight to rail amounts to a mitigation potential in the order of 833 $ktCO_2$ per year in 2030.

Costs: For freight, rail is often competitive with road-based transport on a per tonne-km basis, and net benefits for society are accrued in terms of health, environment, reduced road damage and improved congestion conditions. However there are no marginal abatement costs for freight modal shifts available in the environmental-economic literature.



Scenario	2012	2015	2020	2025	2030
Abatement potential ($MtCO_2e$)		54	183	401	833

Feasibility of implementation

The low-carbon scenario requires a significant improvement and expansion of the existing rail system to reduce freight times and enable the switch. Moreover, the current system is based on trucks deliveries from port to door while rail delivers to a depot only, thus a rail-based system needs to be complemented with trucks which cover the remaining distance to the required location. The modernization and expansion of the Kenya's railway system would require significant upfront capital investments. Moreover, there may be resistance from the current freight transport operators and owners of the truck fleets in operation.

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[19] For all options considered in this analysis where a marginal abatement cost were calculated, a constant discount rate of 12 percent per annum was considered, which assumes that costs are calculated from a social perspective. Individual or private discount rates might be expected to be considerably higher in Kenya.
[20] Fuel costs were based on average recent prices for petrol and diesel, and as a conservative assumption were assumed not to change over the period of the study. Should prices increase substantially over the coming years, then this would lead to lower the marginal abatement costs calculated for the low-carbon options and favour their adoption.
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[30] 85 to 91 Research Octane Number local compared with 95 to 99 Research Octane Number in developed nations.

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[55] It should be noted that this figure is a direct result from the 2011 feasibility study for a LRT and BRT in Nairobi developed by Consulting Engineering Services in association with APEC Limited, Kenya, for which no details are provided for the calculations of mitigation potentials. This figure of 2.8 $MtCO_2$ is high (approximately 15 percent of total emissions in 2030) even with our more conservative assumptions on implementation schedules. A more detailed analysis of the BRT and LRT corridors and their realistic mitigation potentials would be required as the basis for taking such an option forward for international support. The on-going Sustrans project in Kenya will provide a starting point for this, but at this time has not prepared detailed calculations of abatement potentials (see http://www.unhabitat.org/categories.asp?catid=666 for additional information).

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