BASELINE SURVEY ON UGANDA'S NATIONAL AVERAGE AUTOMOTIVE FUEL ECONOMY

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Executive Summary

More recently, the global oil demand has steadily increased, largely due to rapid motorization taking place in developing countries. Over 50% of oil use around the world is for transport and nearly all the recent and future expected growth in that use comes from increased transport activity whilst the global transport sector contributes about 25% of the energy related global GHG emissions. Due to the rapid growth in vehicle population in developing countries, especially private passenger vehicles, controlling the fuel energy demand and greenhouse gas (GHG) emissions has become a global concern. The process of burning fuels by driving vehicles produces greenhouse gases such as carbon dioxide (CO_2) into the atmosphere which contributes to climate change. These emissions can be reduced by improving motor vehicle fuel efficiency, which in turn reduces the nation's dependence on oil and saves money.

The Global Fuel Economy Initiative (GFEI) launched in 2009 aimed at reducing localized air pollution and Green-House Gas (GHG) emissions through the promotion of cleaner and more fuel efficient vehicles. Globally, the motivation for implementing CO_2 (GHG) emissions and fuel economy standards emanates from the threat of climate change and potential oil shortages.
Thus, promoting fuel efficiency and reducing carbon dioxide (CO_2) emissions is a key global development agenda. The GFEI has set a target of a 50% improvement in vehicle fuel economy in new LDVs by 2030 and across the total global car stock by 2050 as part of the post-2015 Sustainable Development Goal (SDG) framework. In Uganda, vehicle emissions are a major contributor to poor air quality in urban areas, particularly due to increased importation of used vehicles.

The key objective of the study was to prepare a vehicle inventory and vehicle import trend in order to establish the Uganda's national average fuel economy (baseline setting) and trend. This information was then used to compute carbon emission levels arising from automobile pollution. Information on vehicular emission was used to prepare policy recommendations to support import of cleaner and more efficient vehicles into Uganda.

Data on vehicle inventory in Uganda were obtained from the Ministry of Works and Transport and the Uganda Revenue Authority for public and private vehicles respectively for the period 2000 to 2014. We found that 5.63 percent and 94.37 percent of the automobiles were owned by the state/government and private respectively. Of these automobiles 0.9 percent constituted engineering plants (tractors, bull dozers etc) and 46. 62 percent were classified as motor vehicles (i.e. Station wagons, saloon, etc) and 52.48 percent were motorcycles. A model was developed to incorporate age in the fuel consumption of automobiles, the carbon dioxide emissions were computed using the fuel consumption values after factoring in age. The harmonic average fuel efficiency has declined from 12.52 L/100km in 2005 to 13.73 L/100Km in 2014 and this is attributed to the increase in the average age of vehicles imported into the country. Average carbon dioxide emission has also worsened from 465 g/km in 2005 to 503g/km in 2014. We further found that the age of a vehicle other factors constant greatly influences carbon emission. Also, vehicles

with a higher engine capacity pollute more than those with smaller capacity. In addition diesel engine vehicles pollute more than petro engine vehicles even if they are of the same engine size.

In conducting a cost benefit analysis, we used a simple analysis involving different forms of transport, and we found that a bus carrying 80 passengers for a distance of 21km a day for one year would use fuel worth UGX 3.3 millions and pollute 3.2 tons of carbon dioxide. While to carry the same number of passengers for the same distance we would need 6 commuter taxis of capacity 14 passengers which would require 5 times more fuel and pollute 5 times more than the buses. As for the motorcycles we would need 80 motor cycles which would consume 13 times more than the bus in one year and pollute 6 times more.

We recommend that the line agencies should ensure that their draft policies are put into action so as to reduce the levels of carbon dioxide emissions. Particularly, NEMA should enact the air quality standards to guide the partner institutions in exercising their duties. Other recommendations include differential tax rates/fees based on age of the vehicle such that a higher tax rate is imposed on older vehicles than on newer ones; There should be periodic inspection of all automobiles (vehicles and motorcycles) that are already registered in the country, and government should impose a limit/ceiling of emission per category of engine capacity of the vehicle beyond which the vehicle should either be put off the road, install a catalytic converter or pay a fee for polluting the environment. All imported automobiles should be subjected to compulsory testing for fuel economy and carbon emission before registration. In addition to other specifications, vehicle inspections before importation should include carbon emission levels. Vehicles that are to be imported into the country should be labeled with "Fuel economy and Environmental Labels," for easier comparison during shopping. Encourage public transportation by providing parking places at different entry points into the city for private automobiles. Discourage private transport into the City by increasing parking fees. Make walking and biking safe to the users by providing walk ways, security lights and security along the City roads.

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List of Abbreviations and Acronyms

CC	Cubic Centimeter
CO_2:	Carbon dioxide
GFEI:	Global Fuel Economy Initiative
GHG:	Green House Gases.
GKMA	Greater Kampala Metropolitan Authority
HDV:	Heavy Duty Vehicles
IEA:	International Energy Agency
KCCA	Kampala Capital City Authority
LDV:	Light Duty Vehicle
MDAs:	Ministries, Departments and Agencies (of Government)
MDV:	Medium Duty Vehicle
MEMD:	Ministry of Energy & Mineral Development
MoW&T:	Ministry of Works and Transport
NEDC:	New European Drive Cycle
NEMA:	National Environment Management Authority
NMT:	Non-Motorized Transport
OECD:	Organization for Economic Co-operation and Development
Ppm:	Particulates per Molecule
SDG	Sustainable Development Goal
ToR:	Terms of Reference
UN	United Nations
UNFCCC:	United Nations Framework Convention on Climate Change
UNEP:	United Nations Environment Programme
URA:	Uganda Revenue Authority
USD	United States Dollar

INTRODUCTION

1.1: Background

The Global Fuel Economy Initiative (GFEI) was launched in 2009 and its main aim is reducing localized air pollution and Green-House Gas (GHG) emissions through the promotion of cleaner and more fuel efficient vehicles. Globally, the motivation for implementing CO_2 (GHG) emissions and fuel economy standards emanates from the threat of climate change and potential oil shortages. The United States was the first country to establish fuel economy standards for passenger vehicles after the 1970's oil crisis. More recently, the global oil demand has steadily increased, largely due to rapid motorization taking place in developing countries, in particular in countries with rapidly growing economies, such as Brazil, China, India and others. Over 50% of oil use around the world is for transport and nearly all the recent and future expected growth in oil use comes from increased transport activity (GFEI Plan of action 2012-2015). Due to the rapid growth in vehicle population, especially private passenger vehicles, controlling the fuel energy demand and greenhouse gas (GHG) emissions has become a global concern (Feng, et al 2011).

According to the GFEI report of fuel economy 2014, the global transport sector contributes about 25% of the energy related global GHG emissions. Globally, the transport sector is rising faster than any other sector and the number of vehicles on the planet is set to triple by 2050 - the vast majority in non-OECD countries (GFEI, 2014). Thus, promoting fuel efficiency and reducing carbon dioxide (CO_2) emissions is a key global development agenda. The GFEI has set a target of a 50% improvement in vehicle fuel economy in new Light Duty Vehicles (LDV) by 2030 and across the total global car stock by 2050 as part of the post-2015 Sustainable Development Goal (SDG) framework.

Fuel economy standards have mostly been implemented in the developed (OECD) countries such as the US, Canada, Japan the EU, the BRICS (Brazil, Russia, India, China and South Africa), and a few other emerging economies. According to the GFEI 2014 report, only Mauritius has developed and implemented the first fuel economy/CO_2 based fee-bate system in the developing world. However, through the GFEI, more countries are acknowledging the need for strong policies on fuel efficiency, and more are investigating, developing and implementing those policies (GFEI 2014).

In Uganda, vehicle emissions are a major contributor to poor air quality particularly in urban areas. Vehicular emissions contribute to GHG responsible for global warming. Uganda ratified the United Nations Framework Convention on Climate Change (UNFCCC) aimed at combating the problem of climate change. Over 70% of Uganda's population depends on agriculture, but the productivity of this sector highly depends on good climate. Hence implementing the GFEI is a civil obligation as well as a development concern.

The economic benefits of promoting fuel economy policies range from fuel savings to reductions in respiratory tract infections (RTI) among communities. For example a recent study for the Kenyan economy shows that with around 1.2 million cars, (about 30 vehicles per 1000 people), Kenyans already import about USD 2 billion worth of fuel oil per year (GFEI 2014). Modest projections show that the stock of vehicles will at least triple by 2030 and increase by as much as

10-fold by 2050 to around 10 million vehicles (based on UN population projections). Given the current fuel efficiency rate of 8l/100km from the GFEI 2008 study, the USD 1.5 billion currently spent on fuel would rise to USD 6billion in 2030 and to USD 20 billion in 2050 (in constant dollars). These projections demonstrate the large potential financial savings from promoting fuel efficiency in addition to the benefits accruing from cleaner environment. The savings could be even greater if they were combined with other transport policies, such as shifting vehicles to new fuels, non-motorized transport (cycling and walking) and curbing car travel growth through sensible transport policies.

Uganda has not had a comprehensive policy for fuel economy and this baseline study through the GFEI and UNEP support is the first step to developing and implementing a National fuel economy policy. The draft Urban transport policy, the non-motorized transport policy 2012, the draft KCCA transport management policy guidelines all include elements geared towards improving fuel efficiency, but implementation has hitherto been weak and uncoordinated.

Globally, climate change is considered one of the most important environmental issues due to its effects on global warming. It is caused by both natural processes and human activities. Empirical studies have shown that human activities particularly those that lead to emission of carbon dioxide and other greenhouse gases to the atmosphere are the greatest contributors of global warming. The consequences of air pollution are disastrous and range from health-related problems (respiratory, poor heart conditions and cancer), effects on landscapes, reduction in agriculture production, global warming, acid rain, effects on wildlife and depletion of the ozone layer. It is therefore every ones concern and governments, businesses and consumers to reduce air pollution.

Researchers from Makerere University, including Economists, a Mechanical Engineer, an environmental expert and a Statistician supported by the Ministry of Energy & Mineral Development (MEMD) under the GFEI/ UNEP - contract **(UNEP/SSFA/DTIE/Energy/Transport/2014/CPL-5070-3E37-1111-220700**) were contracted to prepare a vehicle inventory baseline and analyze trends, and propose policy options for Uganda that would inform the National's fuel efficiency policy development.

1.2: Study Objectives, and Activities

1.2.1: Objectives

The key objective of the study was to prepare a vehicle inventory, vehicle import trend and establish the Uganda's national average fuel economy and trends. This information would then be used to compute carbon emission levels arising from automobile pollution. Information on vehicular emission would then be used to prepare policy recommendations to support import of cleaner and more efficient vehicles into Uganda.

1.2.2: Study Activities

The first activity was to carry out a vehicle inventory status in Uganda. The inventory provides the following data:

1. The stock of vehicles imported between 2000 and 2014 including both new and used;
2. The average vehicle age distribution of existing cars;

3. The different vehicle specifications, regarding vehicle model and make, engine size; technology, and any other relevant information that is useful in estimating carbon emission;
4. Fuel efficiency of the newly registered vehicle stock (second-hand and new) in 2005, 2008, 2011 and 2014;
5. Estimated carbon emission by fuel type of the vehicle and engine capacity category.

The second part of the study involves a review of government regulations and incentives to promote cleaner and fuel efficiency vehicles. Thirdly, to conduct a socio-economic analysis (cost-benefit analysis) of key policy interventions to promote fuel efficiency and carbon emission reduction by the different motor vehicle categories. The fourth activity entails providing policy recommendations that are aimed at reducing carbon emission such as regular vehicle inspection, fiscal incentives/disincentive programs, (taxation, fee-bates), traffic control policies, consumer awareness and other technologies.

2.0: BACKGROUND ON VEHICLE FUEL EFFICIENCY POLICIES AND REGULATIONS

2.1: Current Policies for Uganda

There is little documented about the current policy interventions being implemented to promote fuel efficiency (economy) in Uganda. This is largely because there is no national vehicle fuel economy policy in place currently. Nonetheless, the non-motorized transport policy 2012, and the draft Urban Transport policy (2014), contain a number of proposals for traffic management and safety, road quality and promotion of public transport, all of which if fully implemented would contribute to the vehicle fuel efficiency, particularly for motor vehicles within the capital City and other major towns. For instance, according to the Uganda Vision- 2040, at least 80% of Uganda freight transport will be carried by rail and the standard gauge rail will transport at least 10% of all persons for interurban and international trips by year 2040 (NPA 2010). The review of documents and consultations held with stakeholders revealed that there are a few interventions directly related to fuel efficiency. These include a 20% surcharge tax on vehicles older than 8 years; pre-shipment inspection and certification of vehicles for road worthiness and the control of heavy metals and carbons (Lead, Sulphur and Benzene) in gasoline and Diesel.

Starting from year 2011, there has been an initiative through UNEP, to introduce low sulphur diesel fuel in East Africa. Prior to 2011, the sulphur levels found in diesel in the East African region ranged between 5,000 parts per million (ppm) and 10,000 ppm, compared with that in developed countries (US and Europe) standards of 10-15 ppm. In 2011, UNEP supported the countries in the region and lowered the amount of sulphur allowed in diesel fuel from 5,000 ppm to 500 ppm. The target is to achieve 50 parts per million sulphur fuels standards effective

January 2015 (UNEP 2014). However, there is no documentation regarding the progress that has been made towards this goal.

Findings from this study have revealed that the 20 percent surcharge levied on automobiles that are older than 8 years at first registration has not been deterrent enough to the importation of older vehicles; therefore could be judged to be ineffective as an emission efficiency measure. This could be because the *cif* value of older vehicles is low relative to brand new cars and with the low national income per capita, the proportion of potential vehicle buyers/owners who can afford brand new vehicles is very small[1].

2.2: Proposed Interventions for Fuel Efficiency and Carbon Emission in Uganda.

2.2.1: Proposed Interventions for Fuel Efficiency and reduced Carbon Emission in Greater Kampala Metropolitan City

Although still in draft form, several interventions have been designed to reduce traffic congestion hence air pollution arising from motor vehicles. Among these include the following;

2.2.1.1: Promoting the Use of Non-Motorized Transport (NMT).

The Non-Motorized Policy 2012 clearly spells out the strategic objectives and actions required to promote cycling and pedestrian mode of transport within the City (KCCA, 2012). The objectives of this policy (also reflected in the Draft Urban Transport Policy) include:

1. Increasing the recognition of walking and cycling in transport, planning, design, and infrastructure provision;
2. Providing safe infrastructure for pedestrians and cyclists;

[1] The estimates in Tables 3 and 4 show that the average age of all privately owned vehicles imported between 2005 and 2014 ranged between 10 and 17 years.

3. Mainstreaming resources for walking and cycling in agencies' financial planning; Developing and adopting universal design standards that provide for access to all sectors of the community; and
4. Improving regulation and enforcement to enhance safety for pedestrians and cyclists.

Accordingly, government intends to increase the safe space available to NMT users through the consistent enforcement of existing regulations to prevent the encroachment of road shoulders and footways by constructions, stationary vehicles and informal trading enterprises. Government will also ensure that the needs of pedestrians and cyclists are adequately addressed in the planning, implementation, regulation and enforcement of roads and urban infrastructure in KCCA and GKMC. It is further expected that KCCA will promote the provision of adequate facilities for the safe parking of bicycles at public buildings, markets, transport terminals, hospitals, educational establishments, sports grounds, shopping malls and large business premises. Once implemented, this policy will lead to reduced use of motorized transport into the capital city, thereby improving the fuel efficiency ratings and emission reduction in the country.

2.2.1.2: Development of an Integrated Public Transport System

The draft Urban Transport Policy (2014) stipulates that government will, "develop a safe, affordable, fast, comfortable, reliable and sustainable public transport system with a strong mass transit network supplemented by other modes (pedestrian, cycling, minibus, bus, motor cycles commonly known as *boda-boda*) that meets the needs of various socio-economic and special interest groups in the GKMA". Under this model, government will encourage high capacity public transport systems, and raise the profile of walking, cycling, and public transport, and the benefits of these transport modes through the provision of information, facilities and active promotion to drive change in travel behaviour. Implementing this policy will translate into more people relying on public transport rather than driving their personal vehicles into the city on each travel, hence translating into personal and societal cost savings (fuel and environmental efficiency gains).

2.2.1.3: Equitable Allocation of Road Space with priority to Public Transport

Under this policy, government will ensure that priority (and preference) is given to, and right of way to public transport modes in terms of allocating time, space and facilities along transport corridors with high traffic flow volumes. By giving public transport vehicles priority lanes and preference at intersections in KCCA and KMTC, and allocation of parking space at terminal and public transport routes within the city, Use of public transport system would become more convenient and reduce proliferation of car use for trips to and from Kampala City. It is expected that as more travelers use public transport than personal cars and small omnibuses, fuel efficiency gains shall significantly increase.

2.2.1.4: Enhancement of Traffic Management and Safety

Traffic congestion within the city, especially during peak hours, is a major contributor of fuel inefficiencies, where motor vehicles stay in idling for long periods of time, emitting carbon-gases and consuming fuel unnecessarily. In addition, most roads in the City (and major towns in general) were designed and constructed without taking into account the needs of pedestrians and non-motorized vehicle (NMV) transport, and many still receive irregular and inadequate maintenance. These factors compound the fuel inefficiencies experienced in the City and major towns currently. Government plans to ensure the construction of ring-roads as provided by the KPDP, and flyovers in KCCA to replace the under capacity roundabouts to raise traffic flow speeds and a more smooth traffic flow (Republic of Uganda, 2012). The construction of ring-roads and flyovers, backed by regular effective road maintenance and enhanced implementation of traffic management measures will greatly improve fuel efficiency for all types of motor vehicles within the City.

2.2.2: Proposed Interventions by National Environmental Authority (NEMA)

The Environmental Legislation Act (2008) states that the owner or operator of a production or storage facility, motor vehicle, motorcycle or vessel has to take mitigation measures to control pollution, and the Authority has the powers to seize the polluting production facility, motor vehicle or vessel. The National Environment (Air Quality) draft regulations apply to any activity requiring a pollution licence under Section 58(4) of the Act. The regulations apply to any facility or process that discharges or is capable of discharging air pollutants into open air; and any activity which results in atmospheric emissions and which the Authority believes has or may have significant detrimental effect on the environment including health, social conditions, economic conditions, and ecological conditions.

The National Environment (Air Quality) regulations are to serve the purpose of; setting baseline parameters on air quality and emissions based on a number of practical considerations and acceptable limits, enforce the air quality standards, prescribe general measures for the control of air pollution in all areas including residential, commercial areas and industrial areas, and ensure protection of human health and the environment from various sources of air pollution. It further states that all individuals shall be required to comply with the minimum air quality standards prescribed in these regulations.

The regulations also provide that any person who undertakes an activity likely to pollute the air shall be required to comply with the highest permissible quantity of emission of sulphur oxides, carbon monoxide, hydrocarbon as total organic carbon, dust, nitrogen oxides or lead released into the atmosphere from a pollution source and test methods prescribed under the second schedule to these Regulation.

Our review shows that there is very little regulation on fuel efficiency within the existing environmental and air quality legislations. However, with specific reference to motor vehicles, the regulations provide that: Every automobile (motor vehicle or motorcycle) to be imported or registered on or after the coming into force of these regulations shall conform to the standard of exhaust emission specified in these regulations.

2.2.3: Intervention by Ministry of Works and Transport

The MoW&T has contracted a company that shall carry out a mandatory periodic inspection on all automobiles for both road worthiness and public service worthiness, irrespective of ownership with exception of where exemptions apply. All private automobiles are to be exempted from the mandatory inspections for four years from the date of first registration regardless of the country of registration. Public service vehicles, private omnibuses, trailers and goods vehicles shall be inspected before getting licenses; while motorcycles shall be subjected to the mandatory inspections one year after first registration regardless of the country of first registration. They shall setup different test stations which will include; motorcycle test stations, light vehicle test stations and heavy vehicle test stations. The test stations shall entail semi-automated or fully automated inspection procedures. The inspection is to follow the inspection standards set by UNBS.

2.3: A Review of Fuel Efficiency Policies in other Countries

Whereas the range of policies being implemented in Uganda to promote fuel efficiency is limited, the review of literature shows that a number of policies are being implemented in different forms, especially in the developed and middle income countries. They include: regulatory policies such as import restrictions on used (second hand) vehicles; ban on diesel passenger car imports; and varying registration fees based on type of vehicles (brand new versus used or fuel type and engine capacity). Others are Vehicle inspections[2] and use of catalytic converters. A summary of the vehicle fuel efficiency interventions implemented in different settings, mostly in developed countries, is given in the box below.

[2] Inspection involves; vehicle identification, braking equipment, steering, visibility, lighting equipment and parts of electric system; axles, wheels, tyres and suspension, chassis and chassis attachments. Others are other equipment – safety belts, fire extinguisher, locks and anti-theft device, warning, triangle, first-aid kit, speedometer, etc; nuisance – noise, exhaust emissions, etc; supplementary tests for public transport vehicles – emergency exit(s), heating and ventilation systems, seat layout, interior lighting;

Table 1: Fuel efficiency interventions in developed countries

Approach		Measures/forms	Country/region
Standards	Fuel economy	Numeric standard averaged over fleets or based on vehicle weight-bins or sub-classes	US, Japan, Canada, Australia, China, Republic of Korea
	GHG emissions	Grams/km or grams/mile	European Union (EU), California (US)
Consumer Awareness	Fuel Economy/GHG emission labels	mpg, km/L, L/100 km, gCO_2/km	Brazil, Chile, Repubic of Korea, US and others
Fiscal Incentives	High fuel taxes	Fuel taxes at least 50% greater than crude price	EU, Japan
	Differential vehicle fees and taxes	Tax or registration fee based on engine size, efficiency & CO_2 emissions	EU, Japan, China
	Economic penalties	Gas guzzler tax	US
Support for new technologies	R&D programmes	Funding for advanced technology research	US, Japan, EU, China
	Technology mandates and targets	Sales requirement for Zero Emission Vehicles (ZEVs), PHEVs and EVs	California (US), China
Traffic control measures	Incentives	Allowing hybrids to use high occupancy vehicle (HOV) lanes	California, Virginia and others states in the US
	Disincentives	Banning SUVs on City Streets Inner city congestion charges	Paris, London

Source: Adapted from Table 1 of Feng An and Amanda Sauer (2004) (updated). Comparison of Passenger Vehicle Fuel Economy Standards and GHG Emission Standards around the World.

There are also fiscal incentive programmes aimed at improving fuel economy, especially when implemented in combination with standards. Incentives can be directed at improving the efficiency of the vehicle fleet, through variable registration fees or taxes, or by limiting vehicle use, through fuel taxes and road user fees (Feng et al 2011). Likewise, traffic control measures have been used in different settings, and these include priority lanes, parking restrictions and road pricing. For example, Brazil has banned importation of used vehicles[3] and diesel passenger car imports (Brazil's Developing Automotive Fuel Economy Policy, 2012). There is evidence

[3] Brazil currently manufactures motor vehicles and total ban of used vehicles also serves to promote the local industry.

that new cars are potentially high fuel efficient. For example, the Indian Tata Nano new model has been certified at 4.24 L/100km (4.55 L/100km in the city and 3.85 L/ 100km highway) which is a consumption rate 28% lower than the 2008 estimated average of 5.86 L/100 km (India's Developing Automotive Fuel Economy Policy, 2012). Likewise, there is a program that obliges each car to be kept off the street within the capital (São Paulo), during rush hour for one day each week. There are also special bus lanes that help public transport move more easily. Car manufacturers in Brazil have also implemented a labeling system for cars which informs consumers about the fuel efficiency of the new vehicles they might purchase. There are also restrictions on use of 100% gasoline. Recommended fuels used are 22 percent ethanol (E-22), 100 percent ethanol (E-100), and a mixture of any blend of ethanol and gasoline from 22 percent ethanol to 100 percent ethanol (E22/E-100).

Studies on fuel efficiency in India show a range of strategies that have been adopted and their impact in improving fuel efficiency overtime. For instance, only second hand vehicles not older than three years from the date of manufacturer are allowed into the country. In addition, such vehicles should have a minimum roadworthiness for a period of 5 years from the date of being brought into the country (India's DAFEP, 2012). Besides being less than 3 year old, second hand cars are subjected to testing by the Automotive Research Association of India or an agency appointed by the central government. In order to address the need for fuel efficiency of vehicles in India, an excise rate of 12 percent is imposed on small cars as opposed to 24 percent on bigger cars. This tax differential makes small cars, which are more fuel efficient, cheaper and more desirable. India, also subsidizes diesel fuel and the share of diesel vehicles in the new car market is growing rapidly. By 2013, 1/3 of passenger vehicles were diesel (GoI, 2004). Due to the subsidy, diesel fuel is 33% cheaper than petrol (about 41 v. 64 Rs./Liter; GoI, 2014). Other measures implemented in India since 2003 include improving the quality of gasoline by reducing the Lead, sulphur and Benzene content in the gasoline. Similar improvements in the quality of diesel have been pursued. The 2012 report of an expert committee on Fuel economy in India shows that over the period 2003-2012, the Sulphur and Benzene content in gasoline used had reduced by 50 percent and 80 percent respectively, while lead content in gasoline was phased out in 6 years following the Auto fuel policy 2003 legislation (GoI, 2014).

In summary, the range of policies option available for Uganda to promote vehicle fuel efficiency include: regulatory policies, fiscal-related incentives/disincentives, and traffic control measures. However, the implementation of these policies depends on the level of technology, the level of the infrastructure (e.g. road network) and the institutional capacity for enforcement of these policies.

3.0: AUTOMOBILE INVENTORY, FUEL ECONOMY & CO_2 EMISSION

3.1: Automobile Inventory

The data on automobiles (vehicles and motorcycles) imported into Uganda are captured by three different agencies; namely: URA (for privately-owned automobiles), and Ministry of Works and Transport (MoW&T-for state owned automobiles) and Ministry of Defense (armored vehicles). A complete national vehicle inventory would constitute all vehicles and motorcycles coming through the three channels, but the study is based on data collected from URA and MoW&T.

Data obtained from URA contained 815,382 automobiles (vehicles and motorcycles) imported between the period 2000 and 2014. Automobile data at URA are captured under both the e-tax and customs records. Initial analysis of datasets from these sources revealed that there were multiple entries (in e-tax and customs data sources) based on the chassis number and engine numbers, which are the unique identifiers for any automobile. However, the combined dataset (from e-tax and customs records) did not have all the variables required for fuel efficiency and CO_2 analysis, and also included trailers which we had to exclude from the analysis since they do not emit nor consume fuel. The e-tax dataset[4] (of 416,412 automobiles) which contained most of the variables of interest for this study, while the database from MoW&T included 24,848 automobiles imported over the period 2000 - 2014. After combining URA e-tax data with MoW&T, data cleaning and editing, we obtained an inventory of 441,260 automobiles (both vehicles and motorcycles). It appears that the switch to the e-tax system and computer-based recording of imported vehicles could have led to loss of data, but it was not possible to verify the

[4] The e-tax dataset is a collection of validated automobiles and newly registered automobiles dating 2012 – 2014.

particular source of anomaly with URA. Table1 gives a summary of the vehicle inventory at registration.

Table 2 Vehicle Inventory by status at Registration: 2000-2014

Year of Registration	**DIESEL**				**PETROL**			
	New	**Old**	**Total**	**New as % of total**	**New**	**Old**	**Total**	**New as % of total**
2000	533	254	787	**67.7**	295	367	662	**44.6**
2001	676	391	1,067	**63.4**	297	502	799	**37.2**
2002	788	520	1,308	**60.2**	252	634	886	**28.4**
2003	850	678	1,528	**55.6**	268	769	1,037	**25.8**
2004	973	942	1,915	**50.8**	345	1,245	1,590	**21.7**
2005	1,042	1,227	2,269	**45.9**	392	2,071	2,463	**15.9**
2006	1,218	1,543	2,761	**44.1**	379	2,308	2,687	**14.1**
2007	1,540	2,306	3,846	**40.0**	474	3,557	4,031	**11.8**
2008	1,723	3,034	4,757	**36.2**	434	4,449	4,883	**8.9**
2009	1,510	3,354	4,864	**31.0**	380	5,007	5,387	**7.1**
2010	1,476	3,632	5,108	**28.9**	399	6,939	7,338	**5.4**
2011	2,507	3,274	5,781	**43.4**	350	7,404	7,754	**4.5**
2012	3,206	5,029	8,235	**38.9**	578	13,624	14,202	**4.1**
2013	4,848	12,620	17,468	**27.8**	967	28,770	29,737	**3.3**
2014	5,881	18,176	24,057	**24.4**	1,094	39,405	40,499	**2.7**
Total	**28771**	**56980**	**85751**	**33.6**	**6904**	**117051**	**123955**	**5.6**

Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

From Table 2 above, we note that only 33.6% of diesel vehicles registered by URA and MoW&T are new[5] compared with only 5.6% of petrol registered vehicles for the period 2000 - 2014. Also 59.1% of the vehicle fleet, use petrol (i.e. ratio of petrol fleet to total fleet). We found that the percentage of new vehicles to the total fleet imported by each year of registration dropped from 67.7 to 24.4 percent and 44.6 to 2.7 percent from 2000 to 2014 for Diesel and Petrol vehicle fleet respectively.

[5] According to URA definition, a vehicle is new if at registration, its age from the date of manufacture is less than eight years.

3.2: Vehicle Distribution by Engine Capacity

The distribution of vehicles by vehicle weight, engine capacity and status at registration was assessed and is presented in Table 3.

Table 3 Vehicle Inventory by Engine Capacity and Status at Registration

Category	Engine_CC	DIESEL				PETROL			
		NEW	OLD	Total	New as % of total	NEW	OLD	Total	New as % of total
Light Duty Vehicles[6]	500_1200CC	77	130	207	37.2	160	4457	4617	3.5
	1201_1500CC	69	121	190	36.3	1412	19188	20600	6.9
	1501_2000CC	313	1185	1498	20.9	2589	75355	77944	3.3
	2001_2500CC	5930	3815	9745	60.9	994	7073	8067	12.3
	2501_3000CC	7055	20871	27926	25.3	625	7849	8474	7.4
	3001_3500CC	2523	1740	4263	59.2	378	1961	2339	16.2
	Sub total	***15967***	***27862***	***43829***	***36.4***	***6158***	***115883***	***122041***	***5.04***
Heavy Duty vehicles[7]	3501_4000CC	1075	7902	8977	12	290	478	768	37.8
	4001_5000CC	3810	5539	9349	40.8	343	652	995	34.5
	>5000CC	7919	15677	23596	33.6	113	38	151	74.8
	Sub total	***12804***	***29118***	***41922***	***30.5424***	***746***	***1168***	***1914***	***38.976***
	Grand Total	**28771**	**56980**	**85751**	**33.6**	**6904**	**117051**	**123955**	**5.6**

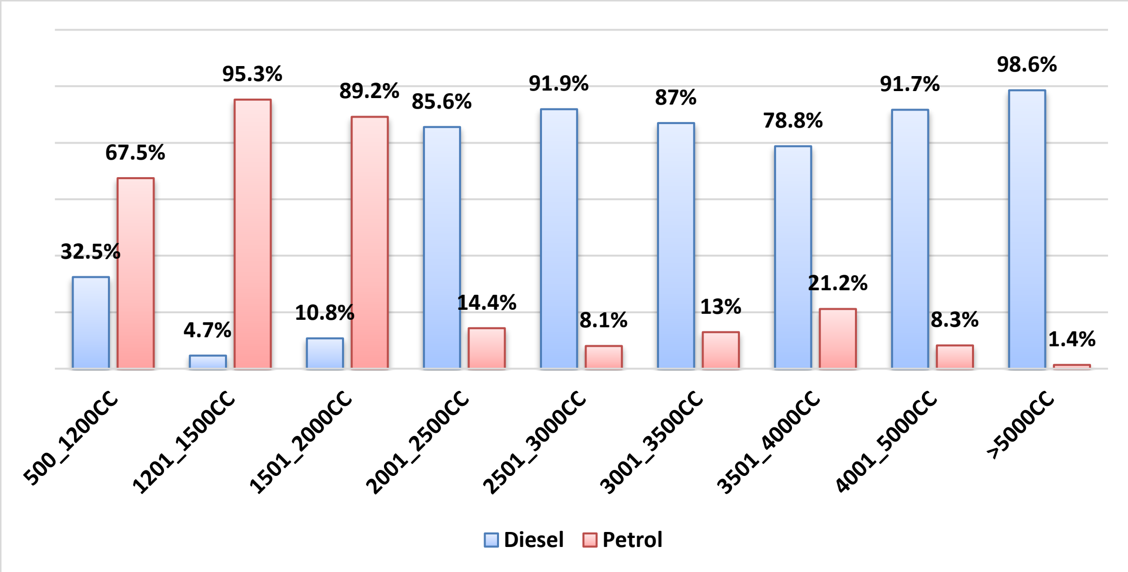
Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

From Table 3, we observe that 36.4 percent of LDV's using diesel are new on first registration while those using petrol are only 5 percent. We have noticed in table 3, that most of the LDV automobiles use petrol fuel (ie. 73.6 percent). Higher percentages of new vehicles which use diesel fuel come in capacities of 2001_2500CC and 3001_3500CC where the new vehicles supersede the old ones. We also note that most vehicles that use petrol in the capacity of >5000CC are new.

---

[6] Light Duty Vehicles (LDV) are vehicles that weigh 3500kgs.
[7] Heavy Duty Vehicles (HDV) are vehicles that weigh over 3500kgs.

Figure 1: Distribution of New Vehicles by Fuel Type and Engine Capacity.



Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

From figure1 above, majority of the new vehicles that use petrol are of lower engine capacity i.e. <500CC – 2000CC; while the majority of new vehicles that use diesel vehicles are of higher engine capacity (i.e. >2000CC).

3.3: Age Distribution of Vehicles

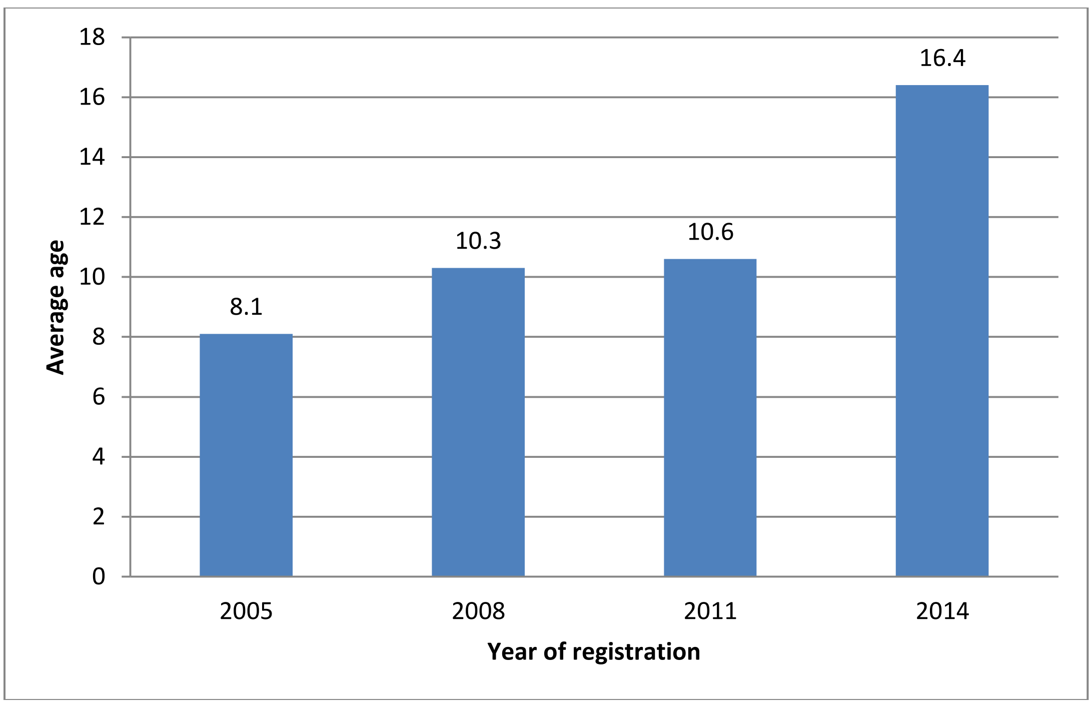
The age distribution of existing vehicles by engine capacity was assessed to provide insights into the implications of a regulatory policy on age of vehicles imported into the country. Table4 shows the average age of vehicles by engine capacity and fuel type registered in the years; 2005, 2008, 2011 and 2014, which are the data points used in computing the fuel efficiency and CO_2 emissions. Illustrations are presented in figures 2 and 3 for diesel and petrol fleet respectively.

Table 4: Average Age and Engine capacity by Fuel type and year of Registration

Engine_CC	Diesel				Petrol			
	2005	2008	2011	2014	2005	2008	2011	2014
500_1200CC	14.0		6.4	16.1	13.5	11.9	14.3	16.3
1201_1500CC	12.0	8.0	5.0	14.8	10.8	12.4	13.1	15.8
1501_2000CC	8.8	13.5	17.1	18.5	10.4	11.9	13.1	15.7
2001_2500CC	9.3	6.5	3.9	8.6	7.3	8.6	11.3	13.6
2501_3000CC	5.8	9.3	11.1	16.6	9.2	9.9	12.5	14.7
3001_3500CC	4.1	5.4	6.3	15.8	4.5	9.5	11.6	13.5
3501_4000CC	14.2	17.9	20.5	22.7	11.0	8.5	7.0	11.2
4001_5000CC	7.7	8.1	8.9	16.2	4.8	7.8	10.4	12.3
>5000CC	9.6	12.8	12.0	15.9	4.0	8.8	8.6	6.3
Total ave. age	**8.1**	**10.3**	**10.6**	**16.4**	**10.4**	**11.7**	**12.8**	**15.4**

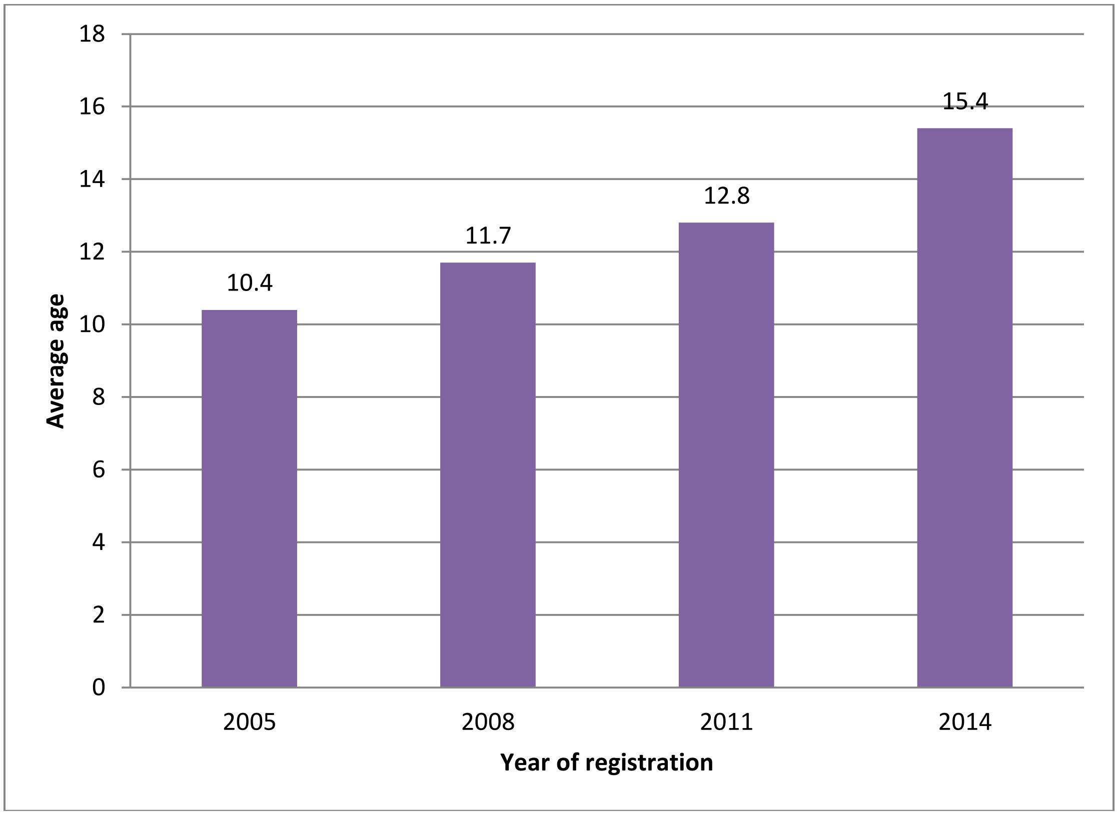
Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

Figure 2: Average age of Diesel vehicles



Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

Figure 3: Average age of Petrol engine vehicles



Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

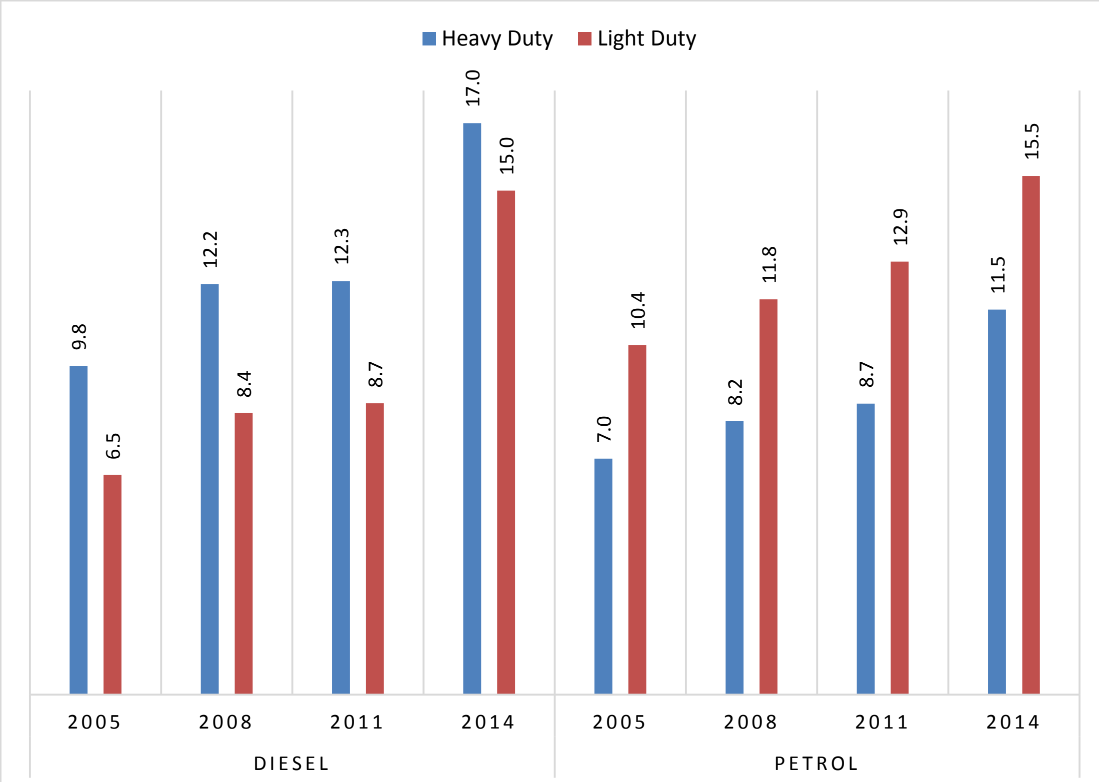
An analysis by weight category did show that most light duties have also been coming in new especially the ones that use Diesel fuel, compared to those using petrol fuel as presented in table 5 below. An illustration is presented in figure 4 below.

Table 5: Average Age and category by Fuel type and year of Registration

	Diesel				Petrol			
Weight Category	**2005**	**2008**	**2011**	**2014**	**2005**	**2008**	**2011**	**2014**
Heavy Duty	9.8	12.2	12.3	17.0	7.0	8.2	8.7	11.5
Light Duty	6.5	8.4	8.7	15.0	10.4	11.8	12.9	15.5
Grand Average	**8.1**	**10.2**	**10.5**	**16.4**	**10.4**	**11.7**	**12.8**	**15.4**

Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

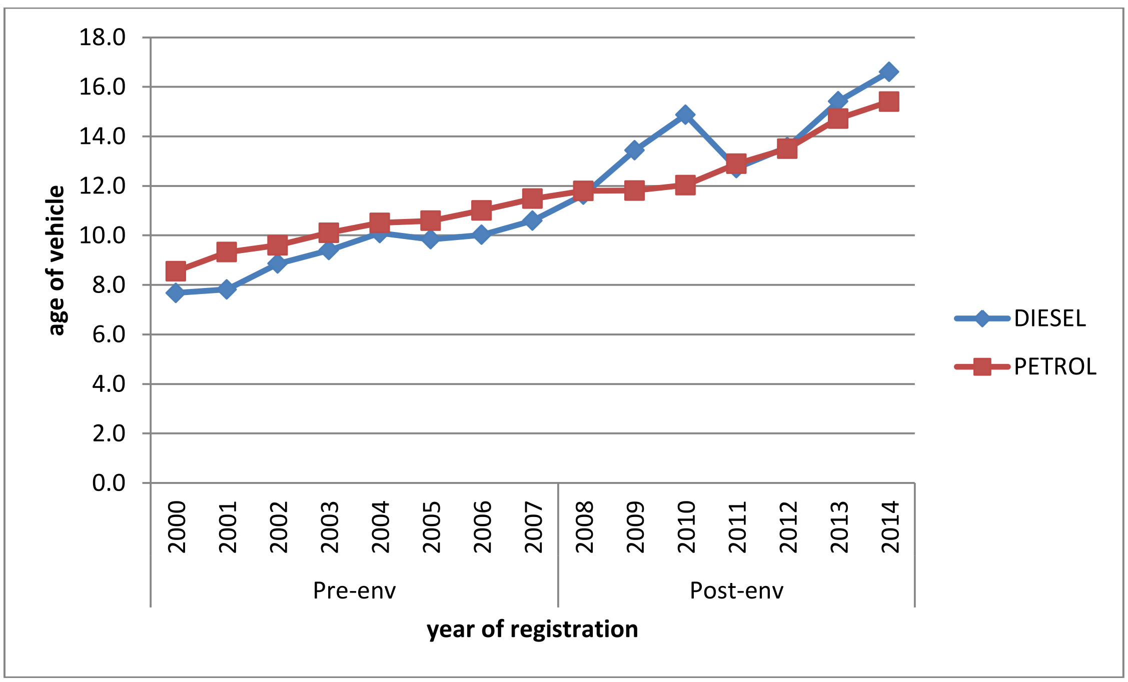
Figure 4: Average age of vehicles by weight category.



Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

From Table 4, table 5 and figure 3 below; we notice that despite the imposition of the environmental tax by URA in 2008, the average age has been worsening for all categories of engine capacity. Over the time, the average age of diesel vehicles has been increasing from 8.1 years in 2005 to 16.4 years in 2014. Similarly the average age of petrol vehicles increased from 10.4 years to 15.4 years over the same period. The relatively high age of vehicle at registration is of concern to promoting fuel economy national policy, since older cars for any engine capacity and vehicle technology consume more fuel and hence emit more CO_2 per kilometer. This in one way attempts to suggest that the objective of the 20% environmental tax imposed on old vehicles (ie vehicles first registered at age greater than 8 years), that was aimed at discouraging importation of old vehicles has not been realized instead it is the case of "*bad goods driving good ones out of the market*." This however has a serious negative implication on carbon emission. One major weakness of a flat environmental tax for instance the current 20% on the value of the vehicle irrespective of age, is that older vehicles have a lower value hence carry a lower charge, accordingly their purchase price is low; and the reverse is true for newer versions; they are of a higher value and they fetch a higher environmental fee hence making their purchase price to rise. For that matter most of the consumers would opt to purchase older cheaper vehicles instead of the newer ones.

Figure 5: Average age and environmental levy



Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

3.4: Vehicle Fuel Economy and CO_2 Emissions

The fuel economy and CO_2 emission computations were based on the GFEI methodology. Using 2005 as the baseline year, (as the GFEI preferred year of reference for ease of comparison with estimates from other countries), average fuel efficiency rates (L/100 Km) and CO_2 emission rates (gCO_2/Km) were computed for vehicles registered in 2005, 2008, 2011 & 2014, and estimates compared with those in the base year. The vehicle fuel economy ratios are computed by fuel type and engine capacity. The vehicle database reports data on engine capacity in cubic centimeter (cc), horsepower (HP) or Kilowatts (KW). Since CC is displacement and HP as well as KW are for power output, observations transformed into displacement for analysis. Using appropriate conversion factor[8], engine rates were converted to cc measure. The engine capacity were categorized into 9 sub-groups (500cc -1200cc, 1201cc – 1500cc, 1501 – 2000cc, 2001cc - 2500cc, 2501cc – 3000cc, 3001cc – 3500cc, 3501cc – 4000cc, 4001cc -5000cc and > 5000cc). Vehicles with engine capacity in each range are assumed to exhibit similar fuel efficiency and CO_2 emission rates and therefore comparable for the required computations.

According to the GFEI guidelines the key variables for the fuel economy and CO_2 emission computations include;

1. Vehicle make and model
2. Model production year
3. Year of first registration, if different from model year
4. Fuel type
5. Engine size

[8] 1HP = 0.7457 kW = 17 cc (source: http://www.rapidtables.com/convert/power/kw-to-hp.htm)

6. Domestically produced or imported

7. New or second hand import

8. Rated Fuel Economy per model and test cycle basis.

9. Number of sales by model

However, the data obtained from URA and MoW&T on vehicle inventory did not have *Rated Fuel Economy per model, and Test Cycle*. To obtain estimates for fuel economy, we relied on information from manufacturers available on websites for some model and information available from the GFEI recommended websites.[9] We also contacted reputable motor garages and local automobile franchises (e.g. Toyota, Mantrac, Delta, TATA, Bajaj, TVS, Victoria Motors, Motor Care, Cooper Motors Cooperation, and Mahindra). We then used these estimates to compute CO_2 emission (C_i) for particular vehicle categories. Total sales were directly derived from the vehicle inventory for each particular year as reported in the URA and MoW&T database, albeit for only those observations with complete data on key variables. Vehicle fuel economy is expressed in terms of liters of gasoline per 100 kilometers of travel (L/100km) and automobile GHG emission in grams per kilometer (gCO2/km).

3.5: Methodology

3.5.1: Modeling the Relationship between Age of Vehicle, and Fuel efficiency

We used empirical studies to model the relationship between age of a vehicle and its related fuel efficiency ratios. The level of vehicle emissions and fuel efficiency, are related to the age of the vehicle either linearly or exponentially. A decreasing exponential model as used by Rajbahak, *et al* (2011), was considered for the baseline survey in order to estimate the level of fuel efficiency

[9] http://www.epa.gov/fueleconomy/gas-label-1.htm; http://www.carfolio.com/specifications/models; www.edmunds.com/toyota; http://www.naamsa.co.za/ecelabels/; http://www.totalmotorcycle.com/MotorcycleFuelEconomyGuide;

when the units are first registered in Uganda. The model, shows that the fuel efficiency of an automobile decreases exponentially with time. The rate of decrease, $\boldsymbol{\delta}$ depends on various factors such as maintenance, type of fuel, engine capacity among others. The exponential decline is proportional to a fractional power, δ of the usage rate; thus

$$F_\mu = F_0 e^{-\delta A}$$

where;

F_μ = Modelled fuel efficiency of the automobile that incorporates age

F_0 =Fuel Efficiency when the automobile is new. This is known from automobile manufactures,

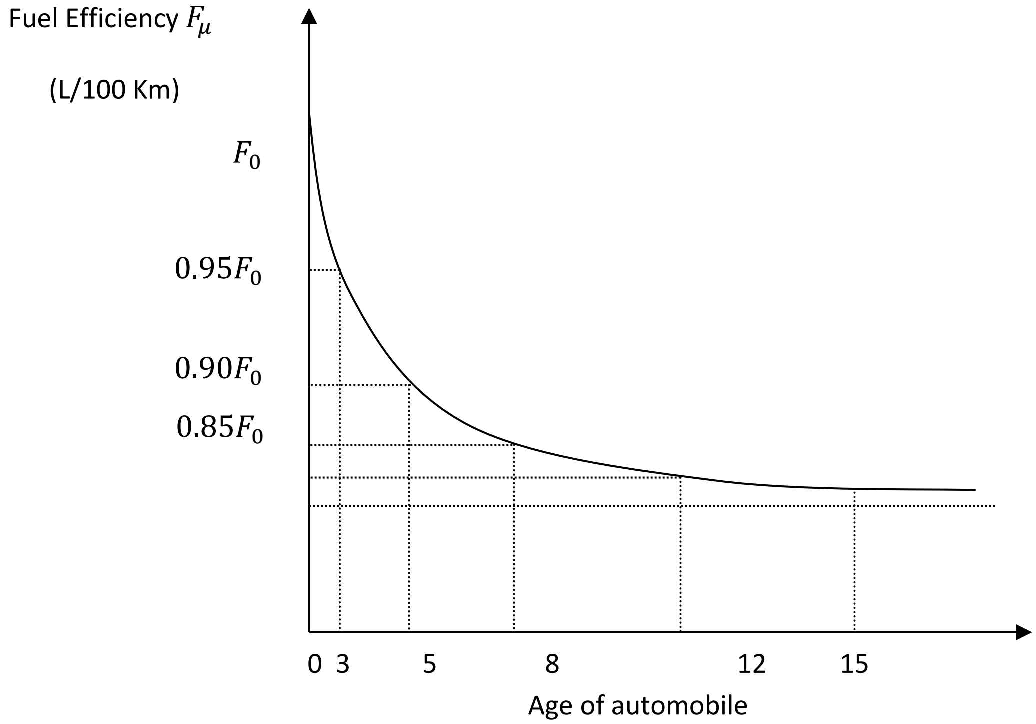
δ = Decreasing rate factor; $0 < \delta < 1$

A = Age of the automobile unit

Fuel efficiency $\boldsymbol{F_0}$ estimates for a particular vehicle segmentation and fuel type were obtained by contacting local automobile franchise (i.e. Toyota, Mantrac, Delta, TATA, Bajaj, TVS, Victoria Motors, Motor Care, Cooper Motors Cooperation, and Mahindra) to provide information on their products' fuel efficiency and from information available from the GFEI recommended websites[10]. Figure 5 shows the relationship between fuel efficiency and age of automobile.

[10] http://www.epa.gov/fueleconomy/gas-label-1.htm; http://www.carfolio.com/specifications/models; www.edmunds.com/toyota; http://www.naamsa.co.za/ecelabels/; http://www.totalmotorcycle.com/MotorcycleFuelEconomyGuide;

Figure 6: Relation between Fuel Efficiency and Age of vehicle



The computed values of $\boldsymbol{\delta}$ that were considered in our study in order to adjust the fuel efficiency of the imported used automobiles were as follows:

For $0 < A \leq 3$, δ = 0.017097764
For $3 < A \leq 5$, δ = 0.021072103
For $5 < A \leq 8$, δ = 0.020314866
For $8 < A \leq 10$, δ = 0.022314355
For $10 < A \leq 15$, δ = 0.019178804
For $A > 15$, δ = 0.023778329

The fuel economy computations are based on the harmonic annual average as per GFEI tool kit and NEDC and the methodology has been included in the appendix. The average annual fuel economy for each year (2005, 2008, 2011 and 2014) is computed as follows:

$$Harmonic\ Average\ Annual\ Fuel\ Economy = \frac{TS_y}{\sum_{i=1}^{n}\frac{SVS_i}{FE_i}}$$

Where;

TS_y = Total Sales (Vehicles *Registered by URA & MoW&T*) in a given year

SVS_i = Sales for a Particular Vehicle Segmentation and Fuel type

FE_i = Fuel Economy for a Particular Vehicle Segmentation and Fuel type

3.6.2: Carbon dioxide (CO_2) Emission Computations

The CO_2 emission rates are based on the annual weighted average emission per segment for petrol and diesel vehicles and estimated for the years 2005, 2008, 2011 and 2014.

$$Average\ Annual\ CO_2\ Emission = \frac{\sum_1^n SVS_i * C_i}{TS_y}$$

where;

TS_y = Total Sales (Vehicles *Registered by URA & MoW&T*) in a given year

SVS_i = Sales for a Particular Vehicle Segmentation and Fuel type

C_i = CO_2 Emission for a Particular Vehicle Segmentation and Fuel type

The fuel economy estimates used in the above formulae were estimated from the model, generated above. Total sales are directly derived from the vehicle inventory for each particular year as reported in the URA and MoW&T database, albeit for only those observations with complete data on key variables. Vehicle fuel economy is expressed in terms of liters of fuel per 100 kilometers of travel (L/100km) and automobile GHG emission in grams per kilometer (gCO2/km). Estimates of the annual average fuel efficiency for petrol and diesel vehicles are presented in Tables 4 and 5 respectively.

3.7: Results of Harmonic fuel efficiency and carbon-dioxide emissions.

3.7.1 Results of Harmonic fuel efficiency of vehicle fleet.

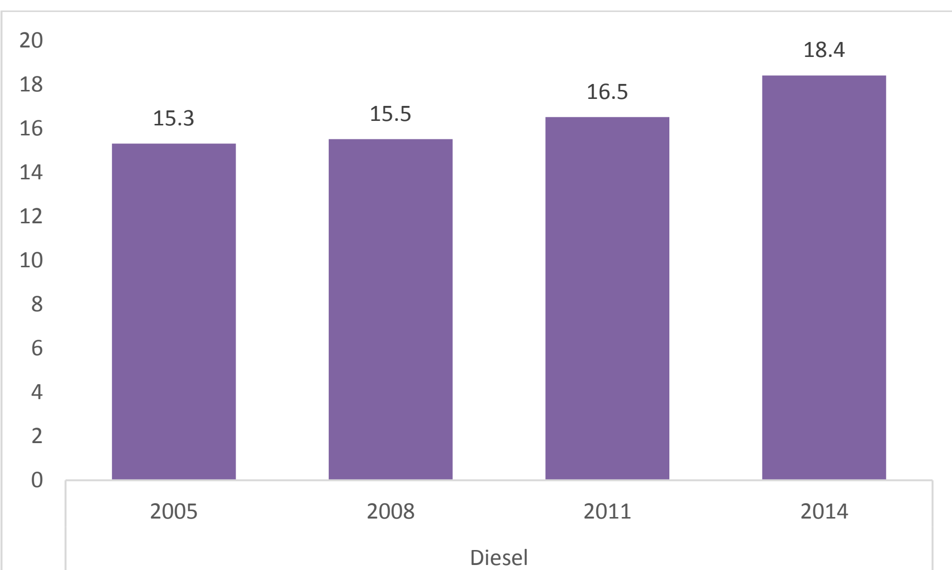
Table 6 below, shows that the fuel efficiency has been declining over the years in both LDV's and HDV's, where it was estimated at 11.6 L/100Km in 2005 and later increased to 13.4 L/100Km in 2014 for LDV diesel fleet, similarly for the LDV petrol fleet the fuel efficiency increased but not by a big margin as it was for the diesel fleet, here it increased from 10.6 L/100Km in 2005 to 11.8 L/100Km in 2014. Same situation has been presented for HDV's. The general trends have been presented in figure 7, 8 and 9 below.

Table 6: Average Fuel Efficiency (L/100Km) by weight category and Year of Registration and fuel type

Weight Category	Diesel				Petrol			
	2005	2008	2011	2014	2005	2008	2011	2014
Light Duty	11.6	11.7	11.9	13.4	10.6	10.8	11.1	11.8
Heavy Duty	24.2	24.9	27.7	29.3	22.2	21.4	21.5	22.9
Total average	**15.3**	**15.5**	**16.5**	**18.4**	**10.7**	**10.9**	**11.2**	**11.9**

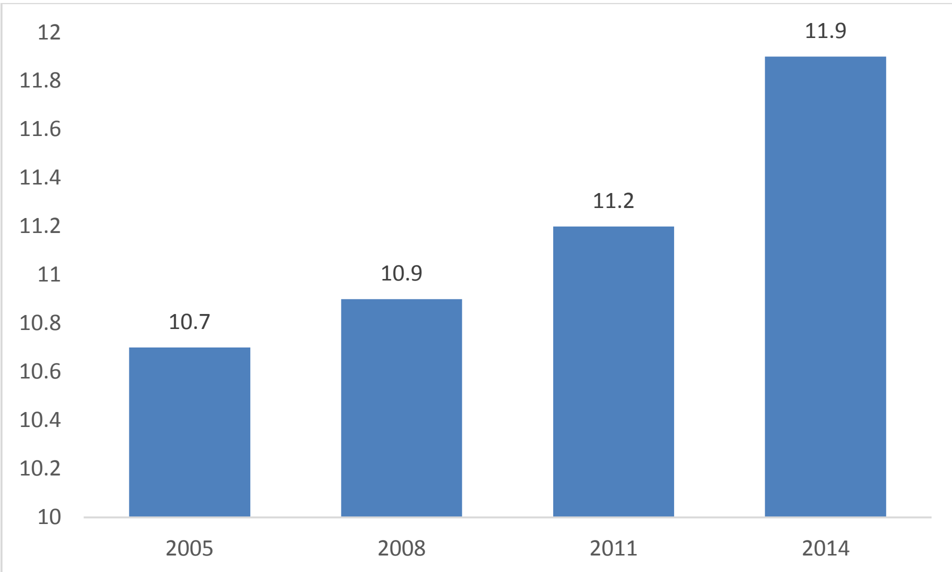
Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

Figure 7; Average fuel efficiency (L/100Km) for Diesel fleet.



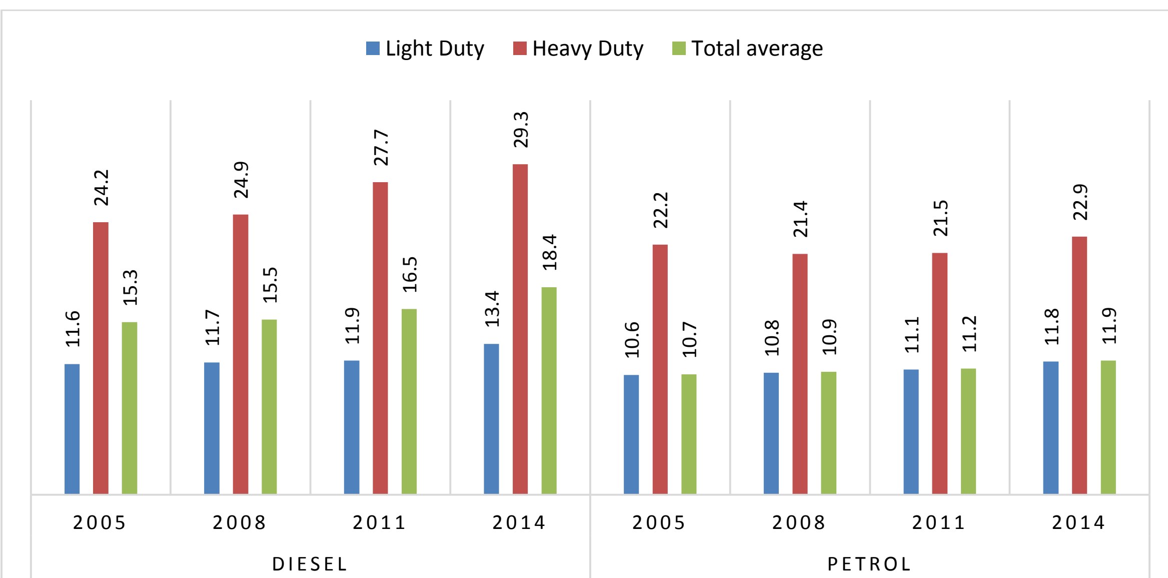
Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

Figure 8: Average fuel efficiency (L/100Km) for Petrol fleet.



Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

Figure 9: Average Fuel Efficiency (L/100Km) by weight category and Year of Registration and fuel type.



Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

3.7.2; Results of Harmonic fuel efficiency of vehicle fleet.

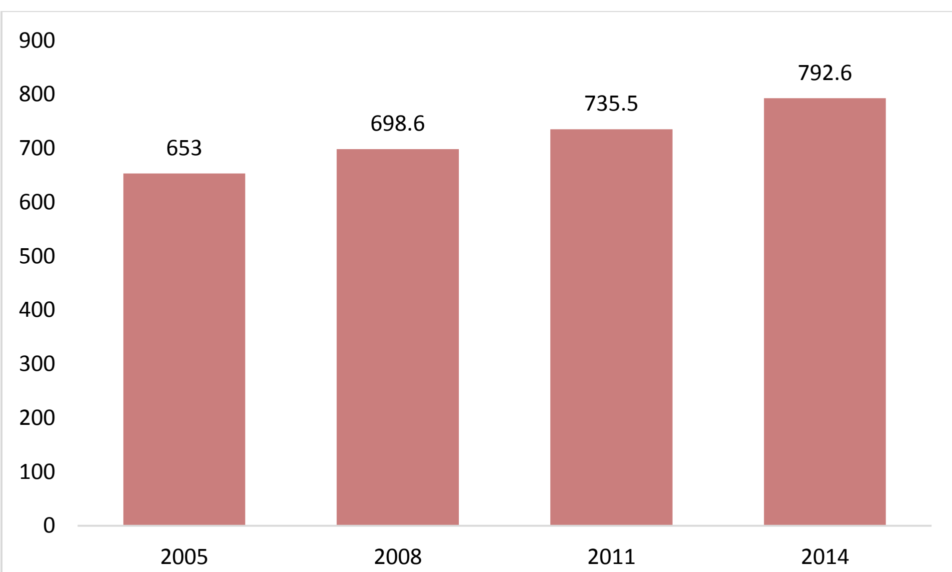
From the figures presented in table 7, diesel fleet averagely pollute more than petrol fleet irrespective of the weight. But the amount of smoke greatly increases with weight this is because even the fuel efficiency increases. The average carbon-dioxide emission has increased from 653 gCO_2/Km in 2005 to 792.6 gCO_2/Km in 2014 for diesel fleet. The carbon-dioxide emission for petrol fleet has also increased from 291.8 gCO_2/Km in 2005 to 331 gCO_2/Km in 2014. The figures have been presented graphically in figure 10, 11 and 12.

Table 7: Average carbon-dioxide emissions by fuel type and year of registration.

	DIESEL				PETROL			
Category	**2005**	**2008**	**2011**	**2014**	**2005**	**2008**	**2011**	**2014**
Light Duty	363.2	367.6	376.8	431.0	287.9	294.6	304.5	325.2
Heavy Duty	986.0	1083.0	1116.7	1149.8	649.2	640.7	692.0	716.5
Grand Total	**653.0**	**698.6**	**735.5**	**792.6**	**291.8**	**300.6**	**311.2**	**331.0**

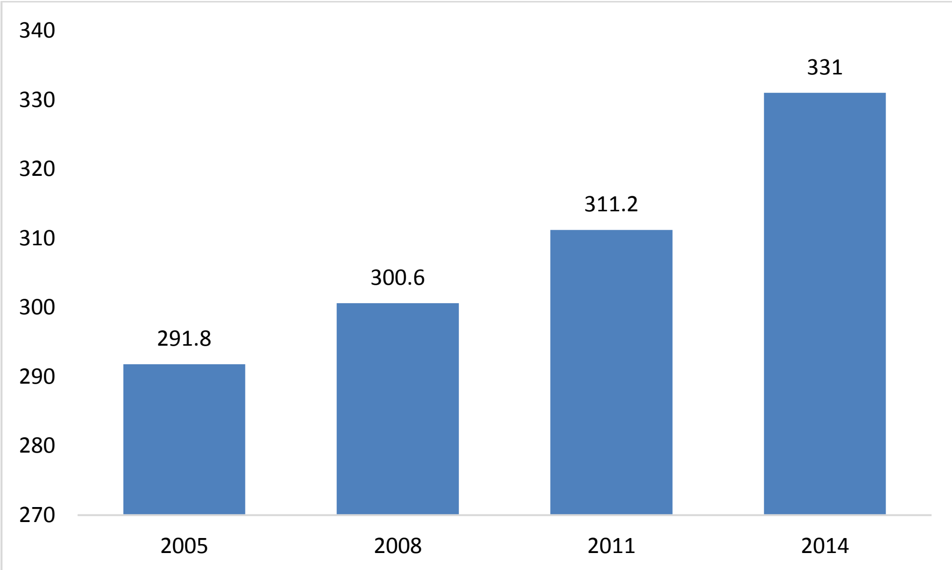
Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

Figure 10: Average carbon-dioxide emissions of diesel fleet.



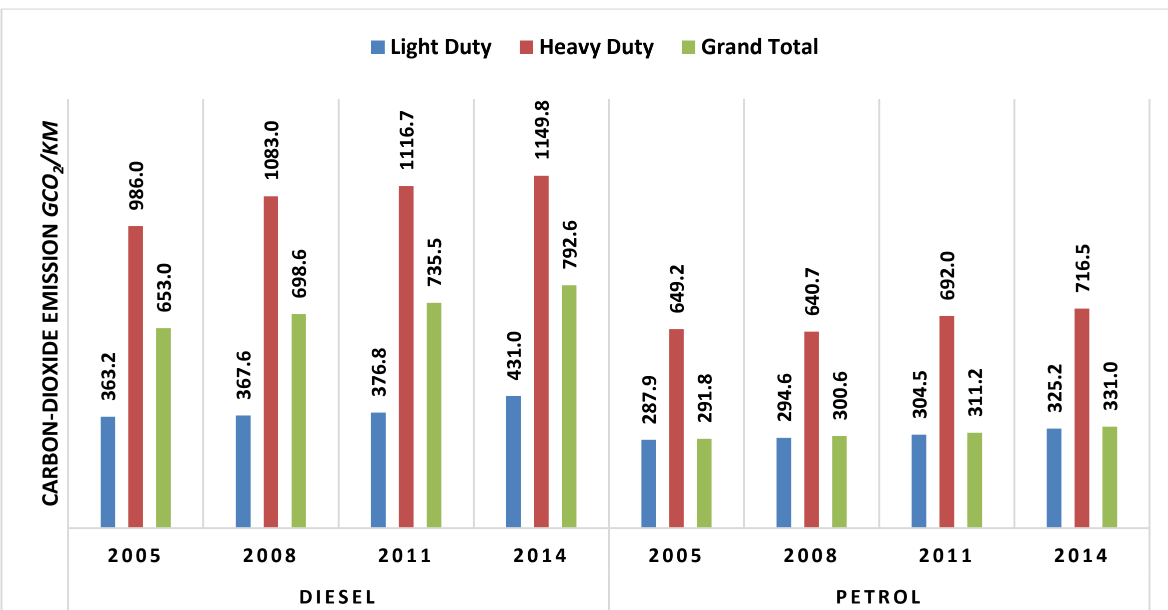
Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

Figure 11: Average carbon-dioxide emissions for petrol fleet.



Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

Figure 12: Average carbon-dioxide emission (gCO_2/Km) by weight category and Year of Registration and fuel type.



Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

We examined annual harmonic fuel efficiency trend and the results are presented in table 8 below. These figures have been presented for the LDV and HDV fleet registered in the period 2005, 2008, 2011 and 2014. The harmonic fuel efficiency has been steadily increasing in both LDV's and HDV's from 10.94 L/100Km and 24.3 L/100Km in 2005 to 12.15 L/100Km and 29.1 L/100Km for LDV and HDV fleet respectively. In the general perspective the annual harmonic fuel efficiency has increased from 12.52 L/100Km in 2005 to 13.73 L/100Km in 2014. Corresponding graphical expression have been presented in figures 13, 14 and 15 showing the trend of fuel efficiency over the years of interest (ie 2005, 2008, 2011 and 2014).

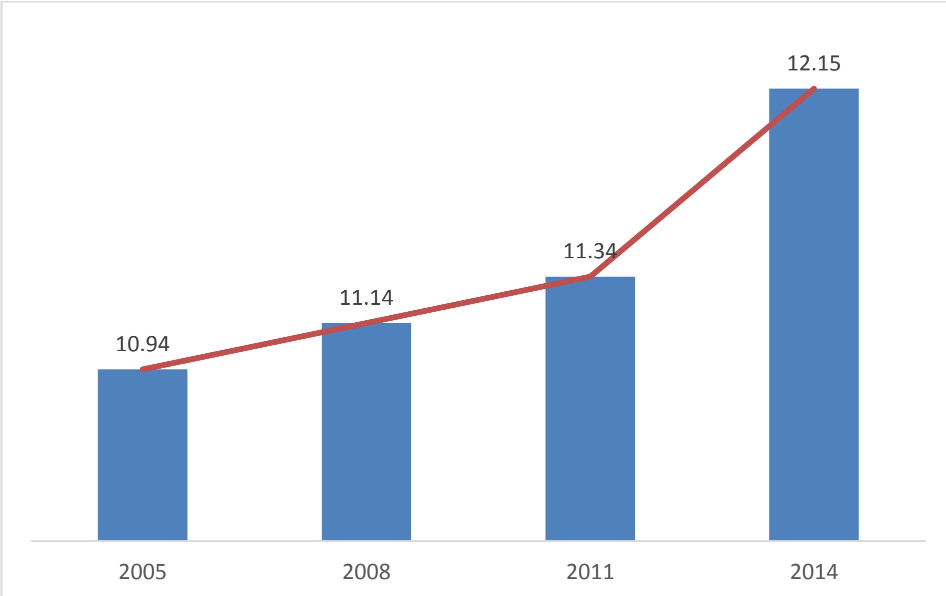
Table 8 also presents figures of the average carbon emissions over the period of interest. Since we modeled the fuel efficiency with age factor and later used the fuel efficiency to estimate the corresponding carbon emissions, an average increase in fuel efficiency would signal a corresponding increase in carbon-dioxide emission. As seen in table 8 below the estimated carbon-dioxide emissions have also increased in both LDV's and HDV's from 312.9 gCO_2/Km and 977.6 gCO_2/Km in 2005 to 349.6 gCO_2/Km and 1129.3 gCO_2/Km respectively. In the general perspective the average carbon-dioxide emissions have also been increasing from an average of 465 gCO_2/Km in 2005 to 503 gCO_2/Km in 2014. Corresponding graphical presentation of the trend in carbon-dioxide emission are given in figures 16, 17 and 18.

Table 8: Annual harmonic fuel efficiency and average carbon-dioxide emissions by year of registration and vehicle category.

		2005	2008	2011	2014
Fuel Efficiency	**LDV**	10.94	11.14	11.34	12.15
	HDV	24.3	24.9	27.7	29.1
	TOTAL AVERAGE	**12.52**	**12.82**	**13.01**	**13.73**
Carbon-dioxide emission	LDV	312.9	320	324.8	349.6
	HDV	977.6	1066.8	1097.3	1129.3
	TOTAL AVERAGE	**465**	**497**	**492.4**	**503**

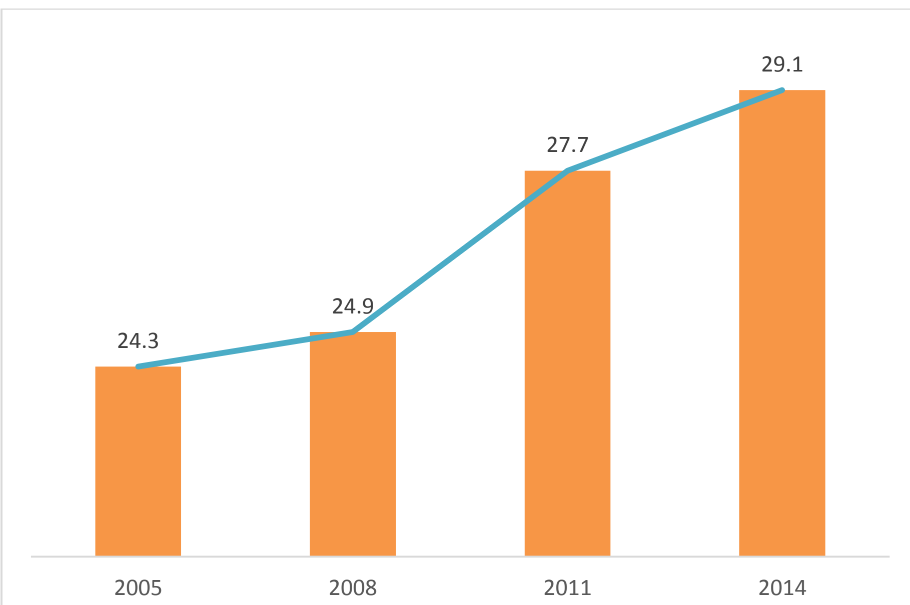
Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

Figure 13: Trend of harmonic fuel efficiency of LDV fleet by year of registration.



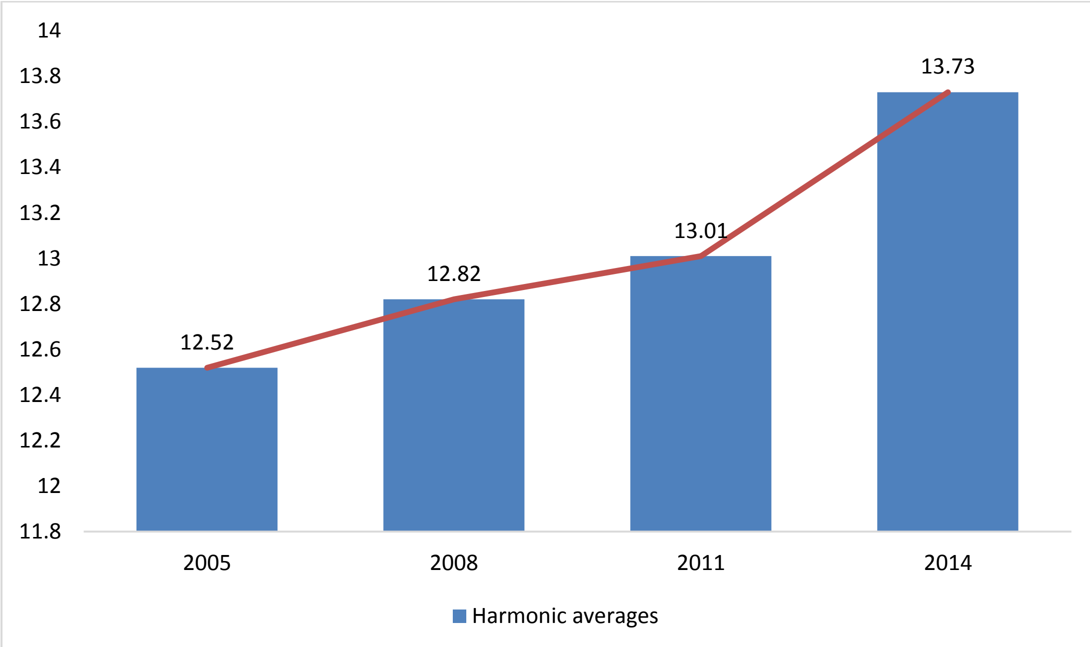
Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

Figure 14: Trend of harmonic fuel efficiency of HDV fleet by year of registration.



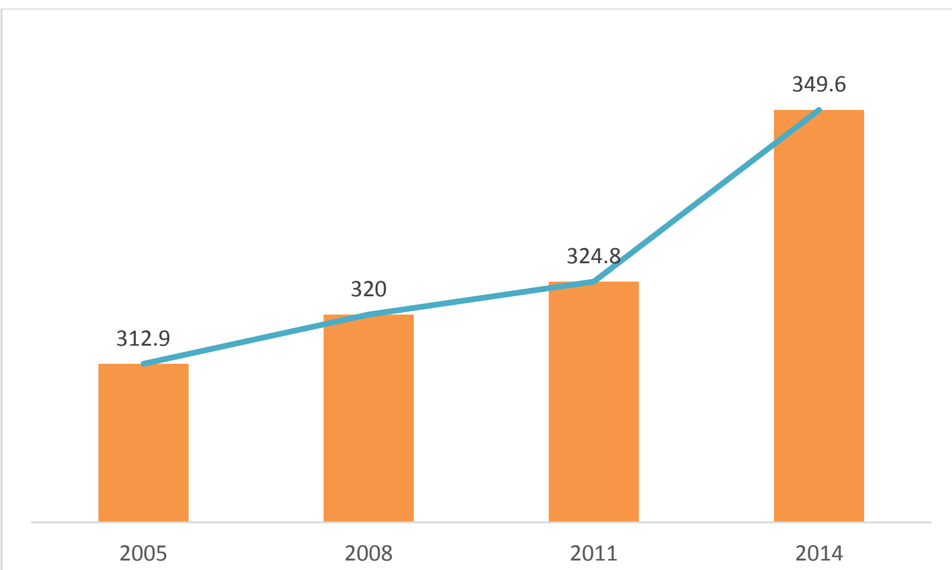
Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

Figure 15: Trend of annual harmonic fuel efficiency by year of registration.



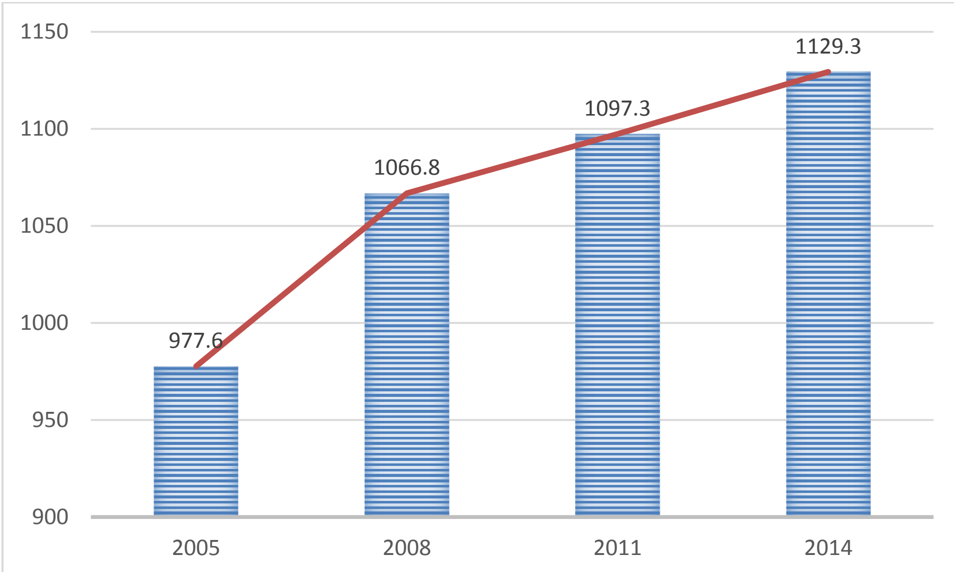
Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

Figure 16: Trend of average carbon-dioxide emissions of LDV fleet by year of registration.



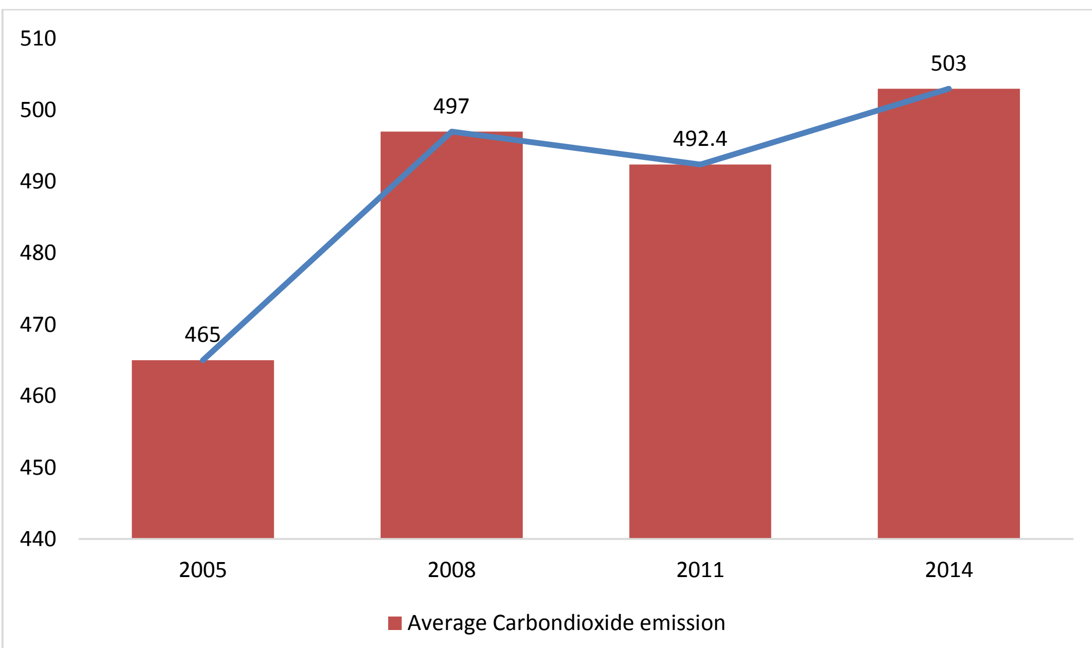
Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

Figure 17: Trend of average carbon-dioxide emissions of HDV fleet by year of registration.



Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

Figure 18: Trend of average carbon-dioxide emissions by year of registration.



Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

3.7.3: Results of Harmonic fuel efficiency of motorcycle fleet (2000 – 2014).

The fleet of motor cycles has been rising as seen from Table 9. The growth picked momentum in 2012 and it has been growing at a high rate of over 17 percent. We note that although the average level of carbon emission of motorcycles compared to vehicles is very low, the total emission coming from motorcycles given their great number, especially in the urban centers is worrying. Accordingly their importation and use need to be regulated specifically with regard to exhaust emission. Findings in the Table show that the average age of motor cycles in Uganda is 1 year, and the average fuel efficiency has improved by 24 percent between year 2000 and 2014. The average carbon emission has improved from 60g/km to 44g/km a 26.7 percentage change in the average emissions over the same time period.

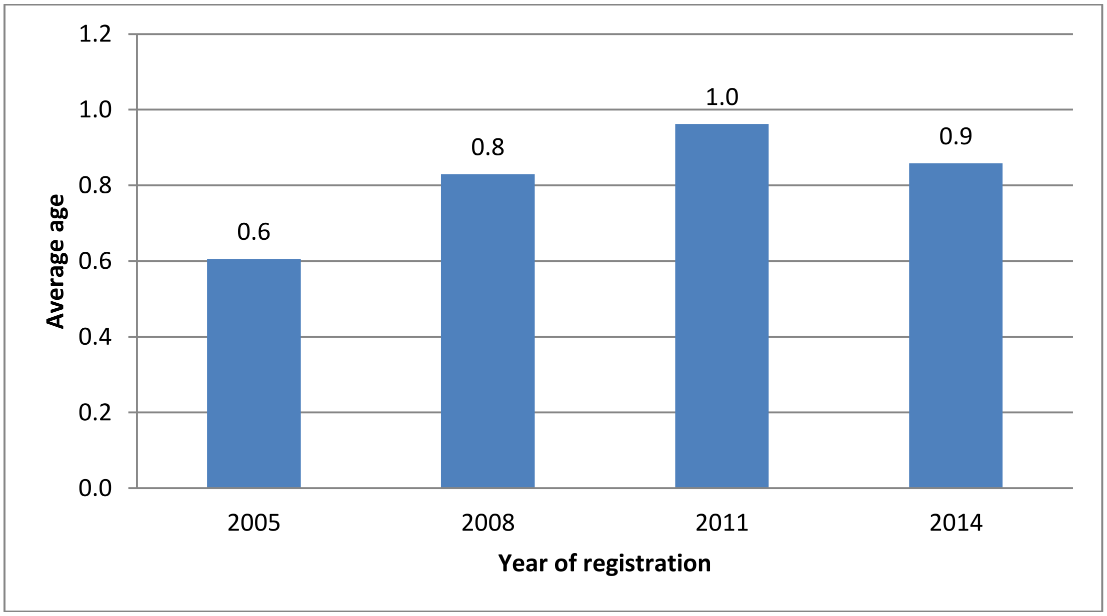
Table 9: Fuel Efficiency and Carbon Emission for Motorcycle by Year of Registration

	PETROL			
Year of registration	**fleet**	**Ave. age**	**Ave. FE (L/100Km)**	**Ave. CO_2 emission**
2000	229.0	0.9	2.5	59.9
2001	408.0	1.0	2.3	54.9
2002	1106.0	0.9	2.5	59.8
2003	919.0	0.8	2.6	60.9
2004	1287.0	0.6	2.5	59.0
2005	970.0	0.6	2.7	62.9
2006	1263.0	0.7	2.4	56.1
2007	2977.0	0.8	2.5	59.2
2008	3082.0	0.8	2.5	58.2
2009	3022.0	0.8	2.4	57.1
2010	3384.0	0.8	2.5	59.3
2011	4646.0	1.0	2.4	57.5
2012	17591.0	1.2	2.1	49.4
2013	87897.0	1.1	1.9	44.1
2014	102773.0	0.9	1.9	43.9

Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

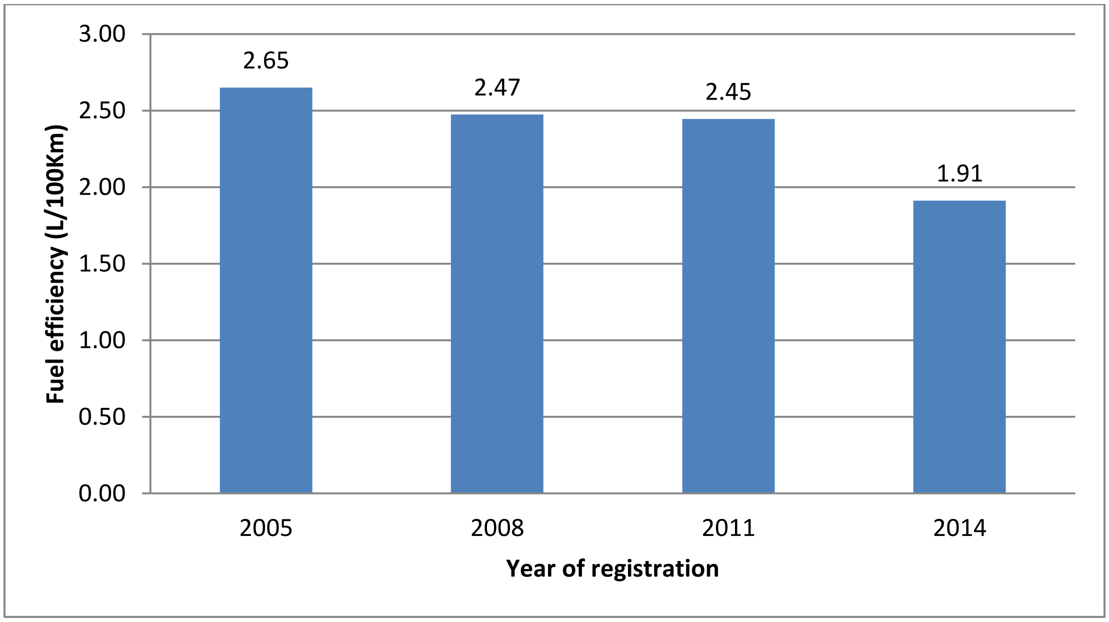
Corresponding graphical expressions are presented in figures, 19, 20 and 21 below for age distribution, fuel efficiency and carbon-dioxide emissions respectively.

Figure 19: Average Age of Motorcycles



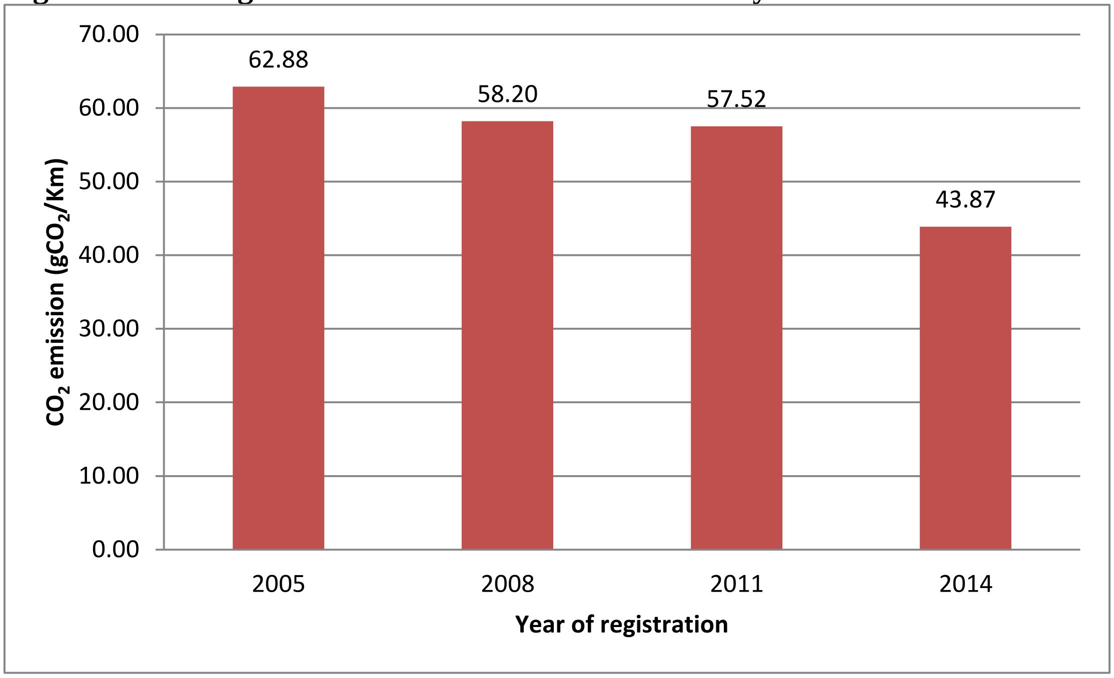
Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

Figure 20: Average fuel efficiency of motorcycles.



Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

Figure 21: Average carbon dioxide emission of motor cycles



Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

4.0: FUEL EFFICIENCY AND CO_2 FORECASTING

4.1: Key Economic Drivers and Assumptions

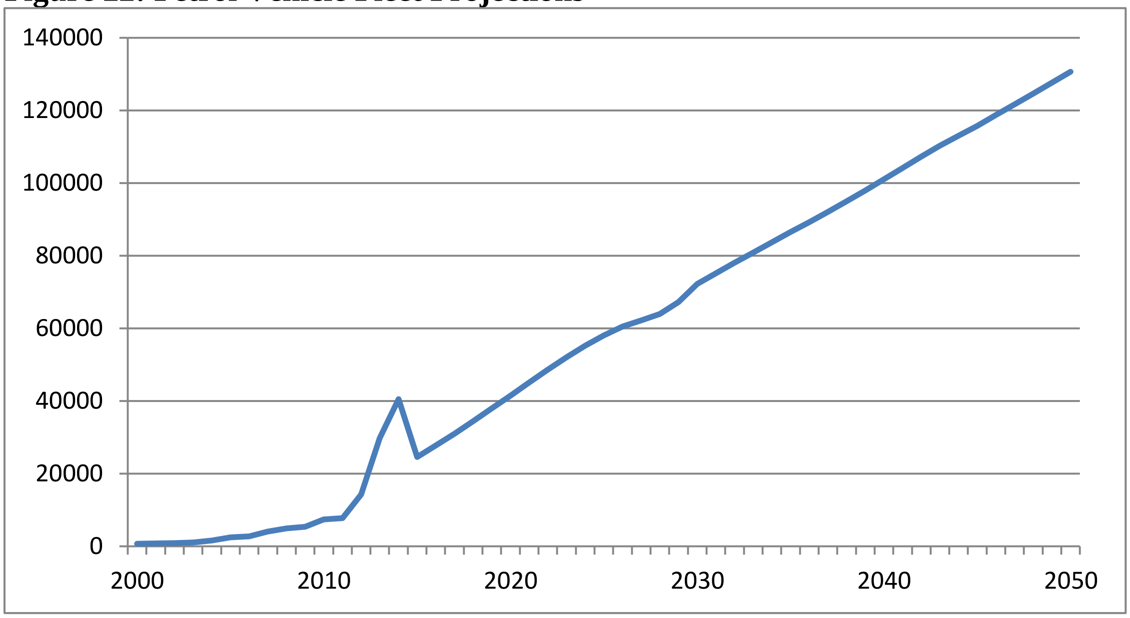
Greenhouse gas (GHG) emission or carbon emission as it is commonly known is influenced by a number of factors among which are the following; level of economic growth, household incomes, world oil and pump price, level of technological change in the car manufacture, and policy decision. Changing any of these factors could lead to variations in emission levels and trends.

In constructing the emissions projections, we need to assume alternative views of changes in certain key factors (e.g. World oil price, the rate of economic growth, policy options) that result in a range of plausible emissions growth trajectories. In this study, the baseline fuel efficiency and emissions projection scenarios represent the state without the environment tax on old vehicles and without any shock in any other factors. Accordingly the following factors are assumed fixed;

i. Economic growth projections (Gross Domestic Product)
ii. Real disposable personal income projections
iii. Consumer price index projections
iv. Labour force projections (Population growth rates)
v. World oil price projections/Pump prices

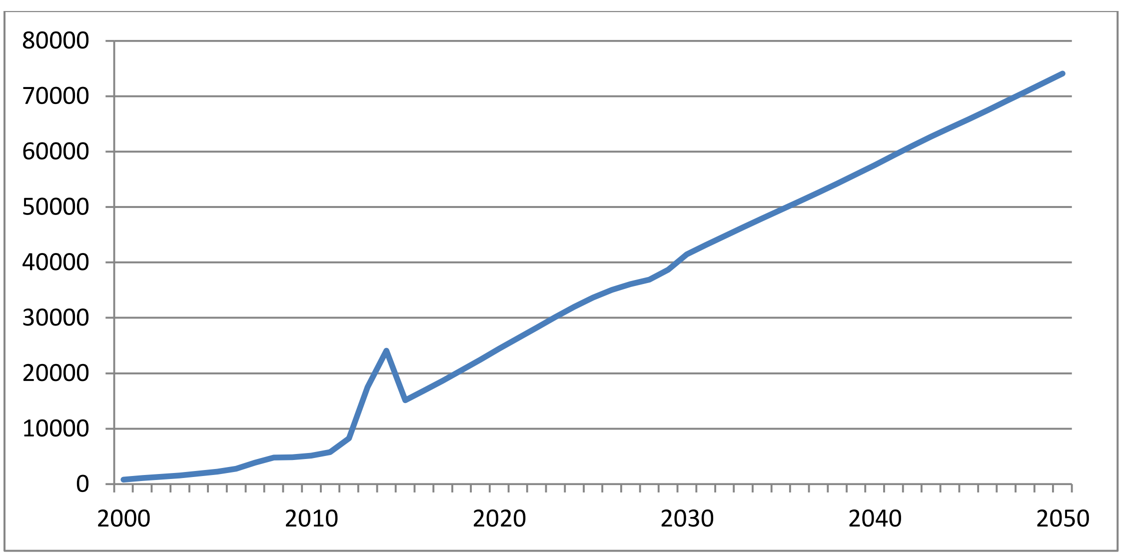
The figures 22 – 24 below, represent projections of the vehicle fleet, fuel efficiency and carbon emission of the baseline senario and a case with imposition of an environment tax which started in 2008. The figures show a steep growth both for diesel and petrol fleet, and for carbon emissions and the fuel eficicency if no interventions are made.

Figure 22: Petrol Vehicle Fleet Projections



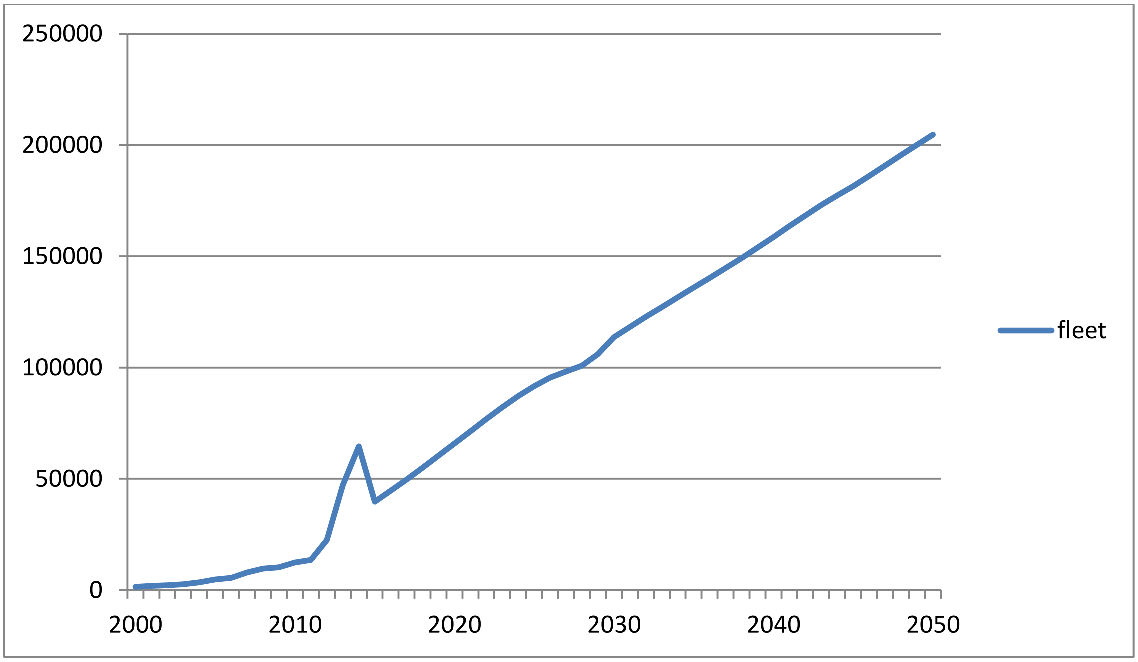
Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

Figure 23: Diesel Vehicle Fleet Projection



Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

Figure 24: All Vehicle fleet Projection

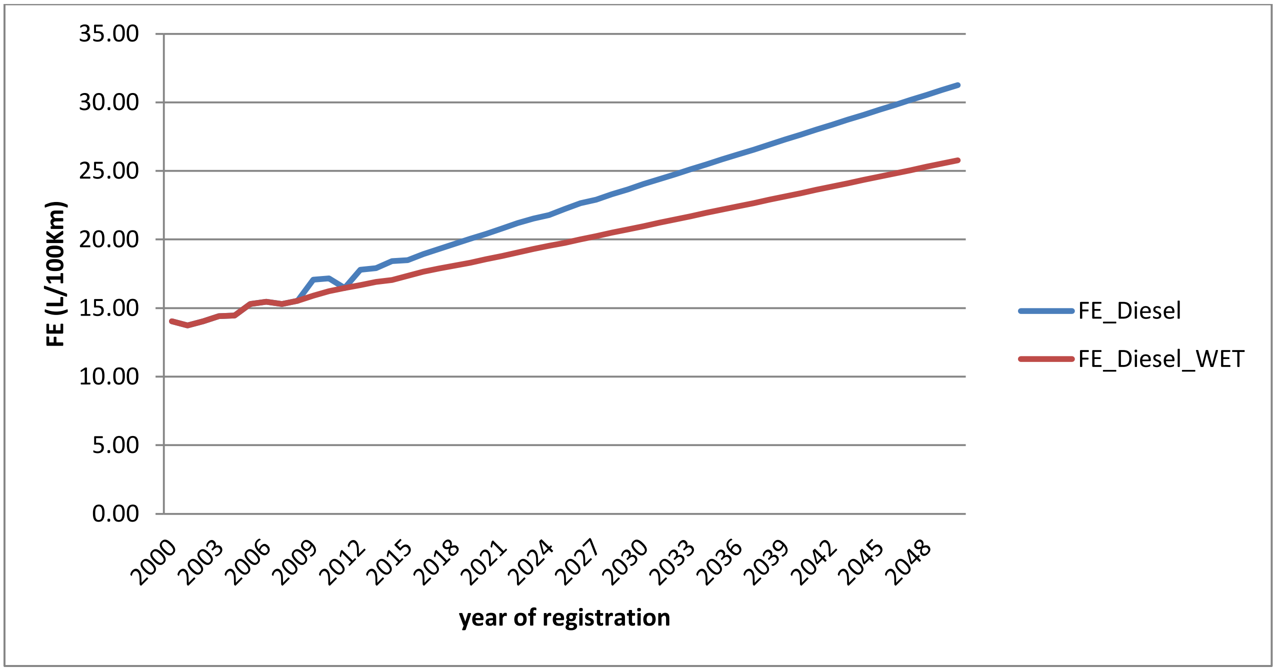


Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

Next we provide a comparison in the projections of average fuel efficiency for diesel and petrol fleet with environmental levy and without the environmental levy. Figures 25 and 26 show the projections of fuel efficiency of diesel and petrol fleet respectively, with environmental levy and without environmental levy[11]. The figures show that the projection of fuel efficiency for diesel fleet without the environmental levy is lower than that with the environmental levy. This is supported by our earlier findings which showed that before introduction of the environmental levy the average age of diesel automobiles was 10.3 in 2008 while in 2014 it had increased to 16.4 years. The situation is similar to that of the petrol fleet where the average age increased from 11.7 in 2008 to 15.4 years in 2014.

[11] The environmental levy/surcharge was introduced in Uganda in financial year 2007/08.

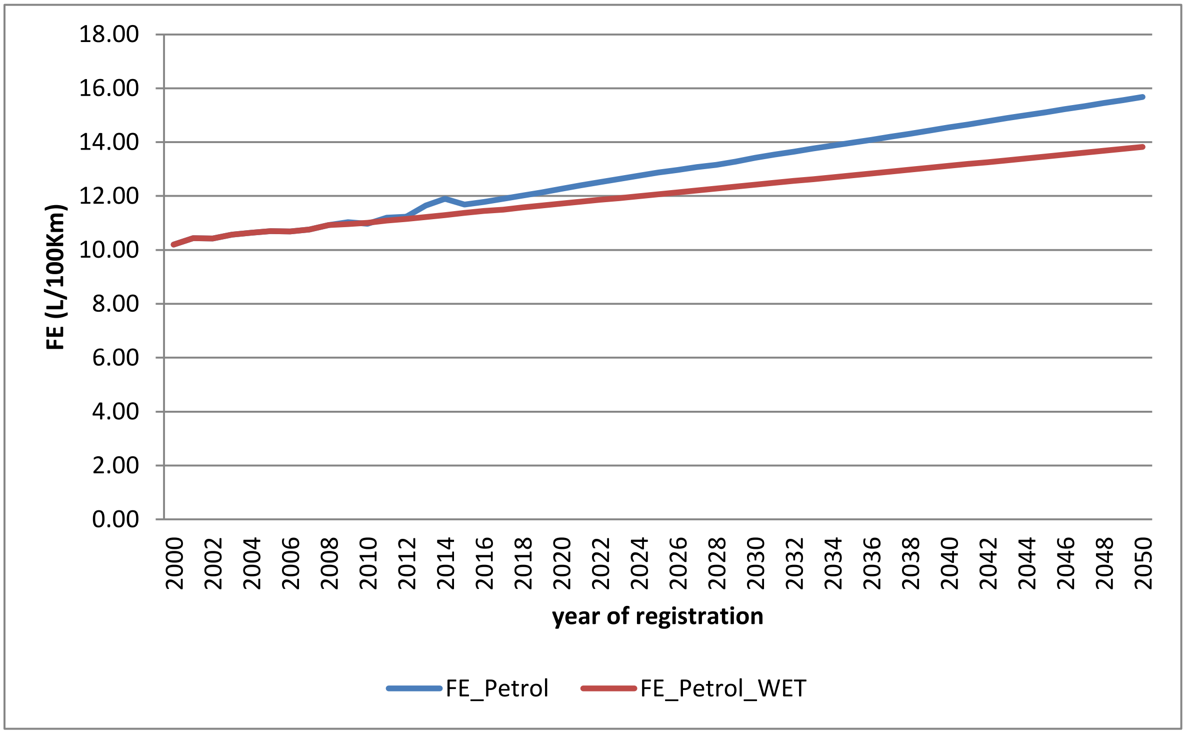
Figure 25: FE with Surcharge and FE without surcharge (WET) policy projections for Diesel fleet.



Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

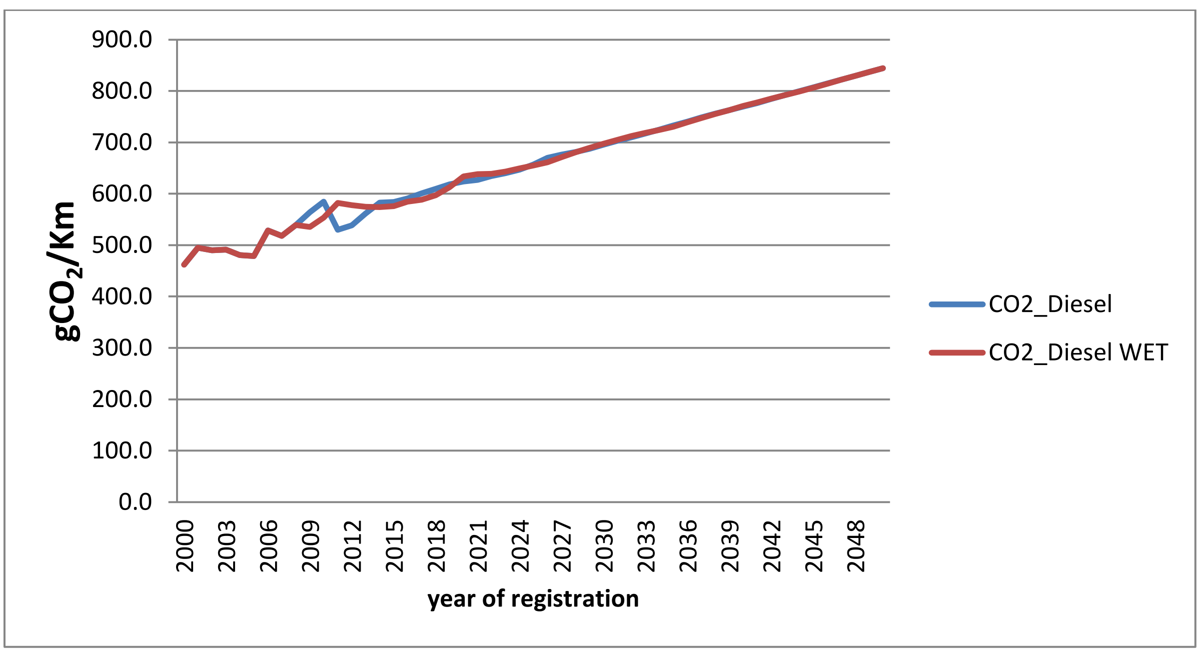
FE_Diesel	*Fuel Efficiency for diesel fleet with environmental levy.*
FE_Diesel_WET	*Fuel Efficiency for diesel fleet without environmental levy*

Figure 26: FE with Surcharge and FE without surcharge policy projections for petrol fleet.



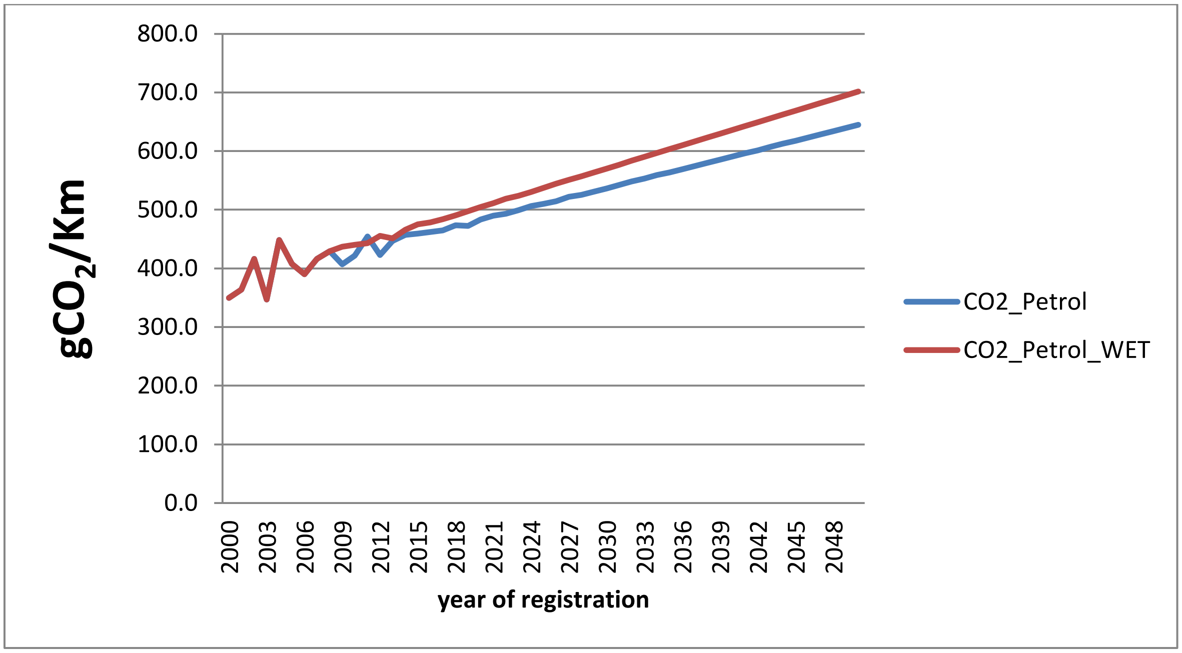
Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

Figure 27: CO_2 Emission with Surcharge and CO_2 without surcharge policy projections for Diesel fleet.



Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

Figure 28: CO_2 Emission with Surcharge and CO_2 without surcharge policy projections for Petrol fleet.



Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

Figures 27 and 28 show the projections of average carbon dioxide emission for diesel and petrol fleet respectively, with environmental levy and without environmental levy. The figure 20 shows that between 2008 and 2014, there some slight variations in carbon emission, but after 2015, the projections show that the trends converge; this implies that the effect of introduction of an environmental levy is not significant. The case is different for petrol fleet as the average carbon emission with environmental levy is less than that without environmental levy. This signifies that the introduction of the environmental levy has a positive impact on carbon emission compared to what the situation would be without the introduction of an environmental levy.

5.0: COST BENEFIT ANALYSIS OF FUEL ECONOMY POLICY INTERVENTIONS

The fourth objective of this study was to conduct a socio-economic implications analysis (cost-benefit analysis) of the various policy interventions to promote cleaner fuels and vehicles including vehicle fuel efficiency. Cost benefit analysis of the fuel economy interventions involves identifying, measuring and valuing the socio-economic benefits and costs of defined policy interventions that promote cleaner fuels (reducing CO_2 emissions) and average fuel consumption (fuel efficiency) by the different categories of vehicles.

The Cost-Benefit Analysis (CBA) framework is applied as a tool to aid in decision making. In the analysis, we define and compare the benefits and costs of the various policy interventions which promote cleaner fuels and fuel efficiency.

The costs and benefits are estimated over a 35 year period and adjusted to their present value using a discounting rate of 11.3%- The current CBR for Uganda (i.e. April 2015). The choice of the discount rate reflects the present cost of financial borrowing (the average Central Bank Rate) in the country while the choice of the intervention period is informed by the GFEI tool kit.

There are both private and public costs and benefits associated with fuel efficiency. These are reflected in fuel costs savings to vehicle owners, say when fuel required to cover 100 Km of travel reduces, this on the other hand could cost government loss in tax revenues. Reductions in CO_2 emissions would have environmental benefits (improved air quality), and public health benefits, say in form of reduced direct medical costs of treating respiratory track illnesses. Such costs and benefits are considered from the perspective of both the private individuals and Government. The vehicle inventory data is used to project the CO_2 emission and average fuel consumed per kilometer (fuel efficiency rates) up to the year 2050.

While there are a range of costs and benefits associated with improvement in fuel efficiency and reduction in CO_2 emissions, some aspects may not be easily monetized. Thus the cost benefit analysis in this study is limited to the monetary costs and benefits of the policy interventions.

Before undertaking the CBA, policy instruments are identified and the analysis conducted separately for each policy intervention and for each vehicle category. The CBA focuses on the differences between the costs and benefits associated with the policy interventions; hence the costs and benefits will be interpreted as incremental. The intervention options are compared with the current situation, i.e. the "business as usual" case (baseline), assuming no further attempt is made to improve the current fuel efficiency levels and to reduce the present carbon emissions by vehicles and motorcycles. Each policy instrument is tested for its effect on fuel efficiency- liters of fuel per 100kilometers (L/100Km) and vehicle emissions- grams of carbon dioxide emitted per kilometer travelled (gCO_2/km). For fuel efficiency, estimates of costs are based on the total fuel consumption, and the fuel (diesel/petrol) price. The financial fuel cost is estimated based on the formula:

Estimated Financial Cost = annual fleet in Km travelled * amount in Ug shs per Km

Where:

- Annual fleet Km = average daily Km*number of vehicles using petrol /diesel *365 (days)

- Amount in UGX per Km = Average fuel economy * average fuel price/ 100

Since the average daily Kms travelled in Uganda is not known, we have adopted the estimate for the Kenyan GFEI country report ('i.e.' 101.6 Kms for Vehicles and 200Kms for motorcycles).

The government of Uganda gets revenue from fuel in form of taxes. The government revenue that will be foregone due to implementation of fuel economy policies will be treated as a cost, while the reduction in annual expenditure on fuel will be treated as a benefit. For the CO_2

emission, the benefit to the economy is the amount of CO_2 emissions avoided and the value accrued upon registering and selling the carbon credits while the costs are those associated with direct costs of treating patients for respiratory tract infection (RTI) illnesses. Savings on treatment costs for RTIs due to a reduction in carbon emissions is treated as a benefit accruing from the policy interventions for CO_2 emissions efficiency.

After establishing the costs and benefits, the Net Present Value (NPV) and Internal Rate of Return (IRR) are used as the criterion for assessing and comparing policy interventions. A policy intervention is acceptable if NPV>0 and IRR> the discount rate and the intervention and rejected if NPV<0 and IRR<discount rate.

Table 10: Financial costs for automobiles in 2014

	Diesel	**Petrol**	**Motorcycles**
Average fuel economy (L/100km)	18.42	11.9	1.9
Average fuel price	3264	3674	3674
Total Amount (Ug shs/100km)	60122.88	43720.6	6980.6
Amount in Ug shs per km	601.2288	437.206	69.806
Average Daily Km travelled	101.6	101.6	200
Number of registered vehicles using diesel	24057	40499	102773
Daily fleet km travelled	2444191.2	4114698.4	20554600
Annual fleet km travelled (365 days)	892129788	1501864916	7502429000
Estimated Financial Cost (UGX)	**536,374,121,883.49**	**656,624,352,464.7**	**523,714,558,774**

Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

In Table 10 above, we used the current estimated for 2014 where; fuel economy level was estimated at 18.42L/100km, 11.9L/km and 1.9 L/100km for diesel, petrol vehicles and motorcycles respectively and this would cost the economy about 536billion UGX, 656.6billion

UGX and 523.7billion UGX for diesel, petrol and motorcycles fleet respectively per year in fuel consumption based on prevailing pump prices. The gross total expenditure on fuel was estimated at 1.716 trillion UGX. Supposing a 30% of fuel cost goes to government as taxes, the government would have UGX 515billion in revenue. Thus a policy which reduces fuel consumption will reduce government revenue and this is treated as a cost to government but a benefit to the private individuals (Vehicle owners) in the CBA. The CBA results are interpreted from both perspectives. Table 11 presents similar estimates for CO_2 emissions. Similar analysis of fuel efficiency and carbon-dioxide emissions has been presented for LDV, and HDV vehicles in tables 13 – 14 for diesel and petrol vehicles and motorcycles.

Table 11: Financial benefit of foregone Carbon emissions for automobiles by fuel type

	Diesel	**Petrol**	**Motorcycles**
Average CO_2 credit per ton (USD)	1.00	1.00	1.00
Exchange rate (1USD to UGX)	2900	2900	2900
Average CO_2 emission(gCO_2/km)	781.7	330.9	43.8
Average daily km travelled	101.6	101.6	200
Total number of newly registered vehicles	24057	40499	102773
Daily fleet km travelled	2444191.2	4114698.4	20554600
Annual fleet km travelled (X 365 days)	892129788	1501864916	7502429000
Average gCO_2 emitted	697377855279.6	496967100704.4	328606390200
Conversion factor	1000000	1000000	1000000
Tones emitted	697377.8552796	496967.1007044	328606.3902
Average carbon credit per ton	2900	2900	2900
Estimated financial Benefit (UGX)	2,022,395,780.3108	1,441,204,592.0428	952,958,531.58

Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

In table 11 above; For the registered fleet in 2014 polluting at 781.7, 330.9 and 43.8 gCO_2/km for diesel, petrol and motorcycle fleet. The total emissions would amount to 1.5million tons of carbon dioxide emissions on top of the emissions made by the other fleet already registered in the country.

The effect of reducing emissions and the benefits to the economy (the amount of CO_2 emissions avoided) are expressed in the value of carbon footprint credits which would fetch an estimate of 4.4 billion Ugshs if traded at 2900 for 1USD per ton.

The direct costs of treating patients of non-communicable respiratory illnesses is the cost to government while savings on treatment costs for respiratory illnesses arising from the policy intervention (reducing the emission rates) are treated as benefits. Estimates for treatment costs for RTI illnesses were expected to be obtained from MoH records[12]. The other costs include institutional costs to implement such a policy - say the UNBS and URA may incur more inspection costs to enforce the policy. The cost estimates are then compared with expected gains (in terms of reduced carbon emissions). These analyses draw on the results of the fuel economy and carbon emission estimates.

A more in-depth analysis has been done for vehicle category by fuel type to better understand the extent of financial cost and benefit to the government by vehicle weight.

[12] RTI infections could be the result of other air quality related hazards other than CO2 vehicle emissions. Reasonable assumptions are used to estimate the proportions associated with vehicle emissions.

Table 12: Financial costs of Diesel and petrol fleet in 2014 by vehicle weight.

	Diesel			Petrol		
	LDV	**HDV**	**Total**	**LDV**	**HDV**	**Total**
Average fuel economy (L/100km)	13.4	29.3	18.4	11.8	22.9	11.9
Average fuel price (Diesel)	3264	3264	3264	13674	13674	13674
Total Amount (Ug shs/100km)	43737.6	95635.2	60057.6	43353.2	84134.6	43720.6
Amount in Ug shs per km	437.376	956.352	600.576	433.532	841.346	437.206
Average Daily km travelled	101.6	101.6	101.6	101.6	101.6	101.6
Number of vehicles using diesel	11956	12101	24057	39900	599	40499
Daily fleet km travelled	1214729.6	1229461.6	2444191.2	4053840	60858.4	4114698.4
Annual fleet km travelled (365 days)	4363940	4416865	8780805	14563500	218635	14782135
Estimated Financial Cost (UGX)	**1,908,682,621.44**	**4,224,077,676.48**	**5,273,540,743.68**	**6,313,743,282.00**	**183,947,682.71**	**6,462,838,114.81**

Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

Table 12 presents the analysis of financial cost by vehicle weight, when the vehicles are categorized into LDV, and HDV. Assuming these vehicles cover an average distance of 101.6km daily for 365 days (ie 1 year), the total expenditure on diesel fuel would be estimated at 6.13 billion Ugshs. In the FY2014/15 the duty tax on diesel fuel was 630 Ugshs per liter. At the prevailing average price per liter of diesel fuel estimated at 3264 Ugshs (in April 2014), an estimate of 1,878,909.41 liters of diesel were imported and consumed by newly registered vehicles, an estimate of 1.18 billion Ugshs. A similar analysis was conducted for petrol fleet in table 12 above.

Table 12 also presents the analysis of financial cost by vehicle category of petrol fleet. Assuming these vehicles cover the same distance as the diesel fleet ie. An average distance of 101.6km daily for 365 days (ie 1 year), the total expenditure on fuel would be estimated at 6.46 billion Ugshs. In the FY2014/15 the duty tax on diesel fuel was 950 Ugshs per liter. At the prevailing average price per liter of petrol fuel estimated at 3674 Ugshs, an estimate of 1,768,560.42 liters of diesel were imported an estimate of 1.68 billion Ugshs.

Table 13: Financial benefits of Diesel and Petrol fleet in 2014 by vehicle weight.

	Diesel			Petrol		
	LDV	**HDV**	**Total**	**LDV**	**HDV**	**Total**
Average CO_2 credit per ton (USD)	1	1	1	1	1	1
Exchange rate (1USD to UGX)	2900	2900	2900	2900	2900	2900
Average CO_2 emission(gCO_2/km)	431	1149	792.6	325.2	716.5	**331.0**
Average daily km travelled	101.6	101.6	101.6	101.6	101.6	101.6
Total number of newly registered vehicles	11956	12101	24057	39900	599	40499
Daily fleet km travelled	1214729.6	1229461.6	2444191.2	4053840	60858.4	4114698.4
Annual fleet km travelled (X 365 days)	443376304	448753484	892129788	1479651600	22213316	1501864916
Average gCO_2 emitted	191,095,187,024.0	515,617,753,116.0	707,102,069,968.8	481,137,679,453.9	15,916,002,006.9	497,053,681,460.8
Conversion factor	1000000	1000000	1000000	1000000	1000000	1000000
Tones emitted	191095.187	515617.7531	707102.07	481137.6795	15916.00201	497053.6815
Average carbon credit per ton	2900	2900	2900	2900	2900	2900
Estimated financial Benefit (UGX)	**554,176,042.37**	**1,495,291,484.04**	**2,050,596,002.91**	**1,395,299,270.42**	**46,156,405.82**	**1,441,455,676.24**

Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

From table 13 above, we notice that the HDV are emitting more carbon-dioxide than the LDV's on average. The financial benefit in 2014 was estimated at 2.04 billion Ugshs from diesel fleet if its carbon credit is traded.

Table 13 above also shows similar analysis for petrol fleet where we found out that still HDV's pollute more than the LDV. The financial benefit in 2014 was estimated at 1.44 billion Ugshs from petrol fleet. In totality this gives about 1.628 billion Ugshs which can be treated as benefit to the government against the cost of bringing the emissions down.

An attempt to conduct a CBA analysis was not successful due to the following limitations;

1. We could not obtain the exact number of vehicle population in Uganda basing on the available vehicle registration data for the period in consideration.
2. We were unable to obtain data on cases related to RTI and their treatment costs from Uganda's Ministry of health and Mulago hospital-the National referral hospital. Data on such cases was unavailable.
3. We were unable to compute the government loss in revenue which would have resulted from the import of old vehicles due to the different variables captured in the datasets used.
4. Data on mileage per a given period of time for each vehicle could not be obtained. This could require a conducting a survey of automobiles that are on the road.

Because of the above limitations, we instead conducted a simple situation analysis using policy options presented in the section below.

The Policy options to consider include:

1. Regulatory policies: For example import restrictions such as a ban on importation of vehicles older than a given number of years, say 20 years.

2. Traffic control measures such as encouraging public transport as opposed to private and commercial motorcycle (*boda boda)* transport within the city.

Imposing Regulatory policies

We examined a policy of banning the importation of vehicles that are over 20 years of age from their date of first registration in Uganda. The results are presented in the tables below.

Table 14: A projected estimate of future financial cost (2050[13])

	Diesel		Petrol	
	2025	**2050**	**2025**	**2050**
Average fuel economy (L/100km)	12.15	12.15	11.66	11.66
Average fuel price (Diesel)	3264	3264	3674	3674
Total Amount (Ug shs/100km)	39657.6	39657.6	42838.84	42838.84
Amount in Ug shs per km	396.576	396.576	428.3884	428.3884
Average Daily km travelled	101.6	101.6	101.6	101.6
Number of vehicles using diesel	33672	74080	58021	130610
Daily fleet km travelled	3421075.2	5894933.6	5894933.6	13269976
Annual fleet km travelled (365 days)	1248692448	2151650764	2151650764	4843541240
Estimated Financial Cost (UGX)	**495,201,456,258.05**	**853,293,053,384.06**	**921,742,228,148.74**	**2,074,916,882,137.62**

Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

[13] Projected estimates of fleet in 2050

Table 15: A projected estimate of future financial benefit from LDV

	Diesel		Petrol	
	2025	**2050**	**2025**	**2050**
Average CO2 credit per ton (USD)	1	1	1	1
Exchange rate (1USD to UGX)	2900	2900	2900	2900
Average CO2 emission(gCO2/km)	389.69	389.69	320.82	320.89
Average daily km travelled	101.6	101.6	101.6	101.6
Total number of newly registered vehicles	33672	74080	58021	130610
Daily fleet km travelled	3421075.2	7526528	5894933.6	13269976
Annual fleet km travelled (X 365 days)	1248692448	2747182720	2151650764	4843541240
Average gCO2 emitted	486602960061.12	1070549634156.80	690292598106.48	1554243948503.60
Conversion factor	1000000	1000000	1000000	1000000
Tones emitted	486602.9601	1070549.634	690292.5981	1554243.949
Average carbon credit per ton	2900	2900	2900	2900
Estimated financial Benefit (UGX)	**1,411,148,584.18**	**3,104,593,939.05**	**2,001,848,534.51**	**4,507,307,450.66**

From table 14 and 15 above, The LDV fleet is projected (see Appendix 8) to grow from 11956 in 2014 to 33672 in 2025 and then 74080 by 2050 for diesel while petrol LDV fleet is estimated to grow from 39900 in 2014 to 58021 in 2025 to 130610 in 2050. Assuming the fuel efficiency of LDV vehicles remains at 13.4 L/100Km and 11.8L/Km for diesel and petrol fleet respectively. The expenditure would grow from UGX 1.9 billion in 2014 to UGX 495.2 billion in 2025 and 853.29 billion in 2050 for diesel LDV fleet, while Petrol LDV fleet would grow from UGX 6.49 billion in 2014 to UGX 921.74 billion in 2025 and 2.074 trillion in 2050.

The financial benefit would increase from 554 million tons in 2014 to 1.4 billion tons in 2025 and 3.1 billion tons in 2050. While the carbon emissions from petrol LDV fleet is expected to grow from 1.39 billion tons in 2014 to 2 billion tons in 2025 and 4.5 billion tons in 2050. This is so as a result of an increase in the annual carbon-dioxide emissions.

Supposing that we imposed ban of no importation of vehicles that are over 20 year old, on all LDV's. We projected the fleet of vehicles that will be imported into the country using the figures of vehilces that have been registered into the country that are 20 years and below.

We re-estimated the fuel efficiency rate at 12.15 L/100km and 11.66 L/100Km for diesel and petrol fleet respectively. The corresponding carbon emissions were estimated at 389.7 gCO_2/Km and 334.4 gCO_2/Km for diesel and petrol fleet respectively.

The future expenditure on fuel would be expected to fall to UGX 242 billion in 2025 and 530.8 billion in 2050 for diesel LDV fleet while that of petrol LDV fleet would fall to 573.4 billion in 2025 and 2.04 trillion in 2050. As presented in table 16.

A corresponding fall in annual carbon emissions estimated at 237,867.8 tons in 2025 and 825,051.56 tons in 2050 for diesel fleet while for petrol fleet, 429,396.95 tons in 2025 and 1,529,396.99 tons in 2050. Would lead to a reduction in financial benefit for trading carbon emission estimated at 689.8 million in 2025 and 2.392 billion in 2050 for diesel LDV fleet, and 1.24 billion in 2025 and 4.43 billion in 2050. As presented in table 17.

Table 16: Analysis of financial cost after imposing a 20 year ban.

	Diesel		Petrol	
	2025	**2050**	**2025**	**2050**
Average fuel economy (L/100km)	12.15	12.15	11.66	11.66
Average fuel price (Diesel)	3264	3264	3674	3674
Total Amount (Ug shs/100km)	39657.6	39657.6	42838.84	42838.84
Amount in Ug shs per km	396.576	396.576	428.3884	428.3884
Average Daily km travelled	101.6	101.6	101.6	101.6
Number of vehicles using diesel	16460	57092	36092	128522
Daily fleet km travelled	1672336	3666947.2	3666947.2	13057835.2
Annual fleet km travelled (365 days)	610402640	1338435728	1338435728	4766109848
Estimated Financial Cost (UGX)	**242,071,037,360.64**	**530,791,487,267.33**	**573,370,340,020.76**	**2,041,746,172,008.96**

Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

Table 17: Analysis of financial benefit after imposing a 20 year ban.

	Diesel		Petrol	
	2014	**2050**	**2014**	**2050**
Average CO2 credit per ton (USD)	1	1	1	1
Exchange rate (1USD to UGX)	2900	2900	2900	2900
Average CO2 emission(gCO2/km)	389.69	389.69	320.82	320.89
Average daily km travelled	101.6	101.6	101.6	101.6
Total number of newly registered vehicles	16460	57092	36092	128522
Daily fleet km travelled	1672336	5800547.2	3666947.2	13057835.2
Annual fleet km travelled (X 365 days)	610402640	2117199728	1338435728	4766109848
Average gCO2 emitted	237867804781.60	825051562004.32	429396950256.96	1529396989124.72
Conversion factor	1000000	1000000	1000000	1000000
Tones emitted	237867.8048	825051.562	429396.9503	1529396.989
Average carbon credit per ton	2900	2900	2900	2900
Estimated financial Benefit (UGX)	**689,816,633.87**	**2,392,649,529.81**	**1,245,251,155.75**	**4,435,251,268.46**

Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

Promoting use of Bulk Public transport

Large carriers are believed to be a solution to the heavy traffic especially in the city centers. A large carrier say a bus can save us tons of carbon-dioxide emissions which could have been caused by use of small saloon cars and motorcycles or any other motorized means of transport on road.

Table 18: Showing Comparative Carbon Emission and cost of fuel using alternative means of Transport

	Bus	Coaster	Taxi	Saloon	Motorcycle
Seat capacity	80	30	14	4	1
Fleet	1	3	6	20	80
FE (L/100Km)	13.3	12.7	10.3	9	1.8
CO_2 (gCO_2/Km)	420.6	398	319.4	275.5	41.02
Cost of fuel	3264[14]	3264[11]	3264[11]	3264[11]	3674[15]
Cost (L/Km)	434.112	414.528	336.192	293.76	66.132
Ave. cost for 21km	9116.352	26,115.264	42360.192	123,379.2	111,101.76
Total financial cost	**3,327,468.48**	**9,532,071.36**	**15,461,470.08**	**45,033,408**	**40,552,142.4**
Daily emissions	88326	25074	42360.192	129548.16	68913.6
Annual CO_2 emission	3223899	9152010	15461470.08	47285078.4	25153464
Tons of carbon	**3.223899**	**9.15201**	**15.46147008**	**47.2850784**	**25.153464**

Source: Computations based on combined dataset (URA e-tax dataset and MoW&T dataset)

The Table 18, shows five different means of transport ferrying 80 people over 21Km. We notice that one bus is equivalent to 3 min-buses or 14 taxis or 80 boda-bodas. Over the same distance and ferrying same number of people an equivalent number of motorcycles' (boda-bodas) would pollute over 8 times the emission by a bus, while saloon cars would produce emission that is 18 times that of a bus; taxis would emit 5 times and coasters/min-buses would pollute 3 times the emissions of a bus. So basing on this simple analysis, we find that it is more beneficial to society in terms of least cost and least amount of pollution, to use a bus other than any other means of transport.

[14] Average price of diesel as at April 2015

[15] Average price of petrol as at April 2015

6.0: POLICY SUGGESTION FOR IMPROVING FUEL EFFICIENCY AND REDUCING CARBON EMISSIONS IN UGANDA

6.1: Introduction:

The process of burning fuels by driving vehicles produces greenhouse gases such as carbon dioxide (CO_2) into the atmosphere which contributes to climate change. These emissions can be reduced by improving motor vehicle fuel efficiency, which in turn reduces the nation's dependence on oil and saves money. In this section we suggest some policies and strategies that could be implemented by the drivers, tax authority, City Council Authorities, Inspection Authority, Police and enforcement agencies to reduce carbon emission in Uganda. Basing on the study findings and on the global policies, strategies aimed at reducing emissions shall include fiscal, regulatory (total ban, inspections), traffic control and consumer awareness campaign.

Our findings show that older vehicles and larger engine capacity vehicles emit more pollution than newer and smaller ones respectively. In addition, diesel engine emit more than petrol engine much as they might be of the same engine capacity. Accordingly, in line with "*Polluter Pay Principle,"* those that pollute more should pay more. We would therefore expect older vehicles, lager engine vehicles and diesel powered ones or a combination to be charged more than the rest. Broadly, policy options for Uganda, should include; total ban on importation of vehicles beyond a given age, annual inspection for road worthiness in terms of emissions, differential vehicle fees and charges/taxes on old vehicles and diesel engine vehicles proportional to the engine capacity and age, regulatory measures and consumer awareness.

6.2: Consumer Awareness Strategies[16]

The following strategies apply mostly to the consume/driver/motor-vehicle owner. These strategies may not be easy to enforce but if adhered to, may lead to significant reduction in carbon emission.

i) Purchase of fuel efficient vehicle

When buying a new or used vehicle (or even renting a vehicle), one should look for the most fuel-efficient one. This is good because it enables one to save on fuel costs and also saves the nation from carbon emission.

ii) Smart driving

While driving, one should ensure improving fuel economy in order to reduce greenhouse gas emissions, by avoiding hard accelerations, reducing one's time spent idling while the engine is running, and unload unnecessary items to reduce weight; obeying highway speed limits can save fuel, as well as prevent pollution. Avoid rapid accelerations and braking, because these processes burn more fuel. If driving an automatic engine car, use *over-drive and cruise control.* Avoid using four-wheel drive instead consider operating in two-wheel drive mode when road conditions make it safe to do so.

iii) Ensure regular vehicle maintenance

Every vehicle is designed to perform best when maintained according to the instructions found in the owner's manual. A poorly maintained vehicle can pollute more and be less fuel-efficient than one that's well maintained. Therefore make sure the vehicle is regularly maintained and well-tuned, follow the manufacturer's maintenance schedule, and use the recommended grade of motor oil. Replace the air filter regularly: A clogged air filter can reduce fuel economy

[16] http://www.epa.gov/climatechange/wycd/road.html

significantly. A well-maintained car is more fuel-efficient, produces fewer greenhouse gas emissions, is more reliable, and is safer.

iv) Check the status of the tyres

Check the tire conditions and tire pressure regularly. Make sure the tyres are of good status well inflated because under-inflation increases tire wear, reduces fuel economy, and hence leads to higher greenhouse gas emissions. If there is need to replace the tyres, purchase those that have *“low rolling resistance”*- an energy-saving feature.

v) Use alternative transport means if possible and drive less

When possible, consider using other means of transport such as public transport, a bike or walking say twice a week. Bicycle riding can improve one’s health, saves money, and helps to protect the environment. It is also advisable that when driving, try combining your errands and activities into one trip. It is estimated that resting a car for just two days a week, can reduce greenhouse gas emissions by an average of two tons per year.

vi) Use high efficient fuels and refuel wisely

1. Always consider using more efficient fuels that contain less sulphur, less lead and particulate matter such as; unleaded fuel.
2. While refueling, ensure that you do not cause fuel spills because fuel fumes are harmful to you and the environment.
3. Also, during very hot weather try to refuel early in the morning or late evening hours to limit your exposure to fumes.

vii) Car pooling:

For the purpose of reducing congestion and emission, people living together and working in the same area, are encouraged to use same vehicle other than driving different vehicles.

6.3: Policies for Ugandan Institutions; URA, KCCA, Police, Uganda Inspection Agency:

Until recently, the environment levy was 20% of the value of the vehicle, however, the problem with such a fee is that it is un-equitable and regressive in nature. It is common knowledge that older vehicles are of much less value than newer ones and also they pollute much more than the newer ones other factors constant. The underlying principle should be the "*Polluter pay principle*," i.e. those that pollute more should pay more. Accordingly, a flat percentage fee regardless of the age of the vehicle would imply that those that pollute more pay less than those that pollute less. This leads to the situation where "bad goods drive good goods out of the market". Indeed since the imposition of the environment levy, more old vehicles have been imported than newer ones, (see appendix 2). We notice that age, engine size and type of fuel matter a lot with regard to emission. For instance vehicles of the same engine capacity but with differences in the age pollute differently. Similarly, vehicles with same engine size but of different fuel type, pollute differently. And also, there are differences in carbon emission arising from differences in engine size. We therefore suggest the following general policies;

1. In line with the polluter pay principle, there should be differential tax rates/fees based on age of the vehicle. In other words, the tax should be targeted in such a way that a higher tax rate is imposed on older vehicles than on newer ones.
2. From our findings, vehicles of same age but different engine capacities pollute differently, such that those with higher engine capacity pollute more than those with

lower capacity (See Appendix 4). For the purpose of equity, a tax based on engine capacity should be imposed such that those that pollute more pay more.

3. There should be periodic inspection of all automobiles (vehicles and motorcycles) that are already registered in the country, and government should impose a limit/ceiling of emission per category of engine capacity of the vehicle beyond which the vehicle should either be put off the road, install a catalytic converter or pay a fee for polluting the environment.
4. All imported automobiles should be subjected to compulsory testing for fuel economy and carbon emission before registration.
5. In addition to other specifications, vehicle inspections before importation should include carbon emission levels.
6. Vehicles that are to be imported into the country should be labeled with “Fuel economy and Environmental Labels,” for easier comparison during shopping. These window stickers provide fuel economy and environmental rating for all newly imported vehicles.
7. Encourage public transportation by providing parking spaces at different entry points into the city for private automobiles.
8. Discourage private transport into the City by increasing parking fees;
9. Make it a mandatory for every new building to have parking space.
10. Make walking and biking safe to the users by providing security lights and security along the City roads.
11. Discourage daytime loading and offloading of both goods/merchandize and garbage trucks in the Kampala City.

7.0: SUMMARY, CONCLUSION, RECOMMENDATIONS AND LIMITATIONS TO THE STUDY

7.1: Summary

The process of burning fuels by driving vehicles produces greenhouse gases such as carbon dioxide (CO_2) into the atmosphere which contributes to climate change. These emissions can be reduced by improving motor vehicle fuel efficiency, which in turn reduces the nation's dependence on oil and saves money that could be used in other investment ventures that would lead to economic growth.

7.2: Conclusion

The unavailability of air pollution policies in Uganda could lead to disastrous environmental situations in the country. The study has also shown that fuel efficiency and carbon emissions are worsening in Uganda despite the imposition of an environment levy. This therefore calls for strict policies that should also be enforced in a bid to reduce emission of green house gases in Uganda.

7.3: Recommendations

The following recommendations arise from the difficulties we encountered while under taking this study. We are therefore opportunistic that if adhered to, a comprehensive study could be undertaken;

1. URA needs to harmonize its datasets i.e. e-tax and customs.
2. URA and MoW&T need to build a strong business intelligence to check consistency of entries made by custom and importing agency.

3. Among the important variables that should be captured by URA, UNBS, MoW&T should include; automobile type, fuel type, make name, model, chassis and engine numbers. Others are power/displacement in cubic centimeters (CC), Transmission (i.e manual/automatic), weight, year of manufacture, year of registration, status of the vehicle (new or second hand), rated fuel economy per model and test cycle basis i.e. (Fuel efficiency and carbon emission for each vehicle registered).
4. A comprehensive study with physical tests on used automobiles to estimate more accurate fuel efficiency rates and carbon emissions rates and generate factor.
5. The government through MoW&T should ensure that car franchise in Uganda publish their automobile efficiency rates and carbon emissions.

7.4: LIMITATIONS

1. Incomplete data on privately owned vehicles.
2. Insufficient and unavailable data in government institutions.
3. Limited or no documentation on environmental policies issues from NEMA, KCCA and the Ministry of energy related to vehicle -related pollution (emissions) has been obtained.
4. Lack of access to data on government vehicles that belong to Ministry of Defense

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APPENDICES

Appendix 1: Conversion factor used to generate Fuel Economy ratios

Table 1: NEDC standard conversion factors

Source (X)	Target (Y)	A	B	Calculate Conversion Factor	Calculate Target
CAFÉ mpg	NEDC mpg	-0.1033	1.473	CF = A*ln(X)+B	Y=X/CF
NEDC mpg	CAFÉ mpg	0.0816	0.6243	CF = A*ln(X)+B	Y=X/CF
JC08 km/L	NEDC km/L	-0.0841	1.3464	CF = A*ln(X)+B	Y=X*CF
JC08 km/L	CAFÉ km/L	-0.2038	1.7618	CF = A*ln(X)+B	Y=X*CF

Source: **Methodological Guide on Developing Vehicle fuel Economy Databases**

Appendix 2: Vehicle fleet registered in 2005 and 2014.

2005			2014		
Year of Manufacture	**Fleet**	**Percent**	**Year of Manufacture**	**Fleet**	**Percent**
1912	1	0.02	1949	1	0
1948	1	0.02	1956	1	0
1967	1	0.02	1959	2	0
1973	3	0.06	1960	1	0
1976	1	0.02	1965	1	0
1978	1	0.02	1967	3	0
1979	3	0.06	1968	1	0
1980	2	0.04	1969	3	0
1981	6	0.13	1970	8	0.01
1982	4	0.08	1971	7	0.01
1983	4	0.08	1972	3	0
1984	7	0.15	1973	2	0
1985	13	0.27	1974	17	0.03
1986	29	0.61	1975	16	0.02
1987	44	0.93	1976	9	0.01
1988	76	1.61	1977	12	0.02
1989	150	3.17	1978	16	0.02
1990	199	4.21	1979	24	0.04
1991	312	6.59	1980	28	0.04

	1992	469	9.91		1981	19	0.03
	1993	427	9.03		1982	33	0.05
	1994	504	10.65		1983	48	0.07
	1995	524	11.08		1984	118	0.18
	1996	517	10.93		1985	182	0.28
	1997	192	4.06		1986	357	0.55
	1998	113	2.39		1987	597	0.92
	1999	77	1.63		1988	1,382	2.14
	2000	48	1.01		1989	1,602	2.48
	2001	34	0.72		1990	1,734	2.69
	2002	14	0.3		1991	1,751	2.71
	2003	35	0.74		1992	1,781	2.76
	2004	342	7.23		1993	1,709	2.65
	2005	578	12.22		1994	2,077	3.22
					1995	2,630	4.07
					1996	4,830	7.48
					1997	5,922	9.17
					1998	7,732	11.98
					1999	8,009	12.41
					2000	6,055	9.38
					2001	5,672	8.79
					2002	902	1.4
					2003	720	1.12
					2004	510	0.79
					2005	1,054	1.63
					2006	676	1.05
					2007	551	0.85
					2008	524	0.81
					2009	153	0.24
					2010	156	0.24
					2011	296	0.46
					2012	378	0.59
					2013	2,072	3.21
					2014	2,169	3.36
Total		**4,731**	**100**	**Total**		**64,556**	**100**

Appendix 3: Average CO_2 emission and FE for Toyota[17] cars by Age, Engine capacity and Fuel type

a. **Diesel Engine**

Engine CC	Age = 5		Age = 10		Age = 15		Age = 20	
	CO_2	FE	CO_2	FE	CO_2	FE	CO_2	FE
500-1200								
1201-1500			280.73	9.19	273.16	8.96	369.62	11.82
1501-2000			301.201	9.8	339.13	10.81	411.42	13.05
2001-2500	248.57	8.21	312.54	10.14	358.12	11.49	505.41	15.77
2501-3000	293.39	9.27	373.90	11.95	401.1	12.79	529.32	16.45
3001-4000			441.14	13.93			534.37	16.61
4001-5000	342.511	11.03	531.56	16.52	502.36	15.68	784.71	23.65
>5000			605	18.61	1065.01	31.36		

b. **Petrol Engine**

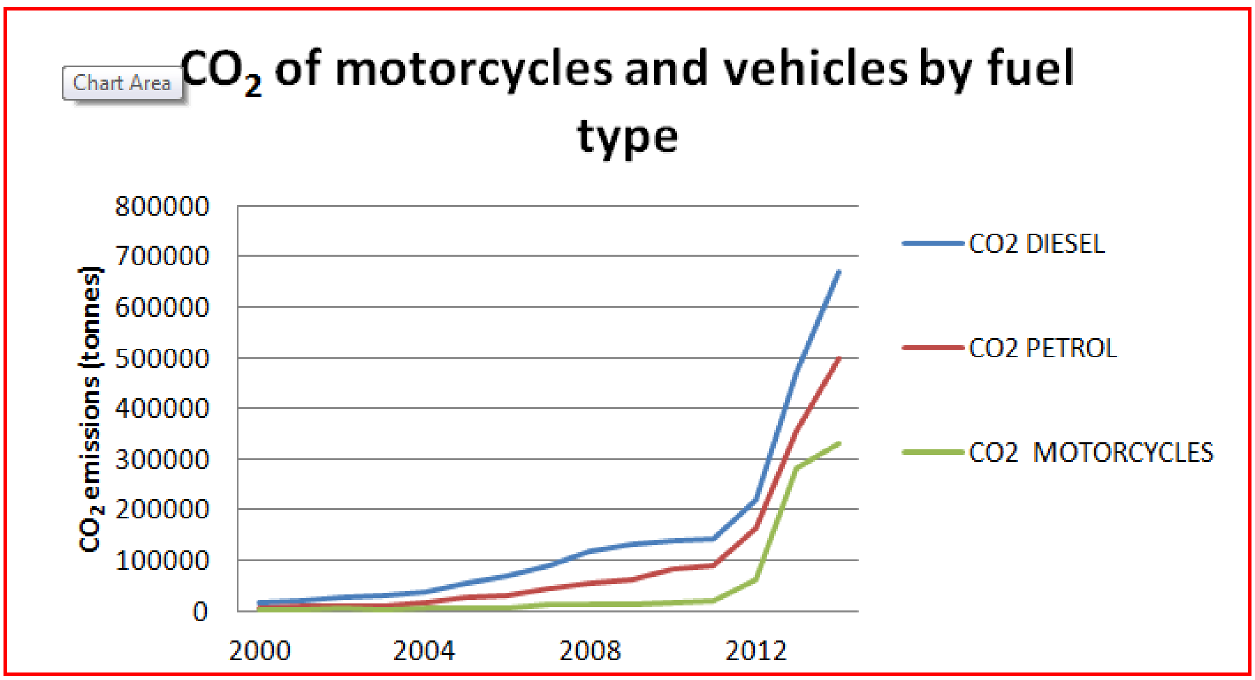
Engine CC	Age = 5		Age = 10		Age = 15		Age = 20	
	CO_2	FE	CO_2	FE	CO_2	FE	CO_2	FE
500-1200	141.15	5.56	202.57	7.73	205.52	7.84		
1201-1500	240.17	9.04	262.19	9.8	303.25	11.2	372.06	13.52
1501-2000	230.58	8.7	283.77	10.53	304.43	11.24	387.07	14.02
2001-2500	308.04	11.36	386.61	14	414.71	14.93	450.12	16.1
2501-3000	358.65	13.07	403.28	14.56	432.59	15.15	566.94	19.92
3001-4000	490.31	17.42			721.87	24.89	884.7	30.04
4001-5000	490.31	17.42	519.48	18.37	1179.94	39.2	1970.85	63.07
>5000	761.04	26.13						

[17] The most common type of vehicles in Uganda is the Toyota

Appendix 4: Total $C0_2$ emissions by year in Uganda from the available data

	CO_2 DIESEL	CO_2 PETROL	CO_2 MOTORCYCLES
2000	15823.19	6788.207	1001.878
2001	20551.42	8397.881	1635.136
2002	26813.08	9272.734	4826.109
2003	31509.6	11002.16	4088.883
2004	38292.87	17116.44	5545.694
2005	53390.05	26582.85	4452.799
2006	67606.21	29035.84	5170.719
2007	91007.26	43992.03	12863.09
2008	116168	54427.72	13093.85
2009	130705.8	60981.31	12590.57
2010	138401.5	82440.22	14639.46
2011	142180.9	89460.52	19509.83
2012	219918.7	163713	63465.26
2013	471462.9	356205.5	283158.7
2014	669656.8	497013.7	329153.3

Appendix 5: $C0_2$ emission by fuel type

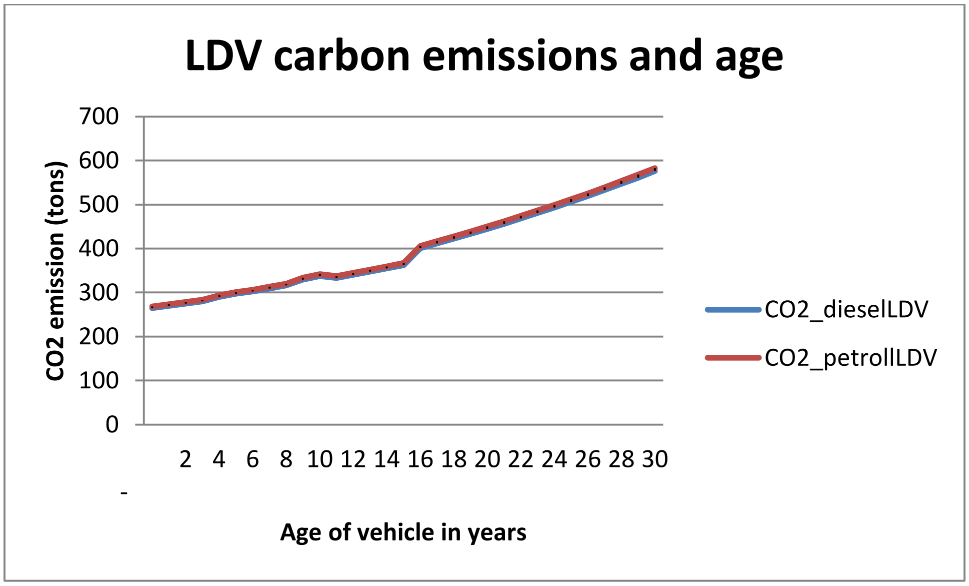


Appendix 6: C0$_2$ emission by age of vehicle, fuel type and engine size

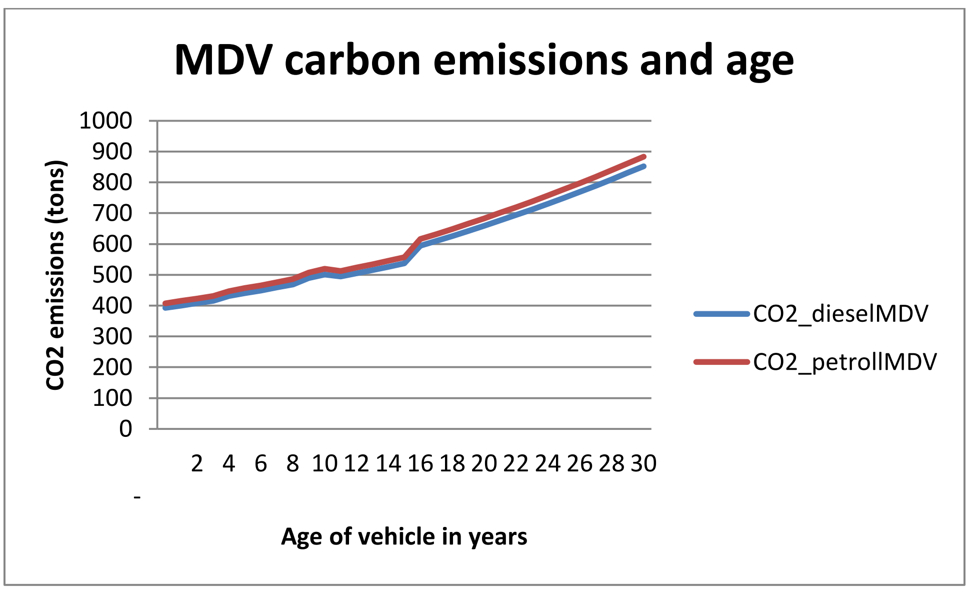
	CO2_diesel LDV	CO2_petrol LDV	CO2_diesel MDV	CO2_petrol MDV	CO2_diesel HDV	CO2_petrol HDV
0	264.9	268.3	393.0	407.7	657.9	864.5
1	269.9	273.3	400.4	415.3	670.2	880.7
2	275.0	278.5	407.9	423.1	682.8	897.1
3	280.1	283.7	415.5	431.0	695.5	913.9
4	290.4	294.1	430.7	446.8	720.9	947.1
5	297.1	300.9	440.7	457.1	737.5	968.9
6	302.6	306.4	448.7	465.4	750.9	986.4
7	309.3	313.2	458.7	475.8	767.6	1008.3
8	316.3	320.2	469.0	486.4	784.7	1030.7
9	329.7	333.9	488.9	507.1	817.9	1074.2
10	337.8	342.1	500.9	519.5	837.9	1100.5
11	333.4	337.6	494.3	512.7	827.0	1086.1
12	340.4	344.7	504.7	523.4	844.3	1108.8
13	347.6	352.0	515.4	534.5	862.0	1132.0
14	355.0	359.4	526.2	545.7	880.1	1155.7
15	362.5	367.0	537.3	557.2	898.6	1179.9
16	401.0	405.9	594.2	616.2	993.5	1304.3
17	411.5	416.5	609.8	632.2	1019.4	1338.2
18	422.3	427.5	625.7	648.8	1046.0	1373.0
19	433.3	438.6	642.1	665.7	1073.2	1408.7
20	444.7	450.1	658.8	683.1	1101.2	1445.3
21	456.3	461.9	676.0	700.9	1129.9	1482.8
22	468.3	474.0	693.7	719.2	1159.3	1521.4
23	480.5	486.4	711.8	737.9	1189.5	1560.9
24	493.1	499.1	730.4	757.2	1220.4	1601.4
25	506.0	512.2	749.5	776.9	1252.2	1643.0
26	519.3	525.5	769.1	797.2	1284.8	1685.7
27	532.8	539.3	789.1	818.0	1318.2	1729.5
28	546.8	553.4	809.7	839.3	1352.5	1774.4
29	561.1	567.8	830.8	861.2	1387.7	1820.4
30	575.8	582.7	852.5	883.6	1423.8	1867.7

Appendix 7: An Extrapolation of Carbon emission by classification of engine size and fuel type

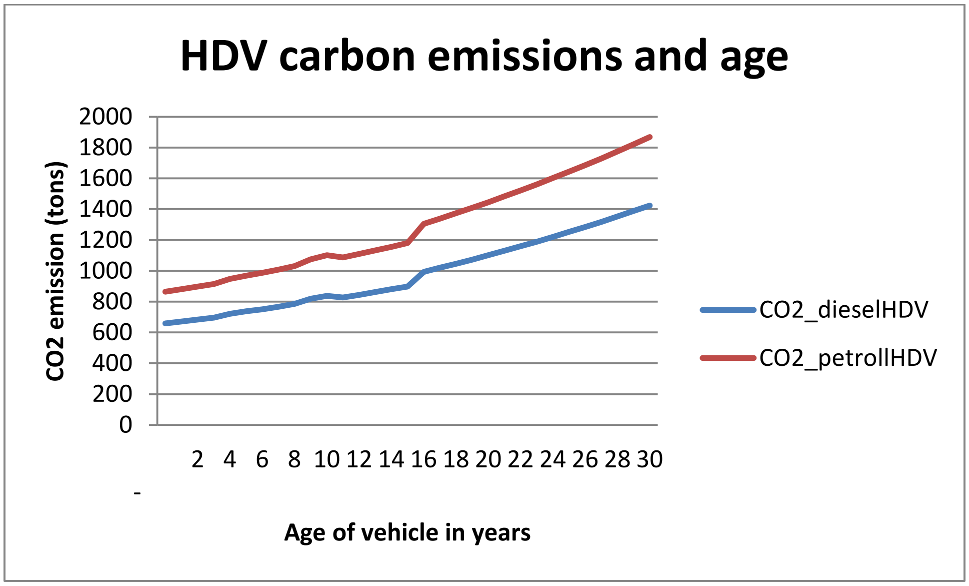
a. **Light Duty Vehicle**



b. **Medium Duty Vehicle**



c. **High Duty Vehicle**



Appendix 8; Projection of LDV fleet with 20year ban policy and without policy

	without policy		with 20 year ban	
year of registation	DIESEL	PETROL	DIESEL	PETROL
2000	787	662	477	651
2001	1067	799	688	787
2002	1308	886	832	882
2003	1528	1037	914	1029
2004	1915	1590	1115	1569
2005	2269	2463	1213	2436
2006	2761	2687	1415	2658
2007	3846	4031	2069	3968
2008	4757	4883	2556	4799
2009	4864	5387	2413	5291
2010	5108	7338	2700	7259
2011	5781	7754	2978	7620
2012	8235	14202	3675	13949
2013	17468	29737	8756	29232
2014	24057	40499	11956	39900
2015	15137	24584	7475	24193
2016	16851	27706	8295	27264
2017	18657	30998	9169	30502
2018	20533	34414	10081	33863
2019	22449	37905	11012	37298
2020	24396	41462	11961	40798
2021	26333	45072	12897	44352
2022	28233	48567	13807	47792
2023	30143	52000	14739	51171
2024	32012	55215	15662	54333
2025	33672	58021	16460	57093
2026	35039	60469	17139	59506
2027	36063	62188	17651	61198
2028	36921	63904	18008	62883
2029	38707	67221	18883	66142
2030	41481	72189	20245	71036
2031	43133	75142	21048	73942
2032	44749	78028	21832	76781
2033	46337	80861	22602	79569
2034	47908	83658	23364	82321
2035	49470	86440	24121	85059

2036	51037	89232	24881	87806
2037	52619	92068	25648	90596
2038	54225	94965	26425	93447
2039	55871	97947	27221	96381
2040	57571	101017	28046	99402
2041	59311	104139	28889	102474
2042	61054	107262	29735	105547
2043	62733	110248	30555	108485
2044	64286	113020	31306	111213
2045	65804	115745	32040	113894
2046	67445	118691	32835	116793
2047	69096	121658	33636	119712
2048	70755	124638	34440	122645
2049	72418	127625	35246	125584
2050	74080	130611	36053	128522