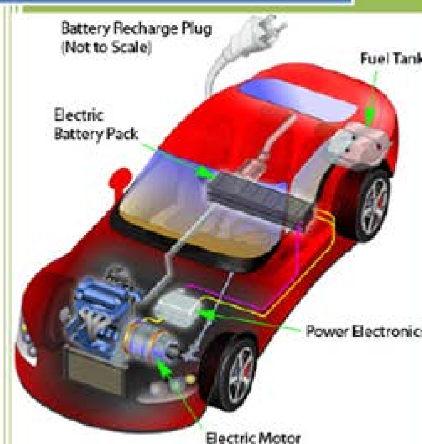
FEDERAL TRANSPORT AUTHORITY

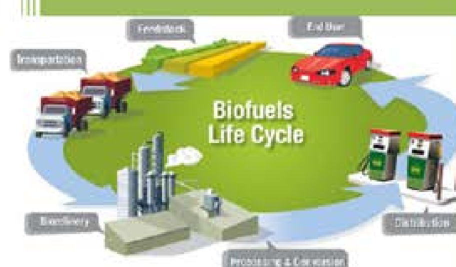
2012

Final Report on Pilot Global Fuel Economy Initiative Study in Ethiopia



By

ADDIS ABABA INSTITUTE OF TEHNOLOGY



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ACRONYM

AACG:	Addis Ababa City Government
AU:	African Union
BAU	Business as Usual
CD	Core Diplomatic
CIF	Cost, Insurance & Freight
DPF	Diesel Particulate Filter
ECRGES	Ethiopia's Climate-Resilient Green Economy Strategy
EFI	Electronic Fuel Injection
EPA	Environmental Protection Authority
EPE	Ethiopian Petroleum Enterprise
ERCA	Ethiopian Revenues & Customs Authority
ETH	Ethiopia
FDRE	Federal Democratic Republic of Ethiopia
FO:	Freight on Board
FTA	Federal Transport Authority
GFEI	Global Fuel Economy Initiative
GHG	Green House Gas
GTP:	Growth & Transformation Plan
ICCT	International Council on Clean Transportation
IEA	International Energy Agency
ITF	International Transportation Federation
LCC	Life cycle costs
No	Number
OPEC	Organization of Petroleum Exporting Countries
Proc	Proclamation
Reg	Regulations
SNNPR	Southern Nations, Nationalities and People Region
UN	United Nations
UNEP	Unite Nation Environmental Protection
UNFCCC	United Nations Framework Convention on Climate Change
VAT:	Value Added Tax

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1. BACKGROUND AND INTRODUCTION

1.1 Country Background

Ethiopia is a country located in East Africa between 3 and 15 ^{0} N latitude and 33 and 40 ^{o} E longitude. The total land area is about 1.1 million square kilometers. Ethiopia is bounded to north and north east by Eretria, to east by Djibouti, to east and south east by Somalia, to south by Kenya, to south west by South Sudan and to west and to north west by Sudan.

Ethiopia's population has slightly exceeded 80 million at present that makes it the second most populous country in Africa. The population is growing at around 2 % per annum. While most part of the country in central, west and north and south Ethiopia are highlands, the lowland areas are mostly located in east, south east and the rift valley part of the country. Most of central, south and western parts of the country receive sufficient rainfall.

Since 1995, Ethiopia is a multi-national Federal Democratic Republic and is currently governed by the Ethiopian People's Revolutionary Democratic Front (EPRDF. Ethiopia has achieved 11% economic in the last 10 years and has planned to reach middle-income status by 2025. Increasing agricultural productivity and the share of the industry to the economy are the main strategies. To achieve this goal Ethiopia's Growth and Transformation Plan (GTP) is an ambitious development plan of the government that is targeted to lay strong foundation for industrialization up to 2015.

Ambitious industrial development in the country with conventional path of development can result in negative environmental impact by increasing GHG emission drastically. To mitigate this, the government has finalized the preparation of Climate Resilient Green Economy development strategy in 2011 and began its implementation. The strategy will enable exploitation of the vast hydropower potential, use of improved stoves in rural areas, efficiency improvements in livestock value chain, preservation of the forest, utilization of electricity from hydropower plants for freight transportation by building railway network and light train transit in cities and use of improved and new technology vehicles with higher efficiency.

1.2 Project Background

While fuel efficiency of a vehicle is the volume of fuel consumed per unit or specified distance travelled, fuel economy of a vehicle is considered to be the distance travelled per unit volume of fuel. The fuel-efficiency of vehicles became a great concern for the first time when OPEC increased fuel prices in 1970s following the Arab-Israel War in 1973. Within few years fuel-efficient cars were considered a necessity to mitigate sky-rocketing fuel price. Starting 1990s, the concern on the global warming made the reduction of fuel consumption of vehicles very urgent. The global car fleet is predicted to triple by 2050 and over 80% of the increase will be in developing countries, which will be a burden to the strained global economy and can accelerate global warming if the current style of industrial development in the developed countries is followed.

The Global Fuel Initiative (GEFI), which was formed by UNEP. IEA and ITF in 2009 and joined by ICCT in 2012, sees that there is an opportunity to improve new car fuel efficiency by 30% by 2020 and 50% by 2030 in a cost effective way [UNEP,2010]. An improvement of fuel efficiency will result in a proportional reduction on fuel consumption. Hence, it means that 30 % of fuel will be saved per km traveled by 2020 and 50 % by 2050. The potential for improvement of vehicle fuel economy can be realized by combination of the following course of actions:

a) Improvement of fuel efficiency of conventional vehicles by reducing old vehicle stock. Newer vehicle can have less frictional resistance and higher combustion efficiency by, lean mixture burning and better electronic control. Improvement of transmission efficiency by using continuously variable transmission.
b) Use of compact vehicles: vehicles with less body weight and projected area have less aerodynamic and gravitational resistance and hence consume less fuel.
c) Use of new vehicle technology: Green vehicles are those that are environmentally friendly compared to conventional gasoline or diesel vehicles. Green vehicles have higher fuel efficiency or use no fossil fuel and hence, release less emission. This category of vehicles includes hybrid vehicles, plug-in electric vehicles, fuel cell vehicles and alternative fuel vehicles. Green vehicles that have completed the technology development stage and in commercialization phase are: hybrid vehicles, plug in electric vehicles and alternative fuels.

d) Road improvement
   - Roadway expansion reduces congestion delay which reduces fuel consumption.
   - Road condition improvement by frequent repair and street resurfacing reduces vehicle braking and wear.

e) Changing driving habits: Driving with minimal acceleration and braking or cruising at constant speed as much as possible

f) Changing transport modalities:- Availability of mass transit reduces passenger cars on the streets or mileage that has to be covered and can contribute to vehicle fuel economy.

Road transport is the biggest mode of transport that has a share over 95%, both in freight and passenger movement in Ethiopia. It is estimated that the vehicle population has exceeded 325,000 and growing by about 10% annually. Most of the vehicles are older than 15 years and beyond their useful service life. As a result high fuel consumption, emission of pollutants, and road accident prevail.

The increase in road passenger-km travelled in Ethiopia was forecasted at an annual growth rate of 8.3%-9.1%. The total passenger transport in passenger-km in Ethiopia is expected to increase from 40 billion in 2010 to 220 billion in 2030 driven by a strong urbanization. According Ethiopia's Climate-Resilient Green Economy strategy, if business goes as usual (BAU), emissions from the motor vehicles will increase from 5 -ton CO_2 in 2010 to 41ton CO_2 in 2030 as shown in Figure 1.1 [FDRE,2011].

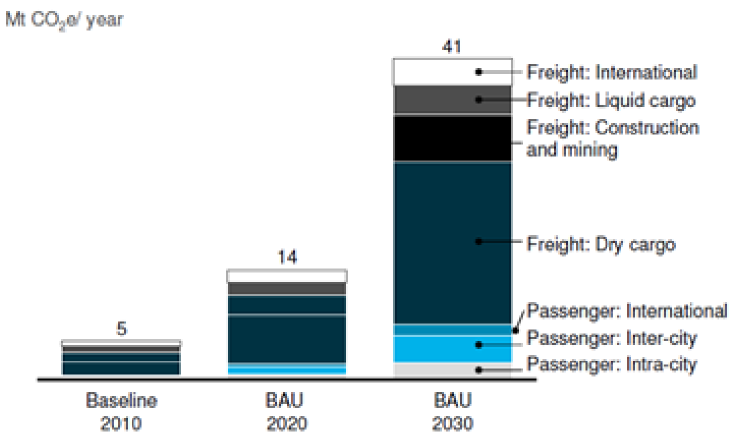


Figure 1.1 CO_2 emissions in million ton from the transport sector in Ethiopia as per BAU scenario

As a result GHG emissions of passenger cars will increase from 2.5 million ton in 2010 to 13.1 million ton CO_2 equivalent in 2030 assuming there will be average fuel efficiency improvement of passenger vehicle fleet by 10% from 2010 to 2030.

By introducing new technologies in the transport sector, the emission of CO_2 is planned to be reduced down to 13.2 million ton CO_2 in 2030 compared to BAU case. The major courses of actions proposed by ECRGES are:

- Reducing demand of passenger cars in Addis Ababa by building a light-rail transit system that goes from east to west and north to south and a bus rapid transit system;
- Improving vehicle fuel efficiency by setting fuel efficiency standards,
- Promoting clean fuels by blending ethanol with gasoline and gasoil with biodiesel
- Adopting hybrid and plug-in electric vehicles,
- Shifting freight transport from road to an electric rail network. Shifting freight to electric rail is the single largest abatement lever in the Transport sector, with a potential of 8.9 ton CO_2 reduction.

With regard to using alternative fuels, the plan is to use 15 % ethanol- 85 % gasoline blend and 5 % biodiesel blend. As there is no limitation, the biodiesel content can be increased provided enough jatropha or castor seed are cultivated and the oil is extracted and esterified. The blending of gasoline with 15 % ethanol will not be a problem as excess ethanol will be available from 10 sugar factories that will be erected in the near future. The use of bio-fuels will reduce emission of greenhouse gases as well as contribute to stabilizing fuel price.

Ethiopia has signed the United Nations Framework Convention on Climate Change in Rio de Janeiro, in 1994. According to the terms of the responsibilities of the convention, Ethiopia has submitted initial communication in 2001 and it is working to contribute to efforts in reduction of global Green House Gas (GHG) emissions by promoting green economic development strategy. It is well known that reduction of GHG emissions requires reduction of fossil fuel consumptions. Hence, Ethiopia is working with United Nations Environment Program (UNEP) to increase vehicle fuel efficiency by identifying and implementing relevant policy package.

Motor vehicles produce more air pollutants than any other single human activity. Nearly 50% of global carbon monoxide (CO), hydrocarbons (HCs) and nitrogen dioxide (NO_2) emissions from fossil fuel combustion come from petrol and diesel engines. In city centers and congested streets, traffic can be responsible for about 80-90% of these pollutants and this situation is expected to be severe in cities in the developing countries. Vehicle emissions mainly result from fuel combustion. The most common type of transport fuels are gasoline (leaded or unleaded form) for light duty vehicles (such as automobiles) and diesel fuel for heavy duty vehicles (such as buses, and trucks). For heavy duty vehicles, other commercial fuels such as biodiesel and compressed natural gas (CNG) are available. These fuels, especially biodiesel, have lower value of emissions per liter. Carbon dioxide (CO_2) (a major greenhouse gas responsible for global warming), is one of the main combustion products emitted to the atmosphere from vehicle exhaust system. The major pollutants emitted from gasoline fueled vehicles are CO, HCs, NOx (oxides of nitrogen) and lead (for leaded gasoline fuel). In addition to these, a vehicle with diesel engine emits sulfur dioxide (SO_2) if sulfur is present in the fuel and particulate matter (PM) emissions. Specially, when the injection pump or nozzle has trouble in functioning properly, the particulate emission becomes high. In addition to these, a worn-out engine results in blue smoke exhaust due to combustion of lubrication oil.

Climate change resulting from the greenhouse effects will present significant challenges including risks to water supply and other resources. Global warming will also increase the frequency of extreme events such as heat waves and wildfires posing additional risks to human health and infrastructure. A changing climate will also make it more difficult to meet air quality standards. Higher temperatures increase the photochemical formation of ozone, as well as emissions from the natural sources such as plants. It also increases the demand for air conditioning resulting in the generation of additional electricity and smog forming emissions. The likelihood of more frequent wildfires also poses a risk for air quality. On the whole, global warming will make the control of smog-forming emissions more difficult and hence, meeting air quality standards.

As per the contract between the Federal Democratic Republic of Ethiopia Transport Authority and Addis Ababa Institute of Technology on “Pilot Global Fuel Economy Initiative (GFEI) Program/Project in Ethiopia”, the consulting team has prepared this draft final report.

1.3 Objectives

This study focuses on the following main objectives and draws possible intervention options to minimize the effects of atmospheric pollution and GHG emissions from cars in Ethiopia. The study:

- Provides baseline data for tracking progress in improvement of vehicle efficiency as per GFEI guidelines
- Ensures that Ethiopian policymakers have sufficient and updated information in order to draft appropriate legislations and guidelines for dissemination of more fuel-efficient vehicles that have fewer emissions of pollutants and GHG.
- Assesses the impact of vehicle emission and fuel quality on the ambient air quality
- Makes the study of GFEI in Ethiopia as a pilot for wide spread application in Africa
- Uses the experience gained for instructing Eastern Africa countries and sharing the experience on GFEI regional and global conferences.

2. NATIONAL REGULATIONS AND INCENTIVES FOR FUEL EFFCIENT AND ENVIRONMENTAL FRIENDLY VEHICLES

2.1 Policy & Strategy, Legal, Institutional & Regulatory Framework

Environmental protection has been given an utmost importance in Ethiopia. The FDRE Constitution (Proc. No. 1/1995) has provided two broad constitutional environmental objectives: viz., the achievement of clean and healthy environment (see Article 92 (1)), and the achievement of sustainable development (see Article 43 (1)).

The Ethiopian Environmental Policy and Conservation Strategy of Ethiopia (1997) provide also detailed & broad directions as to how to realize the two environmental objectives within the Ethiopian context.

In terms of environmental policy(as related to Atmospheric Pollution & Climate Change), it has been stated as follows: The policy recognizes that, even at an insignificant level of contribution of atmospheric green house gases, a firm & visible commitment to the principles of containing climate change is essential and to take the appropriate control measures to show concern and then deal with the rest of the world in a struggle to bring about its containment by those countries which produce large quantities of greenhouse gases.

The recent FDRE's Government GTP, and the ECRGES also incorporate plans, strategies and broad programs on to realize the two fundamental environmental objectives within the Ethiopian context [FDRE, 2011]. The government sees the opportunity to gear the development of the transport sector to contribute to a sustainable development pathway. The policy frame work by ECRGES to promote fuel efficient and environmentally friendly transportation was discussed in chapter 1.

Following the Environmental Policy & Conservation suitable legal and institutional, including regulatory, framework has also been instituted to achieve the two fundamental environmental objectives.

Proc. No. 295/2002 provides the institutional & regulatory framework with respect to environmental protection in Ethiopia. The institutional framework includes the Environmental Council, the Federal Environmental Protection Authority (EPA), the regional (including the two City Administrations i.e., Addis Ababa & Dire Dawa) Environmental

Agencies, and Environmental Units, which are legally expected to be established within each of the specific development sector institution.

The Environmental Council shall have the power to review proposed environmental policies, strategies and laws, and issue recommendations to the government (see Article 9 (1), Proc. No. 295/2002). The draft regulations to be prepared under this project shall then be approved by the Council of Ministers (see Article 20 Proc. No. 300/2002 (Environmental Pollution Control Proc.) cum Article 77 (13), Proc. No. 1/1995 of the FDRE Constitution). The basis for the Council of Ministers legislative action shall be the recommendation submitted to it by the Environmental Council.

The EPA shall have a number of coordination responsibilities under the law. The EPA thus shall have the power & duties to coordinate measures to ensure that the environmental objectives provided under the Constitution and the basic principles set out in the Environmental Policy of Ethiopia are realized (see Article 6 (1), Proc. No. 295/2002). Specifically, with respect to environmental pollution & standards, the EPA, in consultation with the competent agencies, sets environmental standards and ensures compliance with those standards (see Article 6 (7) Proc. No. 295/20020).

The EPA under the Environmental Pollution Control Law (i.e., Proc. No. 300/2002), has been provided with the following clear powers & duties with respect to setting environmental standards. In consultation with competent agencies, the EPA shall formulate practical environmental standards based on scientific & environmental principles (see Article 6(1)). Among such possible environmental standards, one of them is air quality standards that specify the ambient air quality & give the allowable amount of emission for both stationary & mobile air pollution sources (see Article 6 (1) (b)).

From the project perspective, the competent organizations are meant to be the Ministry of Transport and Transport Authority. The Ministry of Transport and the Transport Authority shall also have the legal obligation to cooperate with EPA with respect to setting environmental standards as related to mobile source of air pollution such as from vehicles. As per Article 7 (1) (j) of Proc. No. 468/2005, the Transport Authority, in cooperation with the concerned organs prepares and submits, and upon approval, implements standards related to the smoke, gas, vapor, and the like emitted from the exhaust pipes of the vehicles and trains with a view to preventing pollution, taking into account international criteria and the capacity of the country.

In terms of legal framework, Proc. No. 300/2002, the Environmental Pollution Control Proclamation is another very relevant law with respect to controlling environmental pollution including those from vehicular emission.

In terms of guiding any economic development by the principle of sustainable development, Proc. No. 299/2002, the Law of Environmental Impact Assessment, shall also be relevant.

As related to international obligation & participation of Ethiopia, in terms of GHG reduction, the following international instruments constitute the required legal framework:

- Proc. No. 439/2005
- Kyoto Protocol Ratification Proclamation, which protocol has been based on the UN Framework Convention on Climate Change, and has been ratified by the Ethiopian government.

In terms of the sector (Transport) specific legal regulation, the following proclamations & regulations are very relevant in determining the legal framework. These are:

- Proc. No. 468/2005 (the Transport Authority establishment law)
- Proc. No. 681/2010 (vehicle identification, inspection & registration law)
- Proc. No. 691/2010 (Ministry of Transport empowerment law)
- Regulations No. 208/2011(road transport traffic control law)
- Regulations No. 74/2001 (motor vehicles & trailers identification, inspection & registration law).

In terms of customs & tax systems, and incentive related issues, the following constitute the legal framework:

- Proc. No. 285/2002 (VAT)
- Proc. No. 286/2002 (Income Tax)
- Proc. No. 300/2002 (Environmental Pollution Control Law)
- Proc. No. 622/2009 (Customs Proclamation)
- Proc. No. 691/2010 (Incentives related, as related to the Ministry of Finance & Economic Development)
- Proc. No. 307/2002 (Excise Tax, Withholding Tax, Income Tax Proclamation)
- Regulations No. 133/2007; (Import Sur Tax, except on those exempted motor vehicles for freights & passengers, and special purpose motor vehicles)

The regulation of fuel efficiency & vehicular emission is related to multifaceted legal institutional & regulatory framework**.**

2.2 Vehicles Import Customs Duties & Applicable Taxes and Incentives

2.2.1 Customs Duties & Taxes

The customs tariff for imported vehicles shall be based on CIF cost of the vehicle unlike other goods, which is based on FOB price. The custom & other applicable taxes (tariff) in relation to vehicles are thus calculated based on CIF cost & as provided under the applicable customs tariff & respective tax laws.

The following are the information collected from the relevant sources at the ERCA & the applicable laws. Except those exempted, in relation to vehicles, the possible types of charges (customs & all taxes) applicable to imported vehicles are the following: customs duty, value added tax, excise tax, sur tax, and withholding tax. These are shown in Table 2.1.

a) Customs Duty

The applicable law shall be Proc. No. 622/2009 (Customs Proclamation), the Customs tariff (see Article 45 (1)) & applicable customs related regulations. Customs duty is generally applicable to all types of vehicles. The customs tariff rate may extend from 10% up to 35% depending on the weight or capacity of the vehicle under consideration. The customs value for imported goods shall be the actual total costs of the goods up to the first entry point into customs territory of Ethiopia (see Article 32 (2) cum Article 33 & 39; see also Article 32-Article 44 as related to calculation of customs value; Article 51-Article 53 as related to payment of customs duties and taxes and service charges on imported goods including vehicles; Article 67-Article 68 as related to relief (tax exemption) procedures). The payment of customs tariff on goods including vehicles is based on Vol. II Customs Tariff, officially issued by the ERCA. The latest version is January 2008 based on the 2007 version of the Harmonized System. Vehicles related customs tariff has been provided under Chapter 87 of the Customs Tariff Book (see pp 569-577).

b) Value Added Tax

The legal framework for VAT is Proc. No. 285/2002 and the relevant & applicable VAT regulations. VAT is generally applicable to all imported goods except those exempted transactions (see Article 8 cum Article 8 (2) (j), for example). The rate could be 0% (see Article 7 (2) (b)) or fixed rate i.e., 15%. VAT is applicable to imported goods including vehicles (see Article 2 (7) and here goods mean all kinds of corporal movable items. The person who imports vehicles is a VAT payer (see Article 3 (1) (b). In the VAT proclamation a person carrying out taxable import of goods to Ethiopia, shall be a VAT taxpayer. The value of a taxable import, as per Article 15 (1), is the customs value of goods determined in accordance with the customs legislation of Ethiopia, plus the sum of duties & taxes payable upon the import of the goods into Ethiopia, excluding VAT and income tax withholding.

c) Excise Tax

The legal framework for Excise Tax is Proc. No. 307/2002 and related regulations. Excise Tax may not be applicable to some types of vehicles. The tax rate may also be different from vehicles to vehicles. The tax rate extends from 30% up to 100% depending on the capacity of the vehicle under consideration. The person liable to the payment of excise tax shall be an importer. Importer means any person (natural or juridical) who imports goods, which are subjected to the payment of excise tax, in to the country (see Article 2 (2)). To this effect, the Proclamation under its Schedule (Item No. 15), has provided the following:

- Motor passenger cars, Station Wagons, utility cars & Land Rover, Jeeps, pickups, other similar vehicles (including motorized caravans), whether assembled with their appropriate initial component or not follows the following tax categorization;
    - Item no 15.1: up to 1300 cc 30%;
    - Item no 15.2: from 1301cc up to 1, 800 cc 60%;
    - Item no 15.3: above 1 800 cc 100%.
- According to Article 5 (2), the base for computation of excise tax, with respect to goods imported, shall be based on cost, insurance & freight (CIF).

d) Import Sur Tax:

The applicable law with respect to Import Sur Tax shall be Reg. No. 133/2007. Import Sur Tax shall apply to all goods imported into Ethiopia except those exempted ones (see Article

2). The exemption has two aspects: schedule based exemption & non-schedule based exemption. Under the schedule based exemption & in relation to vehicles, motor vehicles for freight & passengers, and special purpose motor vehicles are exempted (see Article 5 cum the Schedule). Non-Schedule based exemption refers to goods imported by persons or organizations exempted from customs duty by law, directives or by (international) agreement entered into by the (Ethiopian) government. Import Sur Tax of 10% shall be levied & collected on all goods imported except the exempted ones. According to Article 4, the basis of computation for the import surtax shall be the aggregate of CIF value; customs duty, VAT & Excise Tax Payable on the good.

e) Withholding Tax

The applicable law for withholding tax shall be Proc. No. 286/2002 (Income Tax Proc.) specifically Article 52, Collection of Tax on Imports. This tax is applicable in relation to import of goods for commercial use. In particular Article 52 (1) states the follows:

> *A current payment of income tax shall be collected on Schedule C (Income/Business Income Tax) income at the time of import of goods for commercial use, and the collected amount treated as tax withheld that is creditable against the tax payer's income tax liability for the year. The amount (as withholding tax) to be collected on imported goods shall be 3% of the sum of CIF value (see Article 52(2)).*

The charge/tax rate may generally be categorized in to three as 0 rates, low rate, and higher (full) rate.

- Zero rate (0%) applies for the following goods/items: ambulances, fire fighting vehicles, defense vehicles; vehicles for handicapped (physically challenged)
- Low rate applies for the following one item, namely, tractors: The applicable customs duty & tax are as follows:

Customs duty	10%;
VAT	15%;
Withholding tax	3%.

There will be no payment of surtax & excise tax.

- Higher (full) rate shall be paid on vehicles either based on seats or horse power (cc). This is given in Table 2.1.

The vehicles importation system, as related to payment of customs duties and other applicable taxes including incentive regime is administered at two levels, policy & operational level.

At the policy level, the policy related to fiscal matters shall be initiated and administered, if approved by the Ministry of Finance and Economic Development (see Proc. No. 691/2010: Article 18 and see also Article 67 of Proc. No. 622/2009).

Table 2.1 Custom Duty and Tax Rates of Imported vehicles in Ethiopia

No	Goods /Items	Customs Duty %	Excise Tax %	Import Sur Tax %	VAT %	With holding %
1.	**Public Transport** Less than 15 and greater or equal to 10 seats 15 or more seats	 35 10	 - -	 - -	 15 15	 3 3
	Passenger cars Less than 10 seats					
2.	Cylinder capacity not exceeding 1300 cc	35	30	10	15	3
3.	Cylinder exceeding 1300 cc but less than 1800cc	35	60	10	15	3
4.	Cylinder exceeding 1800 cc not exceeding 3000 cc	35	100	10	15	3
5.	Electric/Battery Vehicles	35	30	10	15	3
	Trucks					
6.	Cargo vehicles (based on weight) up to 1500 kg	35	-	-	15	3
7.	Cargo vehicles >1500 kg	10	-	-	15	3
8.	Heavy Duty, 5 - 20 ton	10	-	-	15	3

At the operational level the importation of vehicles system, as related to enforcement of customs duties & other payable taxes on imported vehicles, is administered by the Federal Revenues & Customs Authority based on the Harmonized System (see Proc. No. 587/2008 (ERCA Establishment Proc.) cum Proc. No. 622/2009: Customs Proc. & other applicable laws).

2.2.2 Incentives

Each tax related law may provide incentive regime. The incentive regime shall serve as exemption from the payment of the required tax or customs as provided. Incentives are more commonly as related to economic objectives than related to environmental objectives.

a) As related to Customs Duty

According to Article 67, Proc. No. 622/2009, duty free privilege with respect to import of goods may be granted by law, international agreement to which Ethiopia is a party or by directives to be issued by the Ministry of Finance & Economic Development. There are thus three options to secure incentives: law, international agreement or directives.

In relation to vehicles, the following enjoy such privilege: ambulances (of different capacities in a complete state), fire fighting vehicles, defense vehicles, vehicles for handicapped (physically challenged).

If further privilege is to be provided for other vehicles, it has to be provided by law or by directives to be issued by the Ministry of Finance & Economic Development (see Article 18 (5), Proc. No. 691/2010 cum Article 67, Proc. No. 622/2009).

b) As related to VAT

According to Article 8 of Proc. No. 285/2002, some exempted transactions have been stated in Article 8 (2) as follows:

> As per Article 8 (2) (j) the following types of import goods are exempt from payment of VAT to the extent provided by regulations. These are :
>
> Goods (the legal definition of goods also includes vehicles) imported by the government organizations, institutions or projects exempted from (customs) duties and other import taxes to the extent provided by law or agreement.

Article 8(4) also provides a possibility of granting exemptions for other goods & services, due to directives to be issued by the Minister of Finance & Economic Development.

c) As related to Excise Tax

The Excise Tax law (Proc. No. 307/2002) provides the assessment & payment of excise tax on certain types of vehicles (as per its Schedule) from 30% up to 100% excise tax. The Excise Tax provides no incentive regime.

d) As related to Import Sur Tax

Import Sur Tax is administered as per Import Sur Tax Reg. No. 133/2007. This law provides the following exemptions to the following vehicles as per its Schedule. These are: motor vehicles for freight & passengers, and special purpose motor vehicles.

e) As related to Environmental Objectives

Incentives for environmental objectives have been envisaged under Article 10, Proc. No. 300/2002 (the law of environmental pollution control); given as follows:

Incentives for the introduction of ***methods*** that enable the prevention or minimization of pollution to an existing undertaking shall be determined by the regulations issued under the proclamation. Importation of ***new equipment*** that is destined to control pollution shall, upon verification by the EPA, be exempted from payment of custom duty.

Article 28 of Reg. No. 25/2007 (of the Addis Ababa City Government) also provides the following: Incentives for the introduction of methods to an existing undertaking that enable to prevent or minimize pollution shall be determined by the regulations to be issued by the Federal Government for the implementation of Environmental Pollution Control Proc. No. 300/2002.

The Federal Government has issued Reg. No. 159/2008 in relation to industrial pollution. The Federal Government environmental regulations (i.e., Prevention of Industrial Pollution Council of Ministers Regulations No. 159/2008) deal specifically on industrial pollution. Although these regulations focus mainly on stationary source of pollution from industrial source, smoke limits and maximum CO concentration in motor vehicle exhaust is given. However, the given CO limits are very high.

The incentive regime envisaged under the Federal Government environmental pollution control proclamation & the Addis Ababa City Regulations, however, are only applicable to factories. If there is a possibility of interpreting it differently, the content & scope of tax provisions have to be interpreted restrictively. Therefore, it may not be possible to widen, by interpretation, the scope of Article 10 (under the proclamation) & Article 28 (under the said City regulations) to cover vehicles as well.

This obviously requires a policy dialogue to be held with the Ministry of Finance & Economic Development, based on concrete proposals, to initiate the required incentive regime by way of legislative amendment. Legally, the federal EPA is the key institution to initiate such incentives.

The legislative measure required for consideration of incentives as related to vehicles might depend on the type of the relevant tax or customs regime: viz., customs duty or VAT or Excise Tax or Import Sur Tax.

The legislative measure may be required at two levels: at statutory level and/or non-statutory level. The statutory level amendment may come in two aspects: in relation to amending Proc. No. 300/2002 & in relation to the tax law at statutory level (say customs duty law or VAT). The non-statutory legislative amendment or measure may come into picture in the following way: in relation to a given tax regime law (say Import Sur Tax regulations).

Based on such statutory amendment, the incentive regime has to be provided for vehicles by the new draft regulations (non-statutory) to be prepared under the present project.

By way of conclusion, the envisaged incentive regime under the environmental pollution control laws may not be applicable for vehicles. There is a clear legal gap pertaining to incentives for vehicles. Therefore, a legislative measure, in terms of legislative amendment & new legal instrument, has to be taken to realize the desired incentive regime for vehicles.

2.3 Vehicles Registration & Inspection System

2.3.1 Vehicles Registration System

Vehicles identification, inspection and registration system is governed by Proc. No. 681/2010. As per the proclamation (see Article 2 (1)) vehicles means any type of wheeled motor vehicle other than special military vehicles, for use on roads classified as carriage, bicycle, motor vehicle, semi-trailer & trailer (see also Article 2 (13), Proc. No. 468/2005). Motor vehicle means (see Article 2 (4)) any vehicle moving on a road by mechanical or electrical power. The definition for motor vehicle has been broadly defined by Proc. No. 468/2005: Motor Vehicle means a vehicle moving by mechanical or electrical power, classified as truck, motorcycle, private motor car, public service vehicle, truck, tractor and special mobile equipment. Each of the items under the definition has been defined legally separately.

Vehicles, except those exempted by such proclamation, are identified through the registration system. The exempted groups are the following (see Article 5, Proc. No. 681/2010);

inventory vehicles; vehicles engaged in international traffic; special mobile equipment with a maximum speed of less than 20 km per hour; and carriages of handicaps.

The registration system is based on ownership & identification number plate. The identification number plate is divided into two, federal & regional. The ownership identification system is similar (except for those only to be issued by the federal government like embassies, international organizations & aid plates, ETH) both at federal and regional (including the City of Addis Ababa and Dire Dawa) level, which is identified by different colors and codes. Those colors & codes, except for temporary, transferrable & special mobile equipment plate, provide the ownership dimension of the vehicle under consideration.

As per the Schedule, attached to the said Proc., the following 11 (eleven) plates are provided: Taxi plate; Private Plate; Commercial Plate (see also under ETH Plate); Government Plate (see also under ETH Plate); Religious & Civic Societies Plate; Temporary Plate; Transferable Plate; Special Mobile Equipment Plate; Police Plate; Embassies, International Organizations & Aid Plate; ETH Plate (indicates vehicles engaged in cross country commercial road transport service or owned by the federal government);

The regional (including the city of Addis Ababa & Dire Dawa) plate types have also been provided under the same Schedule with their respective abbreviations (like AA to indicate vehicles registered in Addis Ababa).

Ownership of vehicles may thus conveniently be categorized into the following four groups: private, government, international & non-government which will include:

- Private; taxi, private & commercial
- Government; government itself & police
- International; embassies & international organizations (UN, AU & CD); and
- Non-governmental; domestic & international: religious & civic societies (domestic), and international aid organizations;

The ownership dimension may help design the implementation strategy, from which group of vehicles to commence implementation of the fuel efficiency and the environmental requirement of vehicular emission reduction.

2.3.2 Vehicles Inspection System

The applicable law (i.e., Proc. No. 681/2010) clearly provides a legal requirement for the annual inspection (see Article 25) of vehicles except for those exempted under such law (see Article 26). According to Article 29, there are four vehicles inspection criteria.

Among the inspection criteria environmental criteria is one. According to Article 29 (1) (d), it is stated as follows: An authorized inspector of an inspection station shall inspect each vehicle presented for the purpose of establishing the vehicles *compliance with environmental pollution protection standards* as per the appropriate law. As per this law (Article 29(2)), the federal Transport Authority has also been authorized to issue directives to provide for additional inspection criteria and the implementation of the Article.

Reg. No. 208/2011, as per its Article 10 (1) (a) clearly prohibits the following; No person may drive on a road any vehicle which is not properly maintained, discharges smoke, vapor, oil or fuel of higher amount than the appropriate level and which is likely to cause annoyance or damage to other road users or the environment.

There is no legally prescribed environmentally related standard vehicles inspection criteria yet. As discussed with relevant informants, the Transport Authority has also not yet issued the required directives as provided under Article 10 (2) of the said Proclamation (No. 681/2010).

Therefore, based on the new vehicular emission level, the said directives have to be prepared & issued by the Transport Authority.

2.4 Ethiopia's International Obligation/Participation

Emission of GHG to the atmospheric environment including from vehicular source is of an international concern due to its contribution to climate change. Ethiopia, as one of the member of the international community and therewith to the global environmental system, is an active participant in the protection of the global environment.

This is evident from the number of legislative ratifications already done with respect to international environmental agreements by the Ethiopian government. Among the international environmental agreements ratified by the Ethiopian government, pertaining to atmospheric environment, the UN Framework Convention on Climate Change (ratified in 1994) and the Kyoto Protocol (ratified in 2005) are few. Ethiopia is not as such a country classified as contributor to the atmospheric pollution. Her participation at international level is based on voluntary and thus on moral obligation basis.

2.5 Formulation of Draft Regulations

The need for drafting new draft regulations with a view to promote fuel efficient vehicles & therewith to regulate vehicular emission is evident. However, there are some issues to be discussed, namely, the need to have an ambient air quality standard; the need to establish vehicular emission standard; under which type of tax law the type of incentive to be provided; at what level the draft regulations to be issued as regulations; and the scope of application of the said draft regulations.

Ambient air quality standard is a prerequisite to determine the (vehicular) emission level. There is no legally established ambient air quality standard in Ethiopia. Such quality standard has to be determined by law. The initiative has to be taken by the Federal Government EPA to this effect. There is an already developed draft ambient air quality standard.

The vehicular emission standard has been prepared by adoption, under the current project.

Under which type of tax law the incentive to be provided requires serious discussion by all stakeholders. The recommendation could be to provide an exemption from Excise Tax and/or from Import Sur Tax.

Should the provision of incentives for vehicles undergo two legislative processes, statutory & non-statutory, such legislative process looks as follows.

2.5.1 Statutory Legislative Process

To provide the required incentive regime on environmental objectives, the required legislative amendment has to be made in relation to Proc. No. 300/2002. This is going to be done by the House of Peoples Representatives based on the draft amendment proclamation to be prepared both by the Federal Government EPA in consultation with the Transport Authority, then to be submitted to the Ministry of Finance & Economic Development. The draft proclamation may go through the respective standing committees, for their respective legislative review, before the House deliberates on same for its legislative measure. This is to be so since the incentive regime touches two dimensions: economic dimension (revenue) & environmental dimension (protection).

2.5.2 Non-Statutory Legislative Process

The process to be passed by the draft regulations may look as follows: the draft regulations have to be prepared by the current project (based on the required inputs emission level, incentive regime, implementation strategy, scope of application, etc.); the draft regulations have to be presented for comments by stakeholders in a workshop; comments secured from the workshop have to be incorporated; the draft regulations have to be submitted by the Ministry of Transport and Transport Authority to the Federal Government EPA; the EPA then submits same to the Environmental Council for its due deliberation & recommendation; the Environmental Council then submits the draft regulations to the Council of Ministers for its executive action to issue the draft regulations as legally binding & effective regulations.

The following subjects determine the level of government to issue the required regulations:

- legal power on energy matters (given to the Ministry of Water & Energy; see Article 26 (1)) (j), Proc. No. 691/2010);
- power to formulate minimum emission standard level (through federal EPA as provided under Article 6, Proc. No. 300/2002);
- power to decide on tax & customs including incentive matters (as per the federal Constitution (by the House of Peoples Representatives see Article 55 cum Article 96 (1) the provisions which provide the power of the Federal Government on taxation, specifically, on customs duty & import related taxes);(by the respective customs duty & tax laws by the Council of Ministers through its respective regulations); (by the Ministry of Finance & Economic Development (see Article, 18(5), Proc. No. 691/2010);
- power to manage customs & import tax matters on imported goods (by the ERCA as per Proc. No. 587/2008);
- power to manage vehicles in terms of their classification, registration & inspection (by the federal Transport Authority as per its establishment law Proc. No. 468/2005 & other transport related laws).

All these issues, unless delegated, are the mandate of the Federal Government. Therefore, the draft regulations have to be submitted to the Federal Government for its issuance, instead of submitting same to the AACG.

2.6 Conclusion

This project attempts to address the achievement of double objectives: economic objectives (in terms of increasing vehicles fuel efficiency) & environmental objectives (in terms of reducing vehicular emission). Technological dimension is also an integral part of both objectives.

This part of the project concludes the following:

a) There is no legally established ambient air quality standard in Ethiopia.
b) There is no legally established vehicular emission standard in Ethiopia.
c) The introduction of the vehicular emission standard in Ethiopia imperatively requires the prior legal establishment of a local ambient air quality standard.
d) The introduction of the vehicular emission standard imperatively requires subsequent detail administrative directives to be issued by the Transport Authority.
e) The importation of vehicles (as imported goods) is subjected to the assessment & payment of customs duties and other import taxes: viz., VAT, Excise Tax; Import Sur Tax including Withholding Tax (the last one being creditable to the tax payer).
f) The excise tax is made dependent on cylinder volume. Thus, it penalizes vehicles that consume more fuel per km and emit more exhaust per km. Hence, it is indirectly related to fuel economy and emission. However, the group of vehicles with cylinder volume less than 1000 c.c. are not given tax incentives compared to the group 1000 c.c. -1300 c.c..
g) The heavy tax on passenger cars with seat capacity less than 10 persons is responsible to the aging of the fleet.
h) Incentive for vehicles based on new technologies (hybrid vehicles, electric vehicle etc.) that result in radically higher fuel economy and lower emission has not yet been provided in Ethiopia.
i) The granting of legally recognized & established fiscal incentives for importation of vehicles requires legislative measure at two levels: at proclamation level (as related to amendment of the pollution control law) & at regulations level (in terms of new regulations to be prepared under the Project, which may touch one or more of the import tax laws, viz., VAT, Excise Tax and/or Import Sur Tax).
j) The legislative measure determines at which level of government such measure is to be taken; by the House of Peoples Representative (in case of amending the pollution

control proclamation) or by the Council of Ministers (in terms of issuing the new draft regulations to be /prepared under this Project) or by the Minister of Finance & Economic Development by issuing directives.

k) The new draft regulations to be prepared under this project shall be applicable in all regions of Ethiopia.

l) The registration of vehicles system of vehicles is based on ownership of vehicles (private, government, international & non-governmental) & based on such ownership, the respective code has been given to vehicles.

m) Environmental objectives & criteria has been recognized under the applicable laws in terms of annual vehicles inspection, but lack details (directives) for their due enforcement.

n) The economic & environmental dimensions of the objectives of this project involves multitude of stakeholders for its implementation; this may include government institutions (like the Federal Government EPA, FTA, Ministry of Transport, ERCA, AACG, the Police, relevant ministries (specifically Ministry of Water & Energy, Ministry of Finance & Economic Development,), the private sector (in terms of vehicles inspection) & the relevant civic societies (in terms of education).

3. BASELINE SETTING FOR VEHICLE EFFICIENCY IMPROVEMENT AND EMISSION REDUCTION

One of the major activities of the study on Pilot Global Fuel Economy Initiative Program in Ethiopia is vehicle registration data collection, vehicle data analysis, and vehicle performance determination for the baseline years 2005, 2008 and 2010 from which progress in improvement of vehicle efficiency will be tracked as per GFEI guidelines (GEFI,2011). The process ensures that Ethiopian policymakers have improved information in order to draft appropriate legislations and guidelines for dissemination of more fuel-efficient vehicles that have less emission of pollutants and GHG, and to assess the impact of vehicle emission and fuel quality on the ambient air quality. The accomplished tasks and the way forward in this direction are discussed in the following section.

3.1 Methodology

To undergo the study of the baseline setting for vehicle fuel efficiency improvement and emission reductions, there is a certain methodology set by Global Fuel Economy Initiative.

The methodology consists of the following steps:

- Setting the objectives
- Collecting vehicle registration data
- Cleaning data
- Structuring data
- Estimating baseline fuel economy
- Report findings

This step by step methodology has been adopted for ease of analysis and comparing the result of the study to other countries which underwent similar study.

3.1.1 Objective

The main objective for this study is setting a baseline and developing a national vehicle database, which is necessary to track improvement in fuel economy and reduction of emission of carbon dioxide and other pollutant per unit vehicle.

3.1.2 Data Attributes

Depending on the availability of the vehicles data and the objective of database to be developed, different data attributes might be considered by different organizations. For instance the International Energy Agency (IEA) specifies twenty four key attributes on Auto fuel economy database. While the ERCA recorded a maximum of fifteen data attributes for the purpose of capturing details of vehicles import, collecting taxes and controlling illegal smuggling into the country. Out of the fifteen data attributes some of them are irrelevant for the purpose of auto fuel economy database such as CIF, total tax, country of consignment, chassis number etc. Besides, some important data attributes were not registered for numerous vehicles in the database. As such there was a need to look for other sources to fill the gap, specifically internet was one of the major sources among others. In many developing countries like Ethiopia, it is difficult to find detailed and full-fledged national information regarding vehicle data as mentioned above, where in this context the GFEI specifies the absolute minimum data attributes that are required for auto fuel economy database. These data attributes include key parameters, directly or indirectly, used for quantifying vehicle fuel efficiency and CO_2 emission calculation which are listed below:

i. Vehicle make and model,
ii. Model production year
iii. Year of first registration, if different from model year
iv. Fuel type
v. Engine size
vi. Domestically produced or imported
vii. New or second hand import
viii. Rated Fuel Economy per model and test cycle basis.
ix. Number of sales by model

3.1.3 Data Collection

Newly registered vehicles are those imported and assembled in the country at a particular year. The appropriate locations for this data are the database of imported vehicles at Ethiopian Revenues and Customs Authority (ERCA) and vehicles assembling enterprises. ERCA is an autonomous federal agency responsible for collecting revenues from customs duties and domestic taxes. From ECRA data for newly registered light duty vehicles (LDVs) for selected years were collected. The vehicle data incorporates brand new vehicles as well as used ones with gross weight less than3500 kg and having number of seats less than or equal to 15. Such types of vehicles are known as light duty vehicles.

The light duty vehicles data in this study includes passenger cars and compact cars, saloon cart car, small sport utility vehicles (SUV), as well as pick-ups.

The data was collected only for the years 2005, 2008, 2010 and 2011. Except for the latter, the years were selected based on UNEP guidelines for the ‘‘Pilot Global Fuel Economy Initiative Project in Ethiopia’’.

The second source was from passenger car assembly plants.

3.1.4 Data Cleaning

With respect to the key data attribute suggested by GFEI, the data acquired from ERCA must be cleaned and structured. The first approach would have been to clean the vehicle data on the ERCA’s database by removing unnecessary information, but it was found to be very difficult due to the severe irregularities and missing data. The second approach would have been to fill the data with a new format that suits the GFEI scheme. However, this option was also found to be cumbersome and time taking, at least, to do it manually. The main reason was that most of the data was unstructured or simply written in single record as shown in Table 3.1.

Table 3.1 Example of unstructured raw data in ERCA’s database

TOYOTA COROLLA (CH#JT1EOEE9000447281,M/Y1992 MODEL-EE90L-AEMDEW,ENG-2E-2451657)
ENGINE 3L-5475634, MODEL LN166L-PRMDS,M/Y2004 (TOYOTA HILUX DOUBLE CABINE PICKUP CH.NO. JTFDE626X00128020)
NISSAN X-TRAIL MOD.TVHNLAYT30URAY062Z (CH.NO. JN1TENT30Z0005735 EN.NO. YD22146725)
1*2ND HAND CAR TOYOTA COROLLA,M.Y 1992 (CH#.JT1LOEE9007143710, CC 1295 MOD#.EE90L-ALMDEW,ENG#.2E-2441128)
TOYOTA CORLLA, CH.NO. JTFDE626X00128021

An attempt has been made to develop a computer program to sort out data collected to extract manufacturing year, model, and cylinder volume. However, due to the strong irregularities associated with the original registered data at ECRA, the computer program was not effective in all cases. Hence, the results obtained (sorted data through a computer program) needed manual cleaning and sorting. The process of data cleaning is presented as follows. Table 3.2 shows raw data received from ECRA database

Table 3.2 Example cleaned and structured data

Make	Model	Condition	Body Type	Engine Disp. Vol. CC	Net Weight	Fuel Type	Qty	Production year	Regist. Year	Fuel economy l/km	GHG Emission gCO2/km
TOYOTA	COROLLA	USED	SALOON	1300	950	PETROL	1	1986	2005	12.2	192.9
TOYOTA	COROLLA	USED	SALOON	1300	1000	PETROL	1	2003	2008	15.3	153.8
FORD	FIESTA	NEW	COMPACT	1250	3441	PETROL	3	2010	2010	13.2	178.3
HYUNDAI	GETZ	NEW	COMPACT	1086	961	PETROL	1	2010	2010	17.7	133.0
NISSAN	HARDBODY	NEW	PICK UP	3153	3836	DIESEL	2	2010	2010	11.3	236.6
TOYOTA	HILUX	USED	PICK UP	2779	3000	DIESEL	1	2002	2008	9.0	296.0
TOYOTA	HILUX	NEW	PICK UP	3000	5535	DIESEL	3	2005	2005	9.6	276.7
TOYOTA	LAND CRUISER	NEW	S.WAGON	4164	2060	DIESEL	1	2004	2005	7.5	355.2
TOYOTA	MINIBUS	USED	VAN	2779	1540	DIESEL	1	1988	2005	9.0	296.0
TOYOTA	MINIBUS	USED	VAN	2494	1620	DIESEL	1	2007	2010	11.4	233.7
NISSAN	PATROL	USED	SUV	4169	2400	DIESEL	1	2007	2010	7.5	355.2
V.WAGEN	POLO	USED	SALOON	1450	1435	PETROL	1	1997	2005	10.0	235.4
TOYOTA	PRADO	USED	SUV	2694	2500	DIESEL	1	2007	2010	8.6	309.8
TOYOTA	RAV 4	USED	SUV	2362	1600	DIESEL	1	2007	2010	8.6	309.8
TOYOTA	TACOMA	USED	PICK UP	2326	1600	PETROL	1	2005	2008	8.2	287.1
DAIHATSU	TERIOS	NEW	SUV	1300	2070	PETROL	2	2005	2005	11.5	204.7
TOYOTA	TUNDRA	NEW	PICK UP	5663	2710	DIESEL	1	2010	2010	5.1	522.4
TOYOTA	VITZ	USED	COMPACT	997	1000	PETROL	1	2005	2008	12.9	182.7
NISSAN	X-TRAIL	NEW	SUV	3000	1560	DIESEL	1	2005	2005	8.0	333.0
TOYOTA	YARIS	NEW	SALOON	1299	1000	PETROL	1	2010	2010	15.4	153.1

Table 3.2 shows part of the cleaned data that differentiates vehicles by Make, Model, Condition, Body type, Engine volume, Net weight, Fuel type, Quantity, Production Year, Registration year, Fuel economy and CO_2 emission. These vehicle data are needed to classify vehicles and determine average fuel economy. The data was made complete by searching and filling values for parameters such as fuel economy and specific CO_2 emission from

manufacturers' websites and new vehicle dealers. Even then, after all these attempts, about 8.7% of the total LDVs for the year 2005, 9.14% and 9.12 % for 2008 and 2010 respectively are not qualified for the database because of lack of the absolute minimum important information that are required to calculate harmonic average annual fuel economy and average annual CO_2 emission.

3.2 Baseline Setting

According to the GFEI methodology, 2005 is used as a baseline year for fuel economy and CO_2 emission tracking. In this context, the starting year for the study is 2005. Once this baseline year is established, GFEI recommends that the same calculations be done for 2008, 2010, 2012 and the following calculations after two years. The total number of newly registered light duty vehicles for the years: 2005, 2008, and 2010 are given Table 3.3 and Table 3.4 for imports and locally assembled vehicles, respectively.

Table 3.3 Imported light duty vehicle registered per year

Years	**2005**	**2008**	**2010**
Quantity	5598	10254	14931

Table 3.4 Locally assembled light duty vehicles per year

Years	**2005**	**2008**	**2010**
Quantity	-	257	450

These light duty vehicles have weights less than3500 kg and seats number between 15 and 24. These vehicles are mainly used for personal transportation in urban areas, for public transportation purposes as well as for commercial purpose to transport small goods.

Figure 3.1 shows that there is a continuous increase in the number of newly registered light duty vehicles. The quantity increased by 83% from 2005 to 2008 and by 45% from 2008 to 2010. As local assembly of vehicles in the country started only recently, their share is insignificant, although it is growing as shown in Table 3.4.

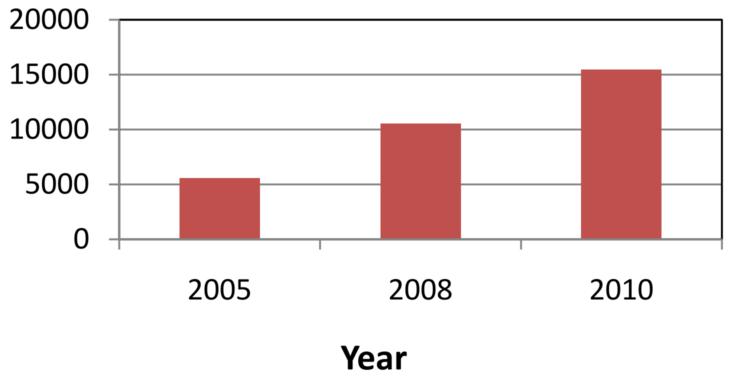


Figure 3.1 Total number of LDVs Registration by year

By comparing manufacturing year and registration year of particular vehicles considered for this study, vehicles are categorized either as used or brand new. The quantity of registered light duty vehicles has increased for both new and used ones from year to year as shown in Table 3.3. However, the rate of growth of used vehicles registration is greater than that of band new ones. Excessive import of used vehicles would by far contribute to CO_2 emission, as used vehicles consume more fuel than brand new.

Table 3.5 Light duty vehicles registration by condition (New and Used)

Import Years	**2005**	**2008**	**2010**
New	2011	3457	4335
Used	3587	6797	10596

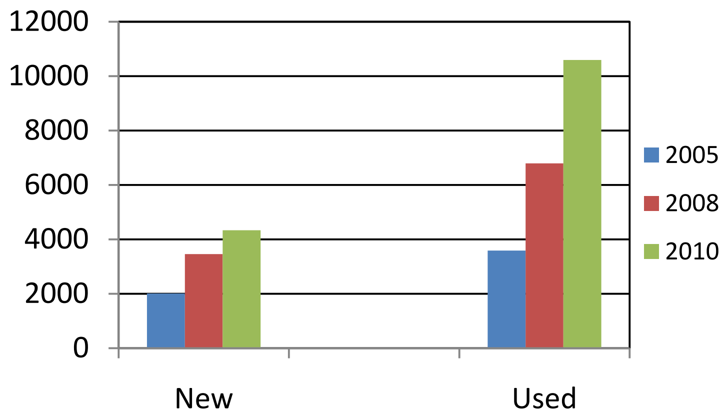


Figure 3.2 Light duty vehicle registration by condition (New and Used)

Table 3.6 and Figure 3.3 show classification of newly registered used vehicles by age group. The age group that consists of the highest number of vehicles is 1-5. Considering the new vehicles, about 50 % of these vehicles are up to 5 years age.

Table 3.6 Classification of registered LDVs by age group for year 2005, 2008, and 2010

Age Years Old	Registeration Year		
	2005	**2008**	**2010**
	2005-2001	2008-2004	2010-2006
1- 5	1989	3875	5500
	2000-1996	2003-1999	2005-2001
6-10	555	2111	3195
	1995-1991	1998-1994	2000-1996
11-15	895	813	2510
	≤ 1990	≤ 1993	≤ 1995
More than 15	1472	2489	1662

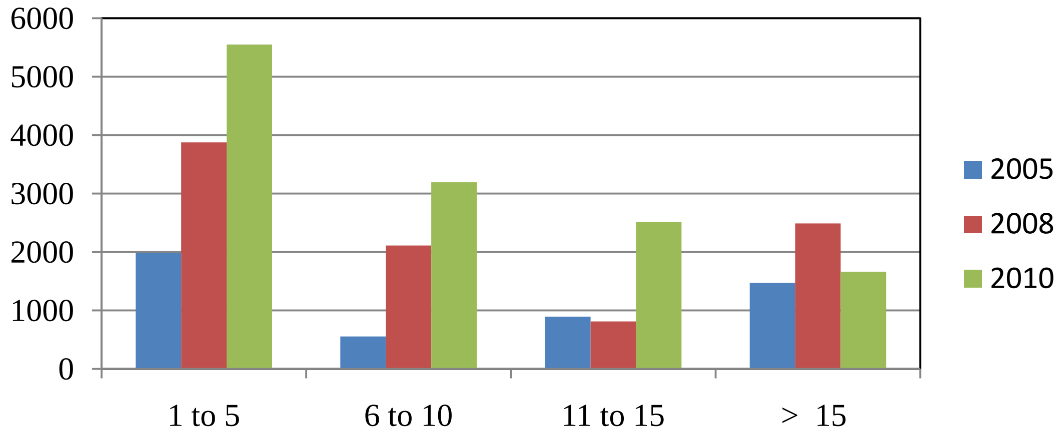


Figure 3.3 Number of registered LDVs in different years by age groups

Table 3.7 shows classification by engine displacement volume. While the most frequent range of engines displacement volume of registered light duty vehicles is 1001-1300 cc for petrol engines, it is engine group 2500-3000cc for that of diesel engines. These medium size diesel engines belong to SUV vehicles, pick up and vans. It can be observed that diesel fueled engines become more in number compared to petrol engines as the engine displacement becomes greater than 2000 c.c. Usually petrol fuel engines are more compact than diesel fuel engines.

Table 3.7 Classification of registered LDVs by engine displacement volume

Volume	**2005**		**2008**		**2010**	
(cc)	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel
≤ 1000	204	-	142	-	1190	-
1001-1300	1834	8	3378	5	3361	333
1301-1800	309	8	417	29	390	54
1801-2000	260	2	122	21	123	16
2001-2500	72	146	68	1181	186	2763
2500-3000	115	1953	192	3841	1590	4250

Figure 3.4 shows quantities of vehicles that were imported in the years 2005, 2008 and 2010. It is obvious that by far the most commonly used vehicle in Ethiopia is Toyota brand followed by Nissan, Suzuki and Mitsubishi. Amazingly the share of Toyota brand is as large as 72%, 78% and 80% respectively for the years 2005, 2008 and 2010, out of the total import of LDVs in Ethiopia. The main reasons for Toyota's brand in wide use in Ethiopia is assumed to be the abundant availability of spare parts, ample maintenance firms or garages, and the well known dealer. The people's perception towards Toyota brand durability is also very strong.

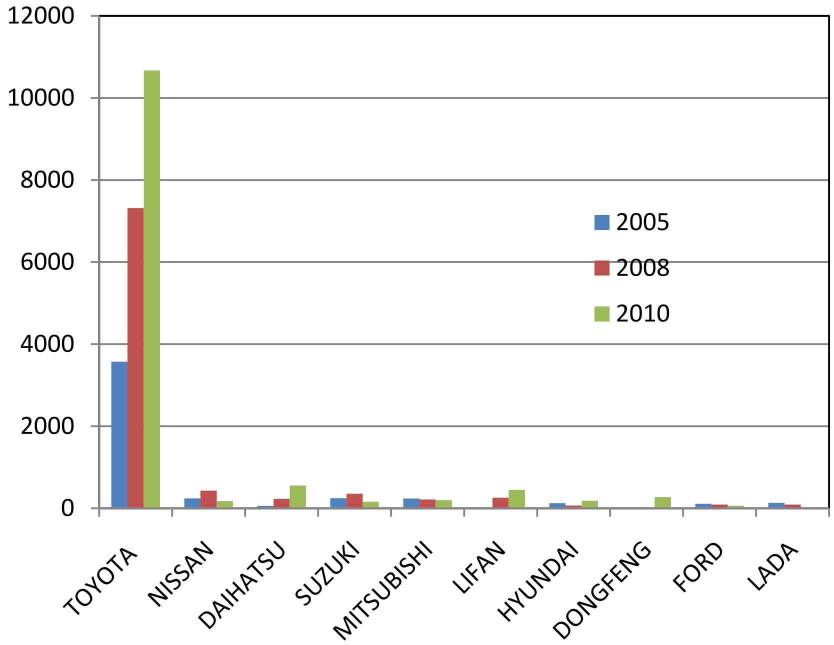


Figure 3.4 Classification of registered vehicles in no by make

It doesn't mean that only the brands shown in Figure3.8 are available in Ethiopia. There are many more brands as well, and just to mention some of them: GMC, Cadillac, Geely, Lexus, Range Rover, Opel, Fiat ,Hummer, Tata, Land rover, Sangyong, BMW, BYD ,Honda, Cherry, Isuzu, Holland car etc

Table 3.8 Classification of registered LDVs by body type

Import Year	2005	2008	2010
Compact	118	140	1257
Saloon	1994	3316	3366
SUV	488	796	934
Mini-SUV	399	812	1315
Van	938	2662	3704
Pick up	974	1562	2280

From Table 3.8 and Figure 3.5 show the classification of registered vehicles by body type. Saloon car took the lead up to 2008 followed by vans that surpassed it in 2010. Although compact vehicles were insignificant 2005-8, considerable increase of this type of vehicles occurred in 2010.

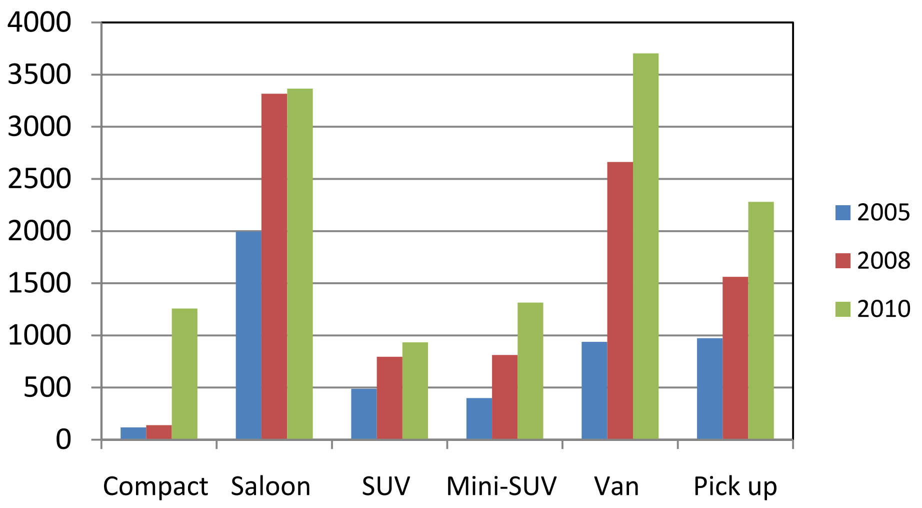


Figure 3.5 Body types of registered LDVs by year in number

As it can be seen from Table 3.9 or Figure 3.6 and Figure3.7, the number of annually registered diesel engine vehicles surpassed that of petrol engine vehicles in 2008. This indicates that the imported vehicles are mainly for public transport and commercial transport.

Table 3.9 Registration of LDVs by fuel type

Fuel type	2005	2008	2010
Diesel	2117	5091	7419
Petrol	2794	4197	5437

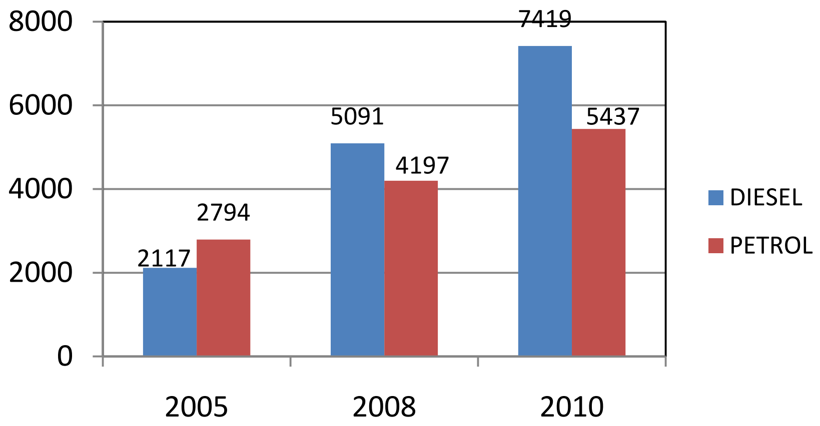


Figure 3.6 Classification of registered LDVs by fuel type in number

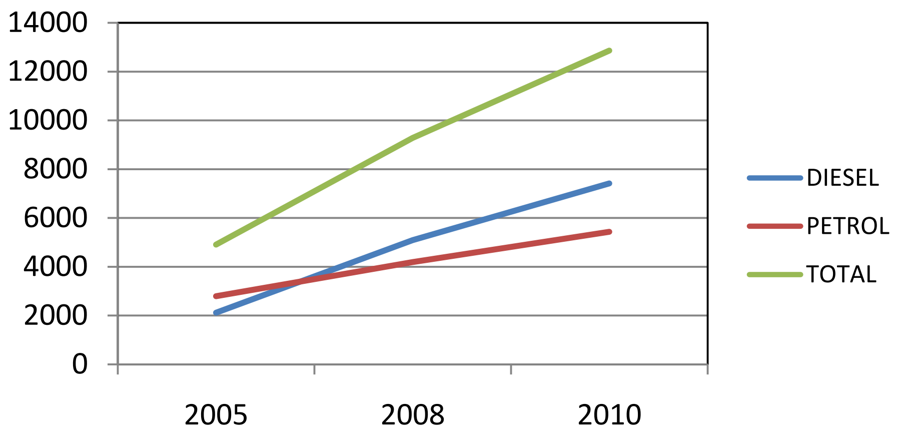


Figure 3.7 Quantity of LD Vehicles registered by fuel type

3.3 Estimating Baseline Fuel Economy

The harmonic average annual fuel economy of all newly registered vehicles in the country in a given year is calculated by taking a weighted average by sales indicated in the database

$$\boldsymbol{Harmonic\ average\ annual\ fuel\ economy} = \frac{\boldsymbol{Total\ sales\ in\ the\ year}}{\sum_i^n \frac{\boldsymbol{sales\ model\ i}}{\boldsymbol{fuel\ economy\ model\ i}}}$$

Similarly the average annual carbon dioxide emission can be calculated through the weighted average with sales of each model.

$$\boldsymbol{Average\ annual\ emission} = \frac{\sum_i^n \boldsymbol{sales\ model\ i} * \boldsymbol{emission\ model\ i}}{\boldsymbol{Total\ sales\ in\ the\ year}}$$

Note that all the auto fuel economy data that have been included in the database are in compliance with the New European Driving Cycle (NEDC). As such conversion factor has not been applied to convert from EPA to NEDC.

European Drving Cycles

The ECE(UDC) +EUDC or combined cycle is performed on a chassis dynamometer. The entire cycle includes four ECE segments, Figure 1, repeated without interruption, followed by one EUDC segment, Figure 2. Before the test, the vehicle is allowed to soak for at least 6 hours at a test temperature of 20-30°C. It is then started and allowed to idle for 40s.

Effective year 2000, that idling period has been eliminated, i.e., engine starts at 0 s and the emission sampling begins at the same time. This modified cold-start procedure is also referred to as the *New European Driving Cycle* or NEDC.

ECE 15

The ECE cycle is an urban driving cycle, also known as UDC. It was devised to represent city driving conditions

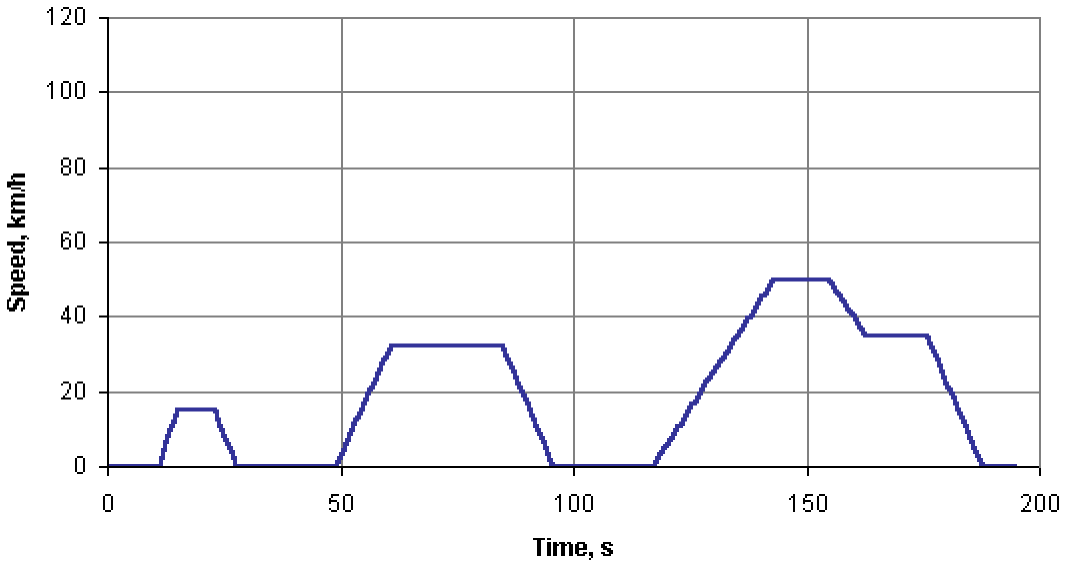


Figure 3.8 ECE 15 or Urban Drive Cycle

Extra Urban Driving Cycle (EUDC)

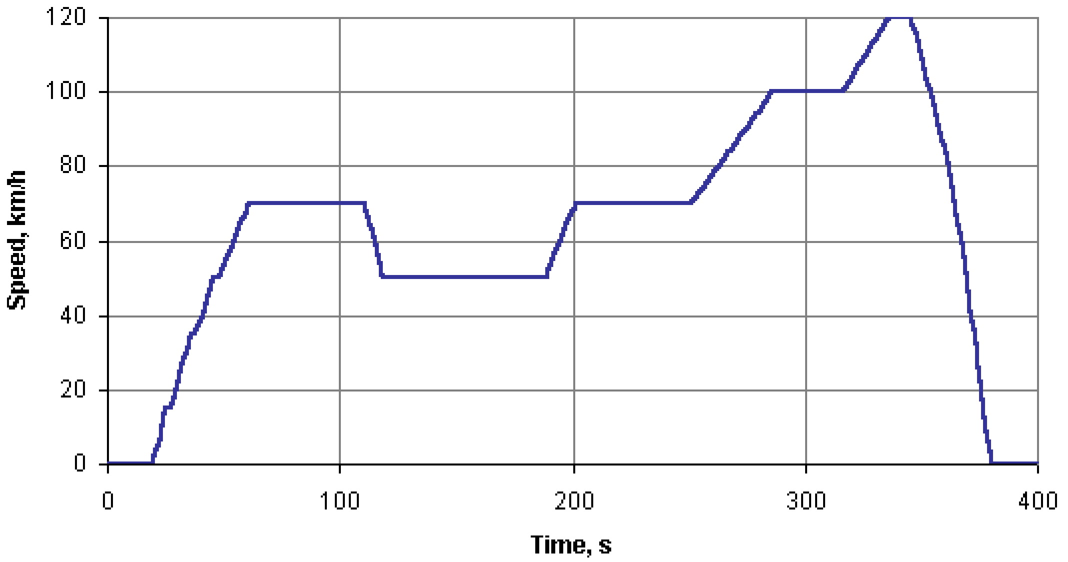


Figure 3.9 EUDC for high power Engine

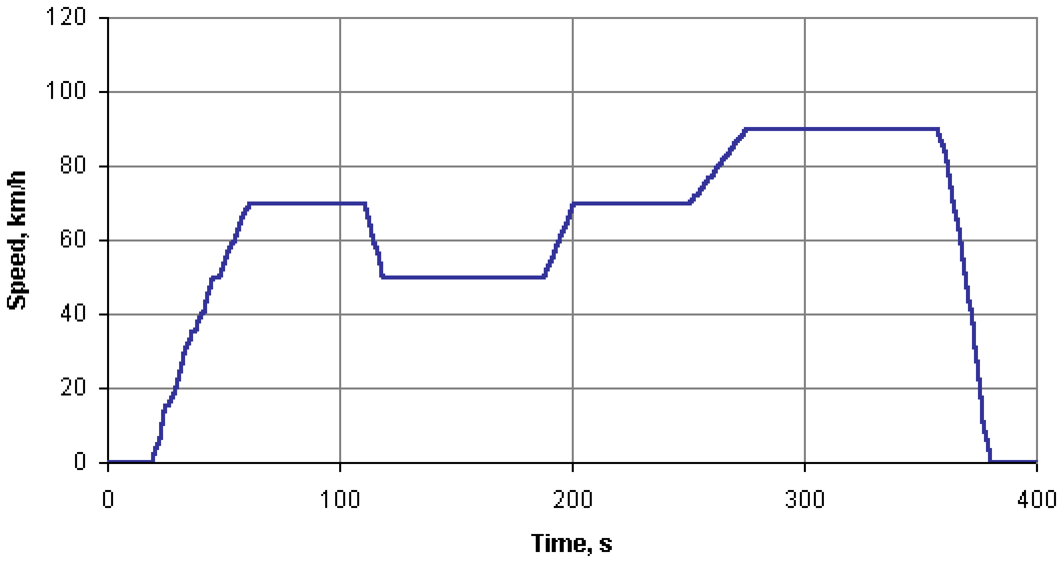


Figure 3.10 EUDC for Low power Engine

The calculation of harmonic average fuel economy and average annual emission has been done with two scenarios. Calculation for the first scenario is done by using the value of fuel economy that are available on manufacturers' websites and from other sources specified for the brand new vehicles, while the second scenario assumes the deterioration of fuel economy with age of the vehicles. As considerable portion of the LDVs imported to Ethiopia shown in Table 3.6 are more than six years old, the fuel economy is assumed to decrease by a certain factor with in an interval of five years from the value mentioned for the brand new vehicles. For instance, for vehicles more than 15 years old it is assumed that the fuel economy decreased by 2km/l from the value specified in the test cycle for brand new vehicles. Such value was specified by interviewing owners of old vehicles.

3.3.1 Average Fuel Economy and Annual Emission for New Vehicles

As mentioned above, the calculation is done assuming that all vehicles perform as brand-new in urban and combined (urban and extra urban) cycles. Table 3.10 and Figure 3.11 show that the fuel economy increased from11.5 km/l in 2005 and 2008 to 12 in 2010. The annual average fuel economy for diesel and petrol engine light duty vehicles are shown in Tables 3.11 and 3.12, where better improvement in fuel economy is obtained for vehicles with petrol engines.

Table 3.10 Harmonic Average Fuel Economy and Average Annual Emission for all LDVs

Registration Year	**2005**	**2008**	**2010**
Harmonic Average Fuel Economy (liter/(100 km)	8.7	8.7	8.3
Harmonic Average Fuel Economy (km/liter)	11.5	11.5	12
Average Annual Emission (g/km)	217	221	212

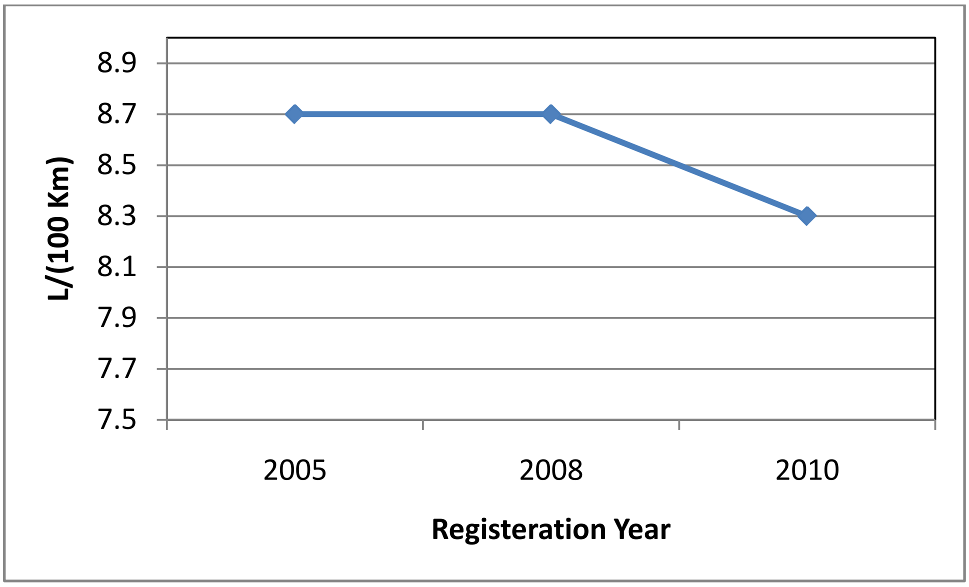


Figure 3.11 Harmonic average fuel economy trends for all LDVs in km/liter

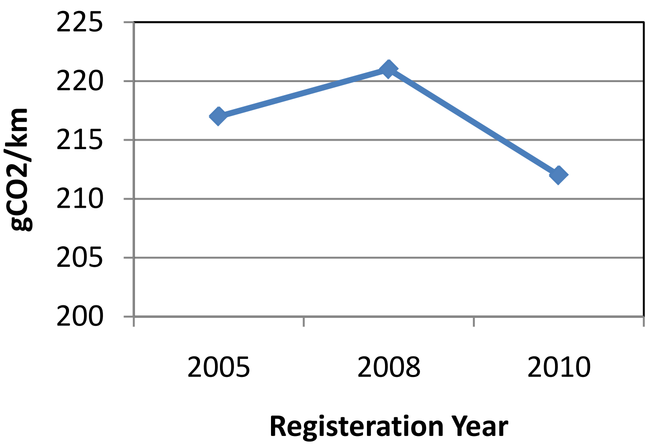


Figure 3.12 Average annual emission trend in g/km for all type of LDVs

Table 3.11 Harmonic average fuel economy and average annual emission for diesel vehicles

Registration Year	**2005**	**2008**	**2010**
Harmonic Average Fuel Economy liter/(100 km)	9.43	9.52	9.17
Harmonic Average Fuel Economy (km/liter)	10.6	10.5	10.9
Average Annual Emission (g/km)	251	255	245

Table 3.12 Harmonic average fuel economy and average annual emission for petrol vehicles

Registration Year	**2005**	**2008**	**2010**
Harmonic Average Fuel Economy liter/(100 km)	8.13	7.63	7.35
Harmonic Average Fuel Economy (km/liter)	12.3	13.1	13.6
Average Annual Emission (g/km)	191	180	173

3.3.2 Average Fuel Economy and Annual Emission Considering Age of Vehicle

As the engine deteriorates with age, it is definite that the specific fuel consumption will increase. Hence, a decrease in fuel economy of 1 km/l, 1.5 km/l and 2 km/l, for vehicles in the age range of 5-10, 10-15 and more than 15 year, respectively, is assumed.

Table 3.13 and Figure 3.13 show that the fuel economy increased from10 in 2005 and 2008 to 11.3 in 2010. The annual average fuel economy for diesel and petrol engine light duty vehicles are shown in Tables 3.14 and 3.15. Better improvement in fuel economy is obtained for vehicles with petrol engines.

Table 3.13 Harmonic Average Fuel Economy and Annual Emission for all LDVs

Registration Year	**2005**	**2008**	**2010**
Harmonic Average Fuel Economy liter/(100 km)	10	10	8.85
Harmonic Average Fuel Economy (liter/km)	10	10	11.3
Average Annual Emission	254	256	220

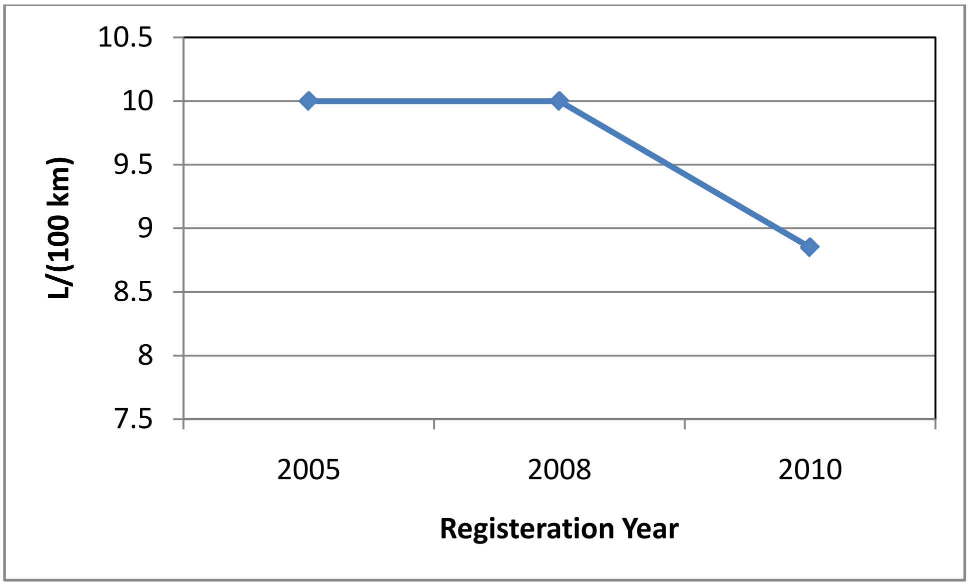


Figure 3.13 Harmonic average fuel economy for all registered LDVs in km/liter considering aging

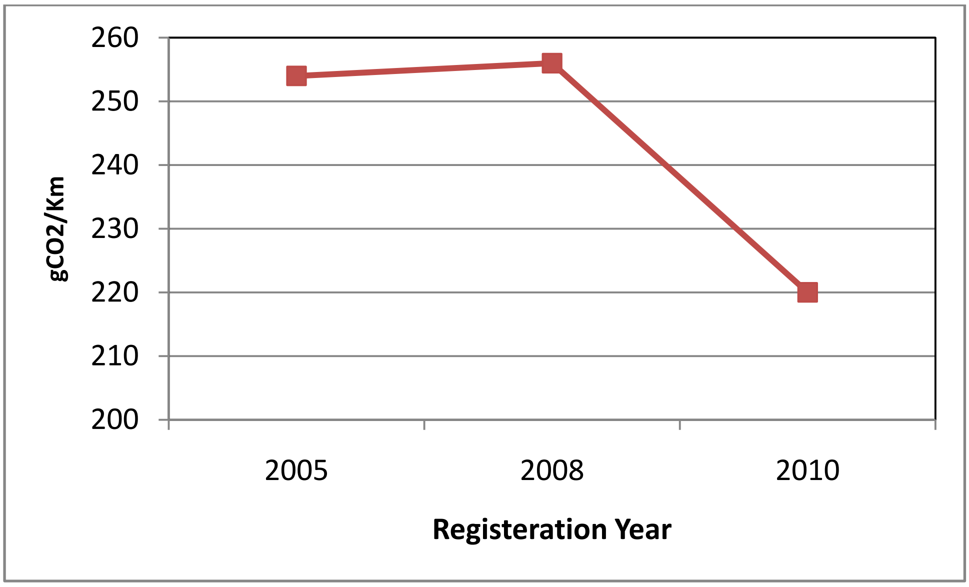


Figure 3.14 Average annual emission trend for all registered LDVs in g/km considering aging

Table 3.14 Harmonic Average Fuel Economy and Average Annual Emission for Diesel Vehicles

Registration Year	**2005**	**2008**	**2010**
Harmonic Average Fuel Economy liter/(100 km)	11.63	11.36	10
Harmonic Average Fuel Economy (km/liter)	8.6	8.8	10
Average Annual Emission (g/km)	310	303	267

Table 3.15 Harmonic Average Fuel Economy and Average Annual Emission for Petrol Vehicles

Registration Year	**2005**	**2008**	**2010**
Harmonic Average Fuel Economy liter/(100 km)	9.01	8.20	8.13
Harmonic Average Fuel Economy (km/liter)	11.1	12.2	12.3
Average Annual Emission (g/km)	211	198	191

3.4 Conclusion

Study from Ethiopian baseline setting of LDVs indicate that the average fuel economy for vehicles in Ethiopia in 2005 and 2008 were 8.7 L/(100 km or 11.5 km/l with corresponding CO_2 emission of 217 and 221 gCO_2/km while in 2010 the fuel economy slightly increased to 8.3 L/(100 km) or 12 km/l with a corresponding CO_2 emission of 212 gCO_2/km. Diesel fueled vehicles were found to travel less kilometer per liter of fuel as compared to petrol engine vehicles and emit more CO_2 than petrol fueled vehicles. This results are in lower regime when compared to that of reported in the literature [ICT,2012], which is caused by importation of old second hand vehicles.

4. VEHICLE STOCK STATISTICS

4.1 Methodology

The methodology employed to deal with the vehicle stock statistics in Ethiopia (Addis Ababa and selected Regional Governments) includes literature review of standard parameters to describe vehicle classification, vehicle technology and vehicle manufacturers' specifications, data collection, and data cleaning and analysis.,

4.1.1 Data Collection

To make complete the statistics of vehicle stock in Ethiopia and estimate environmental impact of vehicle emission, the annual vehicle inspection data available at Federal Transport Authority (FTA), computer database for the year 2011/2012 was utilized. The data available for Addis Ababa have been summarized from sub-city road and transport bureaus using similar template to include parameters. Even though there have been problems in the data entry and incomplete information such as engine cc, manufacture year, emission control technologies etc, the data available in Addis Ababa have been analyzed separately.

In addition, total fleet was collected from selected regional governments (Oromia, Tigray, Amhara, SNNPR and Benshangul Gumuz) to project the impact of vehicle fleet on fuel efficiency and emission across the country. The main challenge to get clean data from Road and Transport bureaus in the regions is that they are not using standard and similar format to record the vehicles history. Furthermore, in some cases, the data entry problem has left important parameters (engine cc, year of manufacturing, vehicle category, etc) incomplete and ambiguous. The total number of vehicles available in Addis Ababa and some regions in 2011/2012 is given in Table 1. The total vehicles number in Ethiopia is estimated to be 344.108 assuming the vehicle population in Afar and Gambella regions is similar Benshanguel Gumez region nand that was of Harari region is similar to Diredawa and 5 % of the the totl fleet were not registered due to several reasons.

4.1.2 Classifications

The total fleet in Addis Ababa and regional governments is broadly classified in to three groups as Motorcycles & Tricycles, Gasoline and Diesel vehicles in order to investigate the effect on fuel efficiency, fuel economy and emission.

Table 4.1 Total vehicles inspected in Addis Ababa and Regions (2010/11)

No	Location	Total number of vehicles from raw data(not cleaned)			Number of vehicles known engine cc and year of manufacture (cleaned data)				
		Motorcycles and tricycles	Gasoline vehicles	Diesel vehicles	Motorcycles and tricycles	Gasoline vehicles	Diesel vehicles		
							light	heavy	Bus
1	Addis Ababa	5015	123645	68322	2084	87736	27690	23490	2290
2	Amhara	6023	3834	10268	2121	1755	3585		
3	Benshangul Gumuz	299	469	334			56		
4	Oromia	4855	11140	17077	3141	5804	11627		
5	SNNPR-Debub	15225	2888	5663	6840	488	3857		
6	Tigray	4774	1763	5515	3339	1181	2881	620	624
7	ET	3305	5631	42867	1641	4323	11095	24381	1809
8	Diredawa	3111	2386	1513					
9	Soimali	1201	1153	2143					
	Total	**43808**	**152909**	**153702**					
	Total accounting for missing data	**49,893**	**344,108**						

a) Motorcycles and Tricycles

Many motorcycles and tricycles today use gasoline 2-stroke engines due to their smaller size and lower investment cost. However, 4-stroke engines in motorcycles are available and have several advantages. A 4-stroke engine is much cleaner and emits substantially less volatile organic compounds (VOCs) compared to a 2-stroke engines. A 4-stroke engine will probably cost a little more (10-15%) but uses less fuel, needs no separate lubricating oil, and require less maintenance. Modern 2-stroke engines with catalyst and direct injection systems have begun to enter the market. However, so far the endurance of the catalyst is a problem and the cost of a direct injected 2-stroke engine is similar to a 4-stroke engine.

b) Diesel Vs Gasoline Vehicles

Diesel vehicles (generally comprised of heavy-duty trucks and currently half of all new passenger cars) are more fuel-efficient compared to petrol vehicles, and emit less CO_2.

However, these engines have relatively higher emission of particulate matter (PM) and Nitrogen oxides (NOx). Gasoline vehicles (generally, passenger cars and some light duty trucks) are not as efficient as diesel but emissions of particulate matter and NOx are less. CO emissions are higher for petrol-powered vehicles; however, CO emissions are easily reduced with a catalyst and are not deemed as harmful to human health as particulate matter and NOx emissions.

4.1.3 Data Cleaning

Records of vehicle registration obtained from Federal Transport Authority (FTA) are considered as the main source of vehicle data for this study. The arrangement was made by Department of Mechanical Engineering and Ethiopian Transport Authority to facilitate access to vehicle records in transport authority, and other potential data sources.

It is well known that FTA collects and maintains vehicle databases to suit their own needs, basically for administrative purpose. Such data may or may not be compatible with the type of data sought for study on fuel efficiency and emission reduction. Hence, data cleaning and gap filling are needed. Information on attributes such as , manufacturing year, model number, engine number, engine capacity, cylinder number, fuel type, engine power, front axle number, rear axle number, front tire number, rear tire number, vehicle gross weight, vehicle cargo capacity, vehicle seat number, and registration date of the vehicle was obtained from the transport authority. Vehicle registration data and other parameters obtained from transport authority were fragmented and incomplete. In addition, there was a total absence of important attributes for this study such as type of air fuel mixture formation and emission controlling technology in the database.

The data cleaning process included sorting out the raw data obtained from the authority to fit the objectives of the study and filling missing information on key vehicle attributes. To fill missing data and include important vehicle attributes indicated above the following methodologies were used:

a. Preparation of standard format to sort the data obtained from Transport Authority. The summary of vehicle classification and important parameters is given in Table 4.2.
b. Unit conversion to make consistent and uniform (e.g. engine capacity was given in cc and liter)

c. Missing performance data, body type, etc. are searched from the manufacturers' website via internet and vehicle sales agents.

Table 4.2 Summary of vehicle classification and important parameters

<table>
<tr><th rowspan="2">Classification</th><th colspan="4">Type of vehicle</th></tr>
<tr><th>Motorcycles and tricycle</th><th>Gasoline Vehicles</th><th colspan="2">Diesel Vehicles</th></tr>
<tr><td>Brand</td><td>√</td><td>√</td><td colspan="2">√</td></tr>
<tr><td>Model</td><td>√</td><td>√</td><td colspan="2">√</td></tr>
<tr><td>Number of strokes</td><td>2 or 4 stroke</td><td>4 stroke</td><td colspan="2">4 stroke</td></tr>
<tr><td>Engine CC</td><td>√</td><td>√</td><td colspan="2">√</td></tr>
<tr><td>Motor Power</td><td>√</td><td>√</td><td colspan="2">√</td></tr>
<tr><td>Number of Cylinder</td><td>√</td><td>√</td><td colspan="2">√</td></tr>
<tr><td>Type of fuel used</td><td>Gasoline or Diesel</td><td>Gasoline</td><td colspan="2">Diesel</td></tr>
<tr><td>Type of air fuel mixture formation</td><td>X</td><td>Carburetor and Gasoline EFI</td><td colspan="2">X</td></tr>
<tr><td>Type of fuel injection system</td><td>X</td><td>X</td><td colspan="2">Diesel mechanical or electronic injection</td></tr>
<tr><td>Year of manufacture</td><td>√</td><td>√</td><td colspan="2">√</td></tr>
<tr><td>Number of wheels</td><td>2 or 3</td><td>4 and above</td><td colspan="2">4 and above</td></tr>
<tr><td>Emission controlling technology (ECT)</td><td>X</td><td>2 way or 3 way catalyst</td><td colspan="2">Diesel Oxidation Catalyst (DOC) or Diesel Particulate Filter (DPF)</td></tr>
<tr><td rowspan="5">Type of body
Or</td><td rowspan="5">X</td><td rowspan="5">Saloon
Van
SUV (Sport utility vehicle)
Pick up</td><td>Light weight diesel</td><td>Saloon
Van
SUV (Sport utility vehicle)
Pick up</td></tr>
<tr><td rowspan="3">Cargo diesel</td><td>Light duty truck</td></tr>
<tr><td>Medium duty truck</td></tr>
<tr><td>Heavy duty truck</td></tr>
<tr><td colspan="2">Bus</td></tr>
<tr><td>Weight (Gross vehicle weight rating)</td><td>X</td><td>X</td><td colspan="2">Class 1-8</td></tr>
<tr><td>Registration date</td><td>√</td><td>√</td><td colspan="2">√</td></tr>
</table>

4.1.4 Parameters for Data Cleaning

The consultant team has identified key parameters to clean the raw data collected that are relevant to fuel efficiency and emission issues from Federal Transport Authority and regional governments transport bureaus. These parameters have effect on fuel economy and emission reduction directly or indirectly. It is obvious that some parameters (air fuel mixture formation, emission control technologies and fuel injection systems) are specific for motorcycles, gasoline vehicles and diesel vehicles that require special attention for each vehicle classifications. On the other hand, age, body type, manufacture year, engine capacity, etc. are common features considered for all vehicle categories.

a) Type of air fuel mixture formation: - Generally, gasoline vehicles have higher fuel consumption as compared to diesel vehicles due to the air fuel mixture technology. The air fuel mixture technology in gasoline vehicles is either carburetor system or electronic fuel injection system. The study has considered that all gasoline vehicles manufactured before 1986 use carburetor systems and those vehicles manufactured since late 1980s use electronic fuel injection.

The fuel system for diesel vehicles is either diesel mechanical injection or diesel electronic injection. The diesel electronic injection system is the new technology introduced in late 1990s. Thus, all diesel vehicles manufactured after 2000 are considered to have diesel electronic fuel injection system which is efficient in fuel delivery based on the load and speed conditions.

b) Emission Controlling Technology:-The emission controlling technologies have a direct impact on emission reduction if they are properly used in motorcycles, gasoline and diesel vehicles. The type of fuel (gasoline or diesel) is the key factor to select the appropriate emission control technology. When strict vehicle emission standards were first set, all vehicles did not possesses the technology to significantly lower vehicle emission before 1970. Then, two way catalytic convertors were installed on gasoline vehicles in the mid 1970s and replaced by three way catalytic convertors in early 1980s.

Diesel vehicles were using diesel oxidation catalysts (DOC) as an emission technology to oxidize hydrocarbons (HC), carbon monoxide (CO) and the soluble organic fraction of particulate matter (PM) since mid 1990s. A DOC can work at sulfur level higher than 500 ppm, but there is a risk that sulfur contained in the fuel will also oxidize and form sulphate and thus actually increase the total emission particulate matter. The lower the fuel sulfur level, the more efficiently the DOC functions. Furthermore, the Diesel particulate filters (DPFs) are new technologies introduced in mid 2000 that function by capturing particulate matter in a filter and oxidizing the particles. Generally, some of the emission control technologies not only applied to new vehicles but can be installed or "retrofitted" in older in-use vehicles. However, many vehicles in Ethiopia are not equipped with emission control technologies because they are removed intentionally due to the lack of knowledge and maintenance facilities.

c) Engine Capacity:- The raw data collected from Federal Transport Authority and regional government transport bureaus include engine capacity having mixed measuring units (cc and liter), incomplete information and errors in the data entry. The engine capacity of gasoline vehicles (light duty cars) is considered in the range from 700 to 2200 cc. On the other hand, light weight diesel vehicles (Saloon, SUV, Minibus and Pickup) have engine capacity from 1200-6000 and heavy weight diesel vehicles (Cargo and Bus) engine capacity is from 1200-13000 cc.

d) Year of Manufacture:-It is an important parameter to know the technology of the total vehicle fleet in order to determine the fuel economy and emission reduction. New vehicles and modern technologies contribute significantly to fuel consumption and emission reduction. If the raw data do not contain the correct year of manufacture, the vehicles are ignored in the data cleaning process. The year of manufacture of all motorcycles, tricycles, gasoline and diesel vehicles is included up to 2011/12 G.C.

e) Gross Weight:- Gross vehicle weight rating is considered as a parameter to classify heavy weight diesel vehicles (trucks) and buses. The heavy weight diesel vehicles are classified as light duty (1000-6350 Kg), medium duty (6351-11793 Kg) and heavy duty trucks (11794-40000 Kg).

f) Body Type:-The shape and size of the vehicle body has a direct impact on the fuel consumption due to light weight and aerodynamic effect. The raw data has included some vehicle descriptions in line with the body type such as automobile, double cabin, pickup, bus, cargo and field vehicles. However, such important parameters were missing for many vehicles in the raw data, mainly from regional government offices. Therefore, additional criteria were set to clearly define the body type of gasoline and diesel vehicles. The summary of vehicle classification by engine and body type is given in Table 4.3.

4.2 Vehicle Stock Analysis in Addis Ababa

4.2.1 Motorcycles and Tricycles

The total number of motorcycles and tricycles in Addis Ababa classified in year of manufacture, engine capacity, number of stroke and fuel type are given in Table 4.4. The number of vehicles in each classification such as engine capacity, number of stroke and type of fuel are given in percentage adjacent to each group. Then, the distribution of vehicles in year of manufacture is given in each row. For example, the number of vehicles having engine capacity less than 100 cc is equivalent to 7.1% of the total population. Among those vehicles having engine capacity less than 100 cc, the number of motorcycles and tricycles manufactured before 1989 and 2005-2009 are 24.3 % and 39.9 %, respectively.

Table 4.3 Summary of vehicle classification by body type and engine capacity

Vehicle Classification by engine type	Vehicle classification by body type	Vehicle description in row data	Engine capacity(cc)	No. seat or weight (Kg)
Gasoline	Saloon	Automobile		
	Minibus	Minibus		
		Bus		
	Pickup	Double cabin		
		Pickup		
	SUV/ Sport Utility Vehicle/	Automobile	>1800	4-9
		Field vehicles	>1850	4-9
Light weight diesel vehicles	Saloon	All type	< 1800	4-9
	Minibus	Bus		≤15
		Automobile		≥ 10
	Double cabin/Pickup	Double cabin		
	SUV /Sport Utility Vehicle)	Not double cabin & field vehicles	≥ 1850	4-9
		All field vehicles		
Heavy weight diesel vehicles	Bus	Bus		
	Light duty truck	Cargo	< 4000	1000-6350
	Medium duty truck		4000-5500	6351-11793
	Heavy duty truck		>5500	11794-40000

The motorcycles and tricycles can use either a two stroke or four stroke cycle engines. Generally, four stroke cycle engines are better in fuel economy and reduced emissions. However, almost all motorcycles and tricycles (98.9%) use two stroke cycle engines and 98.0 % of the total population, use gasoline fuel, as shown in Table 4.4.

In this study, generally the engine capacity is classified as low, medium and high capacity motorcycles and tricycles. Table 4.4 shows that the medium capacity vehicles (151-200 cc) are 61.8 % in comparison with low and high capacity vehicles. Also, the total number of high capacity vehicles in Addis Ababa is 5.9 %.

Table 4.4 Distribution of motorcycles and tricycles in Addis Ababa (Total number of motorcycles and tricycles: 5015)

Motorcycle and Tricycle Classification		**Year of manufacture (%)**					
		≤1989	1990-1994	1995-1999	2000-2004	2005-2009	2010-2011
Engine capacity (cc)	≤100 (7.1%)	24.3	0.7	1.4	5.4	39.9	28.4
	101-150 (25.1%)	4.8	2.3	4.2	6.3	46.2	36.3
	151-200 (61.8%)	8.5	2.3	2.6	14.0	59.3	13.3
	201-400 (1.2%)	38.5	7.7	7.7	19.2	26.9	0
	≥ 400 (4.7%)	16.3	9.2	8.2	13.3	44.9	8.21
No. stroke	2 (98.9%)	9.4	2.5	3.1	11.5	54.2	19.3
	4 (1.1%)	21.7	17.4	13.0	17.4	26.1	4.3
Fuel type	Gasoline (98.0%)	9.7	2.7	3.2	11.5	53.6	19.4
	Diesel (2.0%)	2.3	2.3	0	18.2	70.5	6.8

4.2.2 Gasoline Vehicles

The summary of total fleet in Addis Ababa which was obtained from the raw data is given in Table 4.5. Table 4.5 includes various parameters designed to evaluate the influence of all gasoline vehicles on fuel economy and emission reduction such as body type, engine capacity, year of manufacture, type of air fuel mixture formation and emission control technology.

The number of gasoline vehicles in each classification such as engine capacity, year of manufacture, type of air fuel mixture formation and emission controlling technology are given in percentage adjacent to each group. Then, the distribution of vehicles in body type is

Table 4.5 Gasoline vehicle distribution by body type in Addis Ababa (Total number of gasoline vehicles: 123,645)

Category	Classification	Body Type (%)			
		Saloon 85.76 %	Minibus 10.41 %	SUV 4.19 %	Pickup 13.6%
Engine capacity (cc)	≤ 1000 (8.7%)	87.7	11.8	0.2	0.2
	1001- 1300 (55.3%)	99.9	0.7	0.3	0
	1301 – 1500 (4.5%)	96.8	1.9	0.9	0.4
	1501 – 1800 (16.4%)	75.6	6.3	17.7	0.4
	1801 – 2000 (14.8%)	39.9	53.0	7.0	0.2
	≥ 2001 (0.3%)	76.2	12.6	9.5	1.7
Year of manufacture (G.C)	≤ 1982 (17.5%)	92.0	7.0	0.8	0.2
	1982- 1989 (35.3%)	81.2	17.9	0.9	0.1
	1990 – 1994 (19.0%)	81.9	7.3	10.6	0.1
	1995 – 2000 (9.5%)	84.2	7.3	8.1	0.4
	2000- 2004 (7.8%)	85.9	7.4	6.7	0.4
	2005 -2009 (9.1%)	93.4	2.1	4.3	0.2
	2010-2011 (1.9%)	98.6	0.5	0.7	0.2
Type of air fuel mixture formation	Carburetor (42.2%)	85.5	13.7	0.7	0.1
	Gasoline EFI (57.8%)	85.2	8.0	6.7	0.2
Emission controlling technology (ECT)	No ECT (4.6%)	97.4	1.8	0.5	0.3
	Two way catalyst (9.5%)	92.1	6.9	0.9	0.1
	Three way catalyst (85.9%)	83.9	11.2	4.7	0.2

given in each row. For example, the number of gasoline vehicles having engine capacity less than 1000 and 101-1300 cc is equivalent to 8.7% and 55.3 % of the total population, respectively. In all engine capacity classification, the majority of vehicles are Saloon except in engine capacity range from1801-2000cc. In this particular case, 53.0 % are Minibuses. This indicates that in high engine capacity range (1801-2000 cc), the number of Minibuses increases considerably. This is evident that most gasoline vehicles with high engine capacity used for transportation in Addis Ababa are Minibuses that consume more fuel every day. However, Minibuses are advantageous as they carry 12-14 people at a time for transportation (passenger to km travel). Furthermore, it is recommended that the use of busses and light railway systems for mass transportation can improve the fuel economy as far as passenger to km travel is concerned. Besides the normal fuel consumption of Minibuses, there are other factors such as engine performance, road condition, traffic jam, eco-driving etc that contribute greatly to higher fuel mileage and emission.

The year of manufacture of all vehicles clearly shows the performance of the vehicles and the technology incorporated for fuel consumption and emission reduction. The gasoline vehicle distribution in year of manufacture is also given in Table 4.5. The total number of gasoline vehicles available in Addis Ababa that were manufactured before 2000 are 81.3 %. This shows that most of the gasoline vehicles are relatively old that could consume more fuel in normal condition.

The type of air fuel mixture formation systems in gasoline vehicles (conventional carburetor or Electronic Fuel Injection (EFI)) is determined based on the year of manufacture. The numbers of vehicles using conventional carburetor and EFI system are 42.2% and 57.8%, respectively. This indicates that there is an advantage to use vehicles equipped with EFI system for fuel economy.

There have been two types of emission controlling technologies introduced in gasoline vehicles, namely, two way and three way catalytic converters. Table 4.5 also includes the total vehicle distribution in line with emission control technologies. As most vehicles in Addis Ababa were manufactured in 1980s, most of them are expected to be equipped with three-way catalytic converters. However, evidences show that emission controlling technologies are dismantled from many vehicles available in Ethiopia because there are no rules and regulations that enforce to use them and the fuel quality (leaded gasoline) is a factor that could damage catalytic converters too.

4.2.3 Diesel Vehicles

Generally, diesel vehicles are categorized into three different groups as light duty vehicles, cargo trucks and bus. The summary of vehicle distribution for each group is given in Tables 4.6-4.8.

Tables 4.6-4.8 include various parameters designed to evaluate the influence of all diesel vehicles on fuel economy and emission reduction such as body type, engine capacity, year of manufacture, type of fuel system and emission control technology. The numbers of gasoline vehicles in each classification are given in percentage adjacent to each group. Then, the distribution of vehicles in body type is given in each row. In addition, the body type for light duty vehicles diesel vehicles is the same as gasoline vehicles that include Saloon, Minibus, SUV and Pickup (single and double cabins).

In the low engine capacity range (≤1800 cc), the Saloon vehicles cover 79.8% compared to other body type vehicles. In the medium engine capacity range, there is no Saloon vehicles but the number of Minibus, SUV and Pickup vehicles increases considerably. Furthermore, the SUV vehicles are 85.2% in the high engine capacity range.

The year of manufacture of all vehicles clearly shows the performance of the vehicle and the technology incorporated for fuel consumption and emission reduction. The light weight vehicle distribution in year of manufacture is also given in Table 4.6. The share of light weight diesel vehicles available in Addis Ababa that were manufactured before 2000 is 49.3 %. This shows that almost half of the light weight diesel vehicles are relatively old that could consume more fuel in normal condition.

The type of air fuel mixture formation systems in diesel vehicles (Mechanical Injection or Electronic Injection is determined based on the year of manufacture. The numbers of vehicles using conventional mechanical injection and electronic injection system are 49.2% and 50.8%, respectively.

There have been two types of emission controlling technologies introduced in diesel vehicles called, Diesel Oxidation Catalyst (DOC) and Diesel Particulate Filter (DPF). Table 4.6 also includes the total vehicle distribution in line with emission control technologies. The majority of vehicles (91.2%) use either DOC or DPF. However, evidences show that emission controlling technologies are dismantled from many vehicles available in Ethiopia because there are no rules and regulations that enforce to use them and the fuel quality (high sulfur diesel) is a factor that could damage the emission controlling technology too.

Table 4.7 shows cargo trucks distribution in gross weight. In low and medium engine capacity ranges, the number of light duty trucks is considerably high. On the other hand, in the high engine capacity range (≥5501 cc), there are high number of medium duty trucks. As it is shown in the Table 4.7, the number of heavy duty trucks manufactured after 2000 is 73.6 % of the total population. This indicates that most trucks available in Addis Ababa are new types that include improved technology for fuel system and emission control.

Table 4.6 Light duty diesel vehicle distribution by body type in Addis Ababa (Total number of vehicles: 35381)

Category	**Classification**	**Body Type (%)**			
		Saloon (1.3)	Minibus (30.5)	SUV (36.8)	Pickup (31.6)
Engine capacity (cc)	≤ 1800 (1.6%)	79.8	3.1	8.8	8.4
	1801- 2500 (35.3%)	0.0	29.4	23.6	47.0
	2501 – 4000 (46.0%)	0.0	37.9	30.1	32.0
	≥ 4001 (17.0%)	0.0	13.9	85.2	1.0
Year of manufacture (G.C)	≤ 1982 (1.8%)	8.3	20.9	57.7	13.2
	1982- 1989 (14.4%)	3.2	43.8	40.4	12.6
	1990 – 1994 (13.3%)	1.9	30.7	54.4	13.0
	1995 – 2000 (19.8%)	0.5	37.7	33.9	27.9
	2000- 2004 (21.3%)	0.5	35.0	31.0	33.6
	2005 -2009 (23.2%)	1.1	15.1	34.5	49.3
	2010-2011 (6.3%)	0.1	17.0	23.4	59.5
Type of fuel system	Mechanical injection (49.2%)	1.9	37.0	42.2	18.9
	Electronic injection (50.8%)	0.7	23.7	31.6	44.0
Emission controlling technology (ETC)	No ECT (8.8%)	5.2	42.6	40.9	11.4
	Diesel Oxidation Catalyst (40.4%)	1.2	35.8	42.5	20.5
	Diesel Particulate Filter (50.8%)	0.7	23.7	31.6	44.0

Table 4.8 shows the distribution of diesel buses in various categories such as engine capacity, year of manufacture, type of fuel system and emission controlling technology. Many buses have high engine capacity (≥ 4000 cc). The number of buses manufactured after 2000 is 75% of the total population. This shows that the use of new buses for transportation contributes for better fuel efficiency. Since many buses are of the new types, their fuel systems and emission controlling technology include the modern system.

Table 4.7 Cargo diesel vehicle distribution by gross weight in Addis Ababa (Total number of vehicles: 30015)

Vehicle Category	**Vehicle Classification**	**Vehicle distribution by gross weight (%)**		
		Light duty truck (79.287 %)	Medium duty truck (19.87 %)	Heavy duty truck (0.44 %)
Engine capacity (cc)	≤ 4000 (29.3%)	88.9	10.5	0.2
	4001- 5500 (68.4%)	77.6	22.3	0.1
	≥ 5501 (2.2%)	7.3	77.3	15.4
Year of manufacture (G.C)	≤ 1982 (2.8%)	36.2	60.1	3.7
	1982- 1989 (5.4%)	78.4	18.9	2.7
	1990 – 1994 (7.1%)	94.7	4.0	1.3
	1995 – 2000 (11.2%)	93.5	6.1	0.4
	2000- 2004 (24.2%)	88.9	11.0	0.1
	2005 -2009 (39.8%)	84.2	15.8	0.1
	2010-2011 (9.6%)	21.4	78.1	0.5
Type of fuel system	Mechanical injection (26.4%)	84.8	13.8	1.5
	Electronic injection (73.6%)	77.5	22.3	0.1
Emission controlling technology(ECT)	No ECT	54.0	42.3	3.6
	DOC (21.0%)	92.7	6.4	0.9
	DPF (73.6)	77.5	22.3	0.1

Table 4.8 Bus distribution in various categories in Addis Ababa (Total no of buses: 2926)

Vehicle Category	**Vehicle Classification**	**Bus (%)**
Engine capacity (cc)	2501-4000	37.3
	>=4001	62.7
Year of manufacture (G.C)	<= 1982	6.6
	1982- 1989	2.8
	1990 - 1994	6.1
	1995 - 2000	9.3
	2000- 2004	26.6
	2005 -2009	45.9
	2010-2011	2.8
Type of fuel system	Mechanical injection	24.8
	Electronic injection	75.2
Emission controlling technology (ECT)	No emission controlling technology	8.3
	Diesel Oxidation Catalyst	16.5
	Diesel Particulate Filter	75.2

4.3 Vehicle Stock Analysis in Regional Governments

This section explains the vehicle stock analysis of some regional governments that include Amhara, Benshangul Gumuz, Oromia, SNNPR and Tigray regions. Generally, the row data collected from each region does not contain complete information for the vehicles registered in their respective areas. Furthermore, there is no uniform and standard format to record basic information of all vehicles. Therefore, it is observed that many vehicles are not included in the analysis because of the lack of important parameters such as vehicle description, engine capacity, year of manufacture, number of seat and gross weight.

4.3.1 Motorcycle and Tricycle

a) Amhara

The row data obtained from Amhara region does not include complete information on year of manufacture and number of stroke of motorcycle and tricycle. Thus, the number of stroke ignored and year of manufacture is partially considered in the analysis.

The total number of motorcycles and tricycles in Amhara region classified in year of manufacture, engine capacity and fuel type are given in Table 4.9. The number of vehicles in each classification, such as engine capacity and type of fuel are given in percentages adjacent to each group. Then, the distribution of vehicles in year of manufacture is given in each row. For example, the number of vehicles having engine capacity less than 100 cc is equivalent to 13.8% of the total population. Among those vehicles having engine capacity less than 100 cc, the share of motorcycles and tricycles manufactured from 2005-2009 is 77.8 %.

The motorcycles and tricycles can use either gasoline or diesel fuel. Most motorcycles and tricycles (95.9%) use gasoline fuel, as shown in Table 4.9.

Table 4.9 Summary of motorcycles and tricycles distribution in Amhara region (Total number of motorcycles and tricycles: 6023)

Motorcycle and Tricycle Classification		Year of Manufacture (%)		
		≤ 2004	2005-2009	2010-2012
Engine capacity (cc)	≤ 100 (13.8%)	0.3	77.8	21.8
	101-150 (7.1%)	0.7	70.7	28.7
	151-200 (74.2%)	1.8	63.6	34.6
	201-400 (1.3%)	0	74.1	25.9
	≥400 (3.7%)	0	64.1	35.9
Fuel type	Gasoline (4.1%)	0	69.8	30.2
	Diesel (95.9%)	1.5	66.0	32.4

b) Benshangul Gumuz

The row data obtained from Benshangul Gumuz region does not include engine capacity of almost all vehicles. Therefore, the consultant team couldn't find additional information to analyze the vehicle fleet in the region.

c) Oromia

Like Amhara region, the row data obtained from Oromia region does not include complete information on number of stroke of motorcycle and tricycle. Thus, the number of stroke is ignored in the analysis.

The total number of motorcycles and tricycles in Oromia region classified in year of manufacture, engine capacity and fuel type is given in Table 4.10. The number of vehicles in each classification, such as engine capacity and type of fuel are given in percentage adjacent to each group. Then, the distribution of vehicles in year of manufacture is given in each row. For example, the number of vehicles having engine capacity less than 100 cc is equivalent to 38.6% of the total population. Among those vehicles having engine capacity less than 100 cc, the share of motorcycles and tricycles manufactured from 2005-2009 is 66.6 %. Most motorcycles and tricycles in Oromia region have medium engine capacity (151-200 cc) and only 6.0 % of the total population has high engine capacity (≥ 400 cc). In addition, most motorcycles and tricycles (98.1%), use gasoline fuel, as shown in Table 4.10.

d) SNNPR

The row data obtained from SNNPR does not include complete information on number of stroke of motorcycle and tricycle. Thus, the number of stroke is ignored in the analysis.

The total number of motorcycles and tricycles in SNNPR classified in year of manufacture, engine capacity and fuel type is given in Table 4.11. The number of vehicles in each classification, such as engine capacity and type of fuel are given in percentage adjacent to each group. Then, the distribution of vehicles in year of manufacture is given in each row. For example, the number of vehicles having engine capacity less than 100 cc is equivalent to 39.7% of the total population. Among those vehicles having engine capacity less than 100 cc, the share of motorcycles and tricycles manufactured from 2005-2009 is 81.4 %. Most motorcycles

Table 4.10 Summary of motorcycles and tricycles distribution by year of manufacture in Oromia region (Total number of motorcycles and tricycles: 4855)

Motorcycle and Tricycle Classification		**Year of Manufacture (%)**					
		≤ 1990	**1990-1994**	**1995-1999**	**2000-2004**	**2005-2009**	**2010-2011**
Engine capacity (cc)	≤ 100 (38.6%)	0.2	0	0	0.7	66.6	32.5
	101-150 (5.3%)	0	1.2	0.6	5.4	73.5	19.3
	151-200 (50.2%)	0.1	0.1	0.6	1.8	72.8	24.6
	201-400 (5.1%)	0	0	0	1.9	97.5	0.6
	≥ 400 (0.9%)	0	0	0	0	96.3	3.7
Fuel type	Gasoline (98.1%)	0.1	0.1	0.4	1.6	71.8	26.1
	Diesel (1.9%)	1.7	0	0	1.7	78.3	18.3

and tricycles in SNNPR have low engine capacity (up to 150 cc) and only 0.9 % of the total population have high engine capacity (≥ 400 cc). In addition, most motorcycles and tricycles (99.4%), use gasoline fuel, as shown in Table 4.11.

Table 4.11 Summary of motorcycles and tricycles distribution in SNNPR region (Total number of motorcycles and tricycles: 15225)

Motorcycle and Tricycle Classification		**Year of Manufacture (%)**					
		≤ 1990	**1990-1994**	**1995-1999**	**2000-2004**	**2005-2009**	**2010-2011**
Engine capacity (cc)	≤ 100 (39.7%)	0	0	0	0.9	81.4	17.7
	101-150 (40.4%)	0	0	0	0.5	74.7	24.7
	151-200 (18.7%)	0.4	0.2	1.3	15.3	69.9	12.9
	201-400 (0.3%)	0	5.3	5.3	10.5	78.9	0
	≥ 400 (0.9%)	0	0	0	0	100	0
Fuel type	Gasoline (99.4%)	0.1	0.1	0.4	1.6	71.8	26.1
	Diesel (0.6%)	1.7	0	0	1.7	78.3	18.3

e) Tigray

The row data obtained from Tigray region also does not include complete information on the number of stroke of motorcycle and tricycle. Thus, the number of stroke is ignored in the analysis.

The total number of motorcycles and tricycles in Tigray region is classified in year of manufacture, engine capacity and fuel type as it is given in Table 4.12. The number of vehicles in each classification, such as engine capacity and type of fuel are given in percentage adjacent to each group. Then, the distribution of vehicles in year of manufacture is given in each row. For example, the number of vehicles having engine capacity less than 151-200 cc is equivalent to 42.4 % of the total population. Among those vehicles having engine capacity less than 151-200 cc, the share of motorcycles and tricycles manufactured from 2005-2009 is 52.8 %. Most motorcycles and tricycles in Tigray region have medium engine capacity (151-200 cc) and only 0.3 % of the total population have high engine capacity (≥ 400 cc). This is considerably low. In addition, most motorcycles and tricycles (91.1%), use gasoline fuel, as shown in Table 4.12.

Table 4.12 Summary of motorcycles and tricycles distribution in Tigray region (Total number of motorcycles and tricycles: 4774)

Motorcycle and Tricycle Classification		Distribution in Year of Manufacture (%)					
		≤ 1990	1990-1994	1995-1999	2000-2004	2005-2009	2010-2012
Engine capacity (cc)	≤ 100 (32.3%)	0.1	0	0.3	1.0	57.4	41.2
	101-150 (22.3%)	0.9	0.1	0.7	16.6	52.1	29.5
	151-200 (42.4%)	0.5	0.1	0.4	4.2	52.8	41.9
	201-400 (2.6%)	1.1	0	0	12.5	60.2	26.1
	≥ 400 (0.3%)	0	0	0	0	80.0	20.0
Fuel type	Gasoline (91.1%)	0.5	0.1	0.4	6.5	51.9	40.6
	Diesel (8.9%)	0	0	0.3	2.7	80.5	16.5

f) ET-code

The ET-code category is the summary of all ET-code motorcycles and tricycles collected from each region including Addis Ababa. The row data, obtained from all places, indicated all vehicles registered in each area with ET-code on the number plates. The team has summarized the ET-code category as shown in Table 4.13.

The total number of motorcycles and tricycles having ET-code is classified in year of manufacture, engine capacity and fuel type as given in Table 13. The number of vehicles in each classification, such as engine capacity and type of fuel are given in percentage adjacent to each group. Then, the distribution of vehicles in year of manufacture is given in each row. For example, the number of vehicles having engine capacity less than 151-200 cc is equivalent to 90.7 % of the total population. Among those vehicles having engine capacity 151-200 cc, the share of motorcycles and tricycles manufactured from 2005-2009 is 53.0 %. Most ET-code motorcycles and tricycle have medium engine capacity (151-200 cc) and only 0.9 % of the total population has high engine capacity (≥ 400 cc). In addition, most motorcycles and tricycles (97.0%), use gasoline fuel, as shown in Table 4.13.

Table 4.13 Summary of ET-code motorcycles and tricycles distribution in Addis Ababa and some regions (Total number of motorcycles and tricycles: 3305)

Motorcycle and Tricycle Classification		Year of Manufacture (%)					
		<=1990	**1990-1994**	**1995-1999**	**2000-2004**	**2005-2009**	**2010-2011**
Engine capacity (cc)	<=100 (0.5%)	12.5	0	0	37.5	50.0	0
	101-150 (7.8%)	3.1	1.6	2.3	26.6	59.4	7.0
	151-200 (90.7%)	0.7	0.5	1.9	23.1	53.0	20.8
	201-400 (0.1%)	0	0	0	0	100	0
	>=400 (0.9%)	0	0	28.6	14.3	57.1	0
Fuel type	Gasoline (97.0%)	0.9	0.6	2.1	22.3	54.0	20.0
	Diesel (3.0%)	2.0	0	2.0	57.1	38.8	0

4.3.2 Gasoline Vehicles

The summary of total fleet in some regions is given from Table 4.14-4.18.

a) Amhara Region

The summary of gasoline vehicles in Amhara region which was obtained from the raw data is given in Table 4.14. The number of gasoline vehicles with medium engine capacity (1001-1300 cc) is 37.5% of the total population. In addition, most vehicles are Saloon in comparison with other body types in low and medium engine capacity range. The gasoline vehicle distribution in year of manufacture is also given in Table 4.14. The total number of gasoline vehicles available in Amhara region that were manufactured after 2005 indicates 76.3 %. This shows that most of the gasoline vehicles in Amhara region are relatively new.

Table 14 Gasoline vehicle distribution in Amhara region (Total number of vehicles: 3834)

Category	Classification	Body type (%)			
		Saloon (53.0)	**Minibus (31.2)**	**SUV (2.5)**	**Pickup (13.2)**
Engine capacity (cc)	≤ 1000 (3.8%)	61.5	16.9	9.2	12.3
	1001- 1300 (37.5%)	88.5	5.9	2.6	3.0
	1301 – 1800 (26.0%)	56.4	19.0	3.8	20.9
	1801 – 2000 (32.3%)	7.8	71.4	0.9	19.9
	≥ 2001 (0.3%)	0.0	50.0	0	50.0
Year of manufacture (G.C)	≤ 2004 (23.6%)	42.0	39.1	1.9	16.9
	2005 -2009 (39.3%)	56.2	27.3	4.0	12.5
	2010-2011 (37.2%)	57.4	30.2	1.2	11.2

b) Benshangul Gumuz Region

The row data obtained from Benshangul Gumuz region does not include engine capacity of almost all vehicles. Therefore, the consultant team couldn't find additional information to analyze the vehicle fleet in this region.

c) Oromia Region

The gasoline vehicle distribution by engine capacity in Oromia region is given in Table 4.15. The vehicle classification by body type is not included because there is a lack of information on the vehicle description in the row data.

The gasoline vehicle distribution in year of manufacture is also given in Table 4.15. The total number of gasoline vehicles available in Oromia region that are manufactured after 2005 indicates 56.1%. This shows that most of the gasoline vehicles in oromia region are relatively new as compared to Addis Ababa.

Table 4.15 Gasoline vehicle distribution by engine capacity in Oromia region (Total number of vehicles : 11,140)

Category	Classification	Engine capacity (cc) (%)				
		≤ 1000	**1001-1300**	**1301 -1800**	**1801 -2000**	**≥ 2000**
Year of manufacture (G.C)	≤ 1982 (15.2%)	4.9	22.8	42.5	28.8	1.0
	1982- 1989 (18.4%)	1.7	11.1	10.8	75.4	0.9
	1990 – 1994 (4.4%)	1.6	8.5	21.7	67.8	0.4
	1995 – 1999 (2.8%)	9.4	8.8	20.6	60.0	1.2
	2000- 2004 (3.1%)	2.8	14.0	51.7	29.8	1.7
	2005 -2009 (41.9%)	4.9	19.6	52.3	22.9	0.3
	2010-2011 (14.2%)	14.6	16.0	51.8	17.3	0.4
Air fuel mixture formation	Carburetor (29.1%)	3.3	17.3	27.8	50.6	1.0
	Gasoline EFI (70.9%)	6.5	16.9	46.2	29.9	0.4
Emission controlling technology (ECT)	No ECT (3.4%)	7.1	17.8	64.0	9.6	1.5
	Two way catalyst (7.9%)	5.7	22.3	41.6	30.0	0.4
	Three way catalyst (88.7%)	5.5	16.5	39.9	37.4	0.6

d) SNNPR

The gasoline vehicle distribution by engine capacity in SNNPR is given in Table 4.16. The vehicle classification by body type is not included because there is a lack of information on the vehicle description in the row data.

The gasoline vehicle distribution in year of manufacture is also given in Table 4.16. The total number of gasoline vehicles available in SNNPR that were manufactured after 2005 indicates 24.5%. This shows that most of the gasoline vehicles in SNNPR are relatively old as compared to Amhara and Oromia regions.

Table 4.16 Gasoline vehicle distribution by engine capacity in SNNPR (Total number of vehicles in each category: 2888)

Vehicle Category	Vehicle Classification	Engine capacity (cc) (%)				
		≤ 1000	1001-1300	1301 - 1800	1801 - 2000	≥ 2000
Year of manufacture (G.C)	≤ 1982 (19.7%)	5.2	39.6	28.1	27.1	0
	1982- 1989 (36.5%)	0.6	26.4	14.0	59.0	0
	1990 – 1994 (9.8%)	2.1	2.1	25.0	70.8	0
	1995 – 1999 (6.6%)	3.1	15.6	3.1	78.1	0
	2000- 2004 (2.9%)	21.4	35.7	7.1	35.7	0
	2005 -2009 (18.4%)	6.7	40.0	24.4	25.6	3.3
	2010-2011 (6.1%)	3.3	40.0	40.0	16.7	0
Air fuel mixture formation	Carburetor (44.1)	0	50.0	37.5	12.5	0
	Gasoline EFI (55.9)	9.3	29.6	31.5	29.6	0
Emission controlling technology (ECT)	No ECT (1.6%)	3.1	29.1	18.8	48.4	0.7
	Two way catalyst (11.1%)	2.8	29.8	20.9	46.5	0
	Three way catalyst (87.3%)	4.4	29.3	20.1	45.1	1.1

e) Tigray Region

The summary of gasoline vehicles in Tigray region is given in Table 4.17. The number of gasoline vehicles with high engine capacity (1801-200 cc) is 43.8% of the total population. Most vehicles are Saloon in low and medium engine capacity range in comparison with other body types. As the engine capacity range increases, the number of Minibuses increases considerably.

The gasoline vehicle distribution in year of manufacture is also given in Table 4.17. The total number of gasoline vehicles available in Tigray region that are manufactured after 2005 indicates 13.4 %. This shows that most of the gasoline vehicles in Tigray region are relatively old as compared to Amhara and Oromia regions.

The type of air fuel mixture formation systems in gasoline vehicles (conventional carburetor or Electronic Fuel Injection (EFI)) is determined based on the year of manufacture. The numbers of vehicles using conventional carburetor and EFI system are 54.1% and 45.9%, respectively. This indicates that the number of vehicles with EFI is relatively smaller than the conventional carburetor system.

Table 4.17 Gasoline vehicle distribution by body type in Tigray region (Total number of vehicles: 1763)

Category	**Classification**	**Body type (%)**			
		Saloon (44.2)	Minibus (39.2)	SUV (2.6)	Pickup (14.0)
Engine capacity (cc)	≤ 1000 (4.0%)	63.8	17.0	6.4	12.8
	1001- 1300 (35.8%)	88.9	7.6	1.4	2.1
	1301 – 1800 (16.0%)	48.1	18.5	9.5	23.8
	1801 – 2000 (43.8%)	4.6	74.5	0.8	20.1
	≥2001 (0.4%)	20.0	60.0	0	20.0
Year of manufacture (G.C)	≤ 1982 (19.3%)	61.8	22.4	2.2	13.6
	1982- 1989 (49.4%)	31.2	51.5	1.0	16.3
	1990 – 1994 (9.7%)	36.0	45.6	4.4	14.0
	1995 – 1999 (4.3%)	37.3	37.3	2.0	23.5
	2000- 2004 (3.8%)	62.2	20.0	6.7	11.1
	2005 -2009 (5.8%)	56.5	27.5	10.1	5.8
	2010-2011 (7.6%)	80.0	7.6	4.4	2.2
Type of air fuel mixture formation	Carburetor (54.1%)	43.5	39.3	1.6	15.6
	Gasoline EFI (45.9%)	45.0	39.1	3.9	12.0
Emission controlling technology (ECT)	No ECT (4.6%)	83.3	7.4	1.9	7.4
	Two way catalyst (8.6%)	63.4	23.8	3.0	9.9
	Three way catalyst (86.9%)	40.3	42.4	2.6	14.7

f) ET-code gasoline vehicles in Addis Ababa and some regions

The summary of ET-code gasoline vehicles in Addis Ababa and some region is given in Table 4.18. The number of gasoline vehicles with medium and high engine capacity (1501-1800 cc and 1801-200 cc) is almost the same. Most vehicles in low and medium engine capacity range are Saloon in comparison with other body types. As the engine capacity range increases, the number of SUV increases.

Table 4.18 ET-code gasoline vehicle distribution by body type in Addis Ababa and some regions (Total number of vehicles: 5631)

Category	**Classification**	**Body type (%)**			
		Saloon (63.5)	**Minibus (4.6)**	**SUV (21.9)**	**Pickup (10.0)**
Engine capacity (cc)	≤ 1000 (3.1%)	66.4	6.7	20.1	6.7
	1001- 1300 (28.1%)	94.1	1.5	2.7	1.6
	1301 – 1500 (5.1%)	85.6	1.4	9.0	4.1
	1501 – 1800 (21.8%)	77.7	1.3	16.5	4.6
	1801 – 2000 (21.5%)	33.4	10.1	33.0	23.4
	≥ 2001 (20.4%)	31.8	7.1	45.8	15.3
Year of manufacture (G.C)	≤ 1982 (5.6%)	74.0	5.8	8.3	12.0
	1982- 1989 (14.3%	70.0	5.5	10.7	13.8
	1990 – 1994 (8.4%)	63.7	6.1	19.4	10.8
	1995 – 1999 (15.0%)	58.0	4.3	18.8	18.8
	2000- 2004 (19.4%)	56.0	7.0	22.9	14.0
	2005 -2009 (31.6%)	65.7	3.0	28.7	2.6
	2010-2011 (5.9%)	63.8	0.4	33.5	2.4
Type of air fuel mixture formation	Carburetor (13.5%)	73.7	6.2	8.4	11.7
	Gasoline EFI (86.5%)	61.9	4.4	24.0	9.8
Emission controlling technology (ECT)	No ECT (0.4%)	62.5	0	31.2	6.2
	Two way catalyst (3.5%)	76.0	4.0	6.0	14.0
	Three way catalyst (96.2%)	63.0	4.6	22.4	9.9

The gasoline vehicle distribution in year of manufacture is also given in Table 4.18. The total number of ET-code gasoline vehicles that are manufactured before 2000 indicates 37.7 %. This shows that more than half of ET-code gasoline vehicles in Addis Ababa and some regions are relatively new. Furthermore, since most vehicles are of the new type designs, the number of vehicles with EFI is relatively higher than the conventional carburetor system. If ET-code vehicles are periodically maintained and conditioned, they will be fuel efficient.

4.3.3 Diesel Vehicles

This section explains the diesel vehicle stock analysis of some regional governments that includes Amahra, Benshangul Gumuz, Oromia, SNNPR and Tigray regions. In this study, diesel vehicles are categorized into three groups as light weight vehicles, heavy weight vehicles (cargo) and busses. Due to incomplete information (vehicle description and gross weight) in the raw data, all diesel vehicles (light weight, heavy weight and buses) are treated together in some regions such as Amhara, Benshagul Gumuz, Oromia and SNNPR.

a) Amhara Region

The summary of diesel vehicle distribution in Amhara region is given in Table 4.19. All diesel vehicles in Amhara region are grouped by engine capacity and year of manufacture. The engine capacity and year of manufacture are classified into four and three groups, respectively. The diesel vehicles manufactured before 2004 are in one group because the raw data from Amhara region does not show the respective year of manufacture of the vehicles. The number of diesel vehicles available in Amhara region that are manufactured after 2005 is 70.8%. In addition, most vehicles manufactured in various periods have engine capacity of 2500-4000 cc as shown in Table 4.19.

Table 4.19 Diesel vehicles distribution by engine capacity in Amhara region (Total number of vehicles: 10268)

Vehicle Category	Vehicle Classification	Engine capacity (cc) (%)			
		≤ 1800	1801- 2500	2500 - 4000	≥ 4000
Year of manufacture (G.C)	≤ 2004 (29.2%)	2.8	17.2	44.1	35.9
	2005- 2009 (44.0%)	3.8	7.3	49.3	39.5
	2010 – 2012 (26.8%)	0.8	9.3	40.4	49.5

b) Benshangul Gumuz Region

The raw data of diesel vehicles obtained from Benshangul Gumuz region have relatively more information in comparison with gasoline vehicles. However, many diesel vehicles are ignored in the data cleaning process due to unknown engine capacity and year of manufacture.

The summary of diesel vehicle distribution in Benshangul Gumuz region is given in Table 4.20. The number of diesel vehicles available in Benshangul Gumuz region that are manufactured after 2000 indicates 64.3%. These groups of vehicles are of the new type. This clearly shows that the type of fuel system and the emission controlling technologies are modern type that helps to minimize fuel consumption and emission. In addition, most vehicles manufactured in different periods have engine capacity range of 2500-4000 cc which is similar to diesel vehicles available in Amhara region.

Table 4.20 Diesel vehicles distribution by engine capacity in Benshagul Gumuz region (Total number of vehicles: 334)

Category	**Classification**	**Engine capacity (cc) (%)**			
		≤ 1800	**1801- 2500**	**2500 - 4000**	**≥ 4000**
Year of manufacture (G.C)	≤ 1982 (1.8%)	0	0	0	100
	1982- 1989 (10.7%)	16.7	16.7	66.7	0
	1990 – 1994(1.8%)	0	0	100	0
	1995 – 1999 (21.4%)	0	16.7	33.3	50.0
	2000- 2004 (26.8%)	0	13.3	26.7	60.0
	2005 -2009 (37.5%)	4.8	0	47.6	47.6
Type of fuel system	Mechanical Injection(35.7%)	5.0	15.0	45.0	35.0
	Electronic Injection(64.3%)	2.8	5.6	38.9	52.8
Emission controlling technology (ECT)	No ECT (10.7%)	16.7	16.7	50.0	16.7
	DOC (25.0%)	0	14.3	42.9	42.9
	DPF (64.3%)	2.8	5.6	38.9	52.8

c) Oromia Region

The summary of diesel vehicle distribution in Oromia region is given in Table 4.21. The number of diesel vehicles available in Oromia region that were manufactured after 2000 is 54.1% of the total population. This shows that almost half of the diesel vehicles are of the new type designs. In addition, most vehicles manufactured from 1990-2004 have engine capacity of 2500-4000 cc. On the other hand, many vehicles manufactured after 2004 have higher engine capacity (≥ 4000 cc).

Table 4.21 Diesel vehicles distribution by engine capacity in Oromia region (Total number of vehicles: 17,077)

Category	Classification	Engine capacity (cc) (%)			
		≤ 1800	1801- 2500	2500 - 4000	≥ 4000
Year of manufacture (G.C)	≤ 1982 (7.0%)	3.9	9.4	10.6	76.0
	1982- 1989 (7.7%)	2.2	37.7	30.4	29.6
	1990 – 1994 (8.8%)	1.0	21.0	64.8	13.2
	1995 – 1999 (22.4%)	1.2	10.5	74.4	13.8
	2000- 2004 (33.4%)	1.0	10.5	53.8	34.2
	2005 -2009 (18.1%)	2.9	18.6	11.9	66.5
	2010-2011 (2.6%)	3.3	30.0	19.3	47.3
Type of fuel system	Mechanical Injection (45.9%)	1.8	16.9	55.4	25.9
	Electronic Injection (54.1%)	1.7	14.2	38.1	46.0
Emission controlling technology (ECT)	No ECT (11.1%)	3.6	21.4	14.3	60.7
	DOC (34.8%)	1.2	15.5	68.6	14.3
	DPF (54.1%)	1.7	14.2	38.1	46.0

d) SNNPR

The summary of diesel vehicle distribution in SNNPR is given in Table 4.22. The diesel vehicle distribution in SNNPR have similar pattern with Oromia region as far as engine capacity and year of manufacture are concerned. The number of diesel vehicles available in SNNPR that are manufactured after 2000 indicates 69.2%. These groups of vehicles are of the new type designs. In addition, most vehicles manufactured from 1982-1999 have engine capacity of 2500-4000 cc. On the other hand, many vehicles manufactured after 2004 have higher engine capacity (≥ 4000 cc).

Table 4.22 Diesel vehicles distribution by engine capacity in SNNPR region (Total number of vehicles: 5663)

Category	.Classification	Engine capacity (cc) (%)			
		≤ 1800	1801- 2500	2500 - 4000	≥ 4000
Year of manufacture (G.C)	≤ 1982 (2.1%)	2.5	8.8	26.2	62.5
	1982- 1989 (4.6%)	2.2	30.2	46.9	20.7
	1990 – 1994 (7.6%)	2.7	16.4	59.6	21.2
	1995 – 1999 (26.4%)	0.5	6.4	66.4	26.7
	2000- 2004 (33.4%)	0.3	3.6	40.2	55.9
	2005 -2009 (22.1%)	0.7	8.3	28.8	62.1
	2010-2011 (3.7%)	3.5	14.6	36.8	45.1
Type of fuel system	Mechanical Injection (40.2%)	1.2	11.1	60.9	26.8
	Electronic Injection (59.3%)	0.7	6.1	35.7	57.5
Emission controlling technology (ECT)	No ECT (4.2%)	2.5	19.8	32.7	45.1
	DOC (36.5%)	1.1	10.1	64.1	24.7
	DPF (59.3%)	0.7	6.1	35.7	57.5

e) Tigray Region

The summary of diesel vehicle distribution in Tigray region for each group is given in Table 4.23-4.25. Table 4.23 shows that the Saloon vehicles cover 59.4% in comparison with other body type vehicles in the low engine capacity range (≤1800 cc). In the medium engine capacity range, there is no Saloon vehicles but the number of Minibus, SUV and Pickup vehicles increases considerably. Furthermore, the SUV vehicles are 94.9% in the high engine capacity range.

The total number of light duty diesel vehicles available in Tigray that are manufactured before 2000 are 49.4 %. This shows that almost half of the light weight diesel vehicles are relatively old that could consume more fuel during normal operation.

The type of air fuel mixture formation systems in diesel vehicles (Mechanical Injection or Electronic Injection) is determined based on the year of manufacture. The numbers of vehicles using conventional mechanical injection and electronic injection system are 49.4% and 50.6%, respectively.

There have been two types of emission controlling technologies introduced in diesel vehicles called Diesel Oxidation Catalyst (DOC) and Diesel Particulate Filter (DPF). Table 4.23 also includes the total vehicle distribution in line with emission control technologies. Many vehicles (93.6%) use either DOC or DPF. However, evidences show that emission controlling technologies are dismantled from many vehicles available in Ethiopia because there are no rules and regulations that enforce to use them and the fuel quality (high sulfur diesel) is a factor that could damage the emission controlling technology too.

Table 4.23 Light duty diesel vehicles distribution by body type in Tigray region (Total number of vehicles:3852)

Category	**Classification**	**Body type (%)**			
		Saloon (0.7)	Minibus (47.8)	SUV (18.3)	Pickup (33.2)
Engine capacity (cc)	≤ 1800 (1.1%)	59.4	6.2	9.4	25.0
	1801- 2500 (18.1%)	0	41.4	12.5	46.2
	2501 – 4000 (67.9%)	0	58.5	5.6	35.9
	≥ 4001 (12.8%)	0	3.8	94.9	1.4
Year of manufacture (G.C)	≤ 1982 (1.5%)	4.8	33.3	52..4	9.5
	1982- 1989 (8.3%)	3.3	54.0	32.6	10.0
	1990 – 1994 (10.1%)	0.7	44.3	29.2	25.8
	1995 – 2000 (29.5%)	0.1	61.7	15.4	22.8
	2000- 2004 (33.6%)	0.1	51.6	14.5	33.8
	2005 -2009 (11.5%)	0.6	20.3	14.5	64.5
	2010-2011 (5.6%)	1.9	8.7	14.9	74.5
Type of fuel system	Mechanical injection (49.4%)	0.9	56.0	22.2	20.9
	Electronic injection (50.6%)	0.4	39.8	14.5	45.3
Emission controlling technology (ECT)	No ETC (6.4%)	3.8	55.7	32.4	8.1
	DOC (43.0%)	0.5	56.1	20.7	22.8
	DPF (50.6%)	0.4	39.8	14.5	45.3

Table 4.24 shows the cargo trucks distribution in gross weight. In low and medium engine capacity ranges, the number of light duty trucks is considerably high. On the other hand, in the high engine capacity range (≥5501 cc), there is a high number of medium duty trucks. As it is shown in the Table 4.24, the number of cargo trucks manufactured after 2000 is 49.8 %

of the total population. This indicates that half of the trucks available in Tigray are new types that include improved technology for fuel system and emission control.

Table 4.24 Cargo trucks distribution by gross weight in Tigray region (Total number of vehicles 829)

Category	**Classification**	**Vehicle distribution by gross weight (%)**		
		Light duty truck (0.65 %)	Medium duty truck (47.7 %)	Heavy duty truck \ (33.19%)
Engine capacity (cc)	≤ 4000 (39.0%)	44.6	4.1	51.2
	4001- 5500 (59.5%)	46.1	8.4	45.5
	≥ 5501 (1.5%)	11.1	88.9	0
Year of manufacture (G.C)	<= 1982 (5.0%)	12.9	32.3	54.8
	1982- 1989 (7.6%)	27.7	8.5	63.8
	1990 – 1994 (15.6%)	52.6	1.0	46.4
	1995 – 2000 (21.9%)	30.9	4.4	64.7
	2000- 2004 (29.0%)	55.0	9.4	35.6
	2005 -2009 (18.9%)	52.1	9.4	38.5
	2010-2011 (1.9%)	75.0	0	25
Type of fuel system	Mechanical injection (50.2%)	35.4	6.8	57.9
	Electronic injection (49.8%)	54.7	9.1	36.2
Emission controlling technology (ECT)	No ETC (9.0%)	17.9	25.0	57.1
	DOC (41.1%)	39.2	2.7	58.0
	DPF (49.8%)	54.7	9.1	36.2

Table 4.25 shows the distribution of diesel buses in various categories such as engine capacity, year of manufacture, type of fuel system and emission controlling technology. Many buses have high engine capacity (≥ 4000 cc). The number of buses manufactured after 2000 is 76.1% of the total population. This shows that the use of new buses for transportation contributes towards better fuel efficiency. Since many buses are of the new type designs, their fuel systems and emission controlling technology include the modern system.

Table 4.25 Distribution of buses in various categories in Tigray region (Total number of buses: 834)

Vehicle Category	**Vehicle Classification**	**Bus (%)**
Engine capacity (cc)	2501-4000	20.5
	≥ 4001	79.5
Year of manufacture (G.C)	≤ 1982	2.1
	1982- 1989	2.4
	1990 - 1994	7.4
	1995 - 2000	12.0
	2000- 2004	44.6
	2005 -2009	27.7
	2010-2011	3.8
Type of fuel system	Mechanical injection	23.9
	Electronic injection	76.1
Emission controlling technology (ECT)	No ECT	3.8
	Diesel Oxidation Catalyst (DOC)	20.0
	Diesel Particulate Filter (DPF)	76.1

f) ET-code in Addis Ababa and some Regions

The summary of diesel vehicle distribution in Tigray region for each group is given in Tables 4.26-4.28. Table 4.26 shows that in the low engine capacity range (≤1800 cc), the Saloon vehicles cover 70.7% compared to other body type vehicles. In the medium engine capacity range, there is no Saloon vehicle but the number of Minibus, SUV and Pickup vehicles increases considerably. Furthermore, the SUV vehicles are 94.8 % in the high engine capacity range.

The total number of light duty diesel vehicles available in Addis Ababa that were manufactured after 2000 indicates 34.1 %. The type of air fuel mixture formation systems in diesel vehicles (Mechanical Injection or Electronic Injection) is determined based on the year of manufacture. The numbers of vehicles using conventional mechanical injection and electronic injection system are 34.1% and 65.9%, respectively.

There have been two types of emission controlling technologies introduced in diesel vehicles called Diesel Oxidation Catalyst (DOC) and Diesel Particulate Filter (DPF). Table 4.23 also includes the total vehicle distribution in line with emission control technologies. Many vehicles (95.5%) use either DOC or DPF. However, evidences show that emission controlling technologies are dismantled from many vehicles available in Ethiopia because there are no rules and regulations that enforce to use them and the fuel quality (high sulfur diesel) is a factor that could damage the emission controlling technology too.

Table 4.26 ET-code light weight diesel vehicles distribution by body type (Total number of vehicles: 12756)

Category	Classification	Body type (%)			
		Saloon (2.3)	Minibus (3.9)	SUV (53.5)	Pickup (40.3)
Engine capacity (cc)	≤ 1800 (3.2%)	70.7	2.8	10.1	16.5
	1801- 2500 (19.8%)	0	8.8	26.5	64.7
	2501 – 4000 (39.4%)	0	1.8	31.4	66.8
	≥ 4001 (37.5%)	0	3.5	94.8	1.7
Year of manufacture (G.C)	≤ 1982 (1.5%)	21.7	12.0	41.0	25.3
	1982- 1989 (9.0%)	7.5	6.4	50.6	35.5
	1990 – 1994 (7.6%)	5.3	6.3	66.2	22.2
	1995 – 2000 (16.1%)	2.0	2.6	61.2	34.2
	2000- 2004 (22.9%)	1.9	2.4	50.8	44.9
	2005 -2009 (32.0%)	0.4	3.3	50.5	45.8
	2010-2011 (11.0%)	0	5.5	52.4	42.1
Type of fuel system	Mechanical injection (34.1%)	5.0	4.9	58.6	31.5
	Electronic injection (65.9)	0.9	3.4	50.9	44.9
Emission controlling technology (ECT)	No ECT (4.5%)	17.3	11.6	42.0	29.1
	DOC (29.6%)	3.2	3.8	61.1	31.9
	DPF (65.9%)	0.9	3.4	50.9	44.9

Table 4.27 shows cargo trucks distribution in gross weight. In low and medium engine capacity ranges, the number of light duty trucks is considerably high. On the other hand, in the high engine capacity range (≥5501 cc), there are high number of medium duty trucks. As it is shown in the Table 4.27, the number of heavy duty trucks manufactured after 2000 is 51.4 % of the total population. This indicates that most trucks available in Addis Ababa are new types that include improved technology for fuel system and emission control.

Table 27 ET-code cargo trucks distribution by gross weight (Total number of vehicles: 24381)

Category	**Classification**	**Vehicle classification by gross weight (%)**		
		Light duty truck (1000-6350 Kg)	Medium duty truck (6351-11793 Kg)	Heavy duty truck (11784-40000 Kg)
Engine capacity (cc)	≤ 4000 (6.7%)	50.0	7.9	42.1
	4001- 5500 (4.0%)	64.4	4.9	30.7
	≥ 5501 (89.3%)	44.5	0.9	54.6
Year of manufacture (G.C)	≤ 1982 (13.9%)	78.8	1.5	19.9
	1982- 1989 (15.1%)	67.3	2.1	30.6
	1990 – 1994 (9.4%)	51.2	1.1	47.8
	1995 – 2000 (10.3%)	57.0	0.8	42.1
	2000- 2004 (7.1%)	40.8	4.2	55.0
	2005 -2009 (34.2%)	28.3	1.2	70.4
	2010-2011 (10.1%)	13.2	1.0	85.8
Type of fuel system	Mechanical injection (48.6%)	65.5	1.6	32.9
	Electronic injection (51.4%)	27.2	1.7	71.7
Emission controlling technology (ECT)	No ETC (21.3%)	77.1	1.9	21.0
	DOC (27.3%)	56.5	1.4	42.1
	DPF (51.4%)	27.2	1.7	71.1

Table 4.28 shows the distribution of diesel buses in various categories such as engine capacity, year of manufacture, type of fuel system and emission controlling technology. ET-code buses are used for mass transportation. Many buses have high engine capacity (≥ 4000 cc). The number of buses manufactured after 2000 are 28.0% of the total population. This shows that many ET-code buses are old types that could consume more fuel in normal condition.

Table 4.28 ET-code buses distribution in various categories (Total number of buses: 2080)

Vehicle Category	**Vehicle Classification**	**Bus (%)**
Engine capacity (cc)	2501-4000	8.2
	≥ 4001	91.8
Year of manufacture (G.C)	≤ 1982	14.4
	1982- 1989	20.0
	1990 - 1994	7.7
	1995 - 2000	30.2
	2000- 2004	8.1
	2005 -2009	13.3
	2010-2011	6.6
Type of fuel system	Mechanical injection	72.0
	Electronic injection	28.0
Emission controlling technology (ECT)	No ECT	26.7
	Diesel Oxidation Catalyst (DOC)	45.3
	Diesel Particulate Filter (DPF)	28.0

4.4 Impact of Vehicle Stock Composition on Fuel Economy

4.4.1 Motorcycles and Tricycles

a) *Engine capacity vs fuel economy*

Figure 4.1 shows the distribution of motorcycles and tricycles by engine capacity in number in Ethiopia. Most motorcycles and tricycles have medium engine capacity (151-200 cc). These groups of motorcycles and tricycles contribute towards better fuel consumption compared to high engine capacity.

Besides the engine capacity, the number of stroke is an important factor that should be considered for fuel consumption. The data collected from some regions does not show the type of stroke that the motorcycles and tricycles have. On the other hand, most motorcycles and tricycles in Addis Ababa use 2-stroke cycle gasoline engines that contribute towards high fuel consumption.

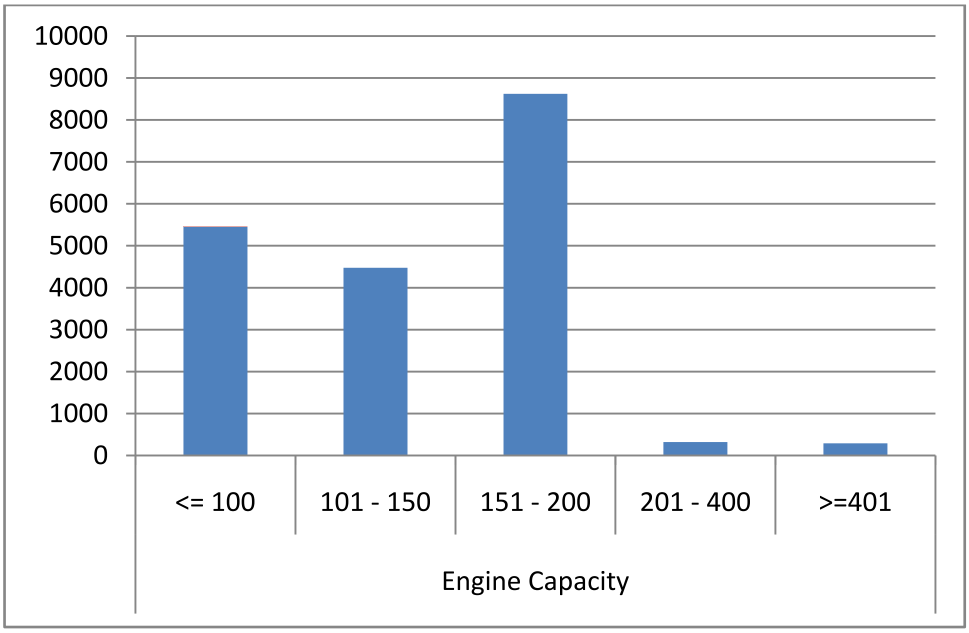


Fig 4.1 Summary of motorcycles and tricycles distribution in Ethiopia by engine capacity

b) Year of manufacture vs fuel economy

Figure 4.2 shows the distribution of motorcycles and tricycles by year of manufacture in number in Ethiopia. Many motorcycles and tricycles available in Ethiopia were manufactured in the years 2005-2009. This is due to the introduction of new tricycles across the country to use them for transportation. Generally, the use of new vehicles with appropriate technology contributes towards better fuel economy. On the other hand, few motorcycles and tricycles were manufactured before 1989. These groups are very old and consume more fuel if they are not maintained periodically.

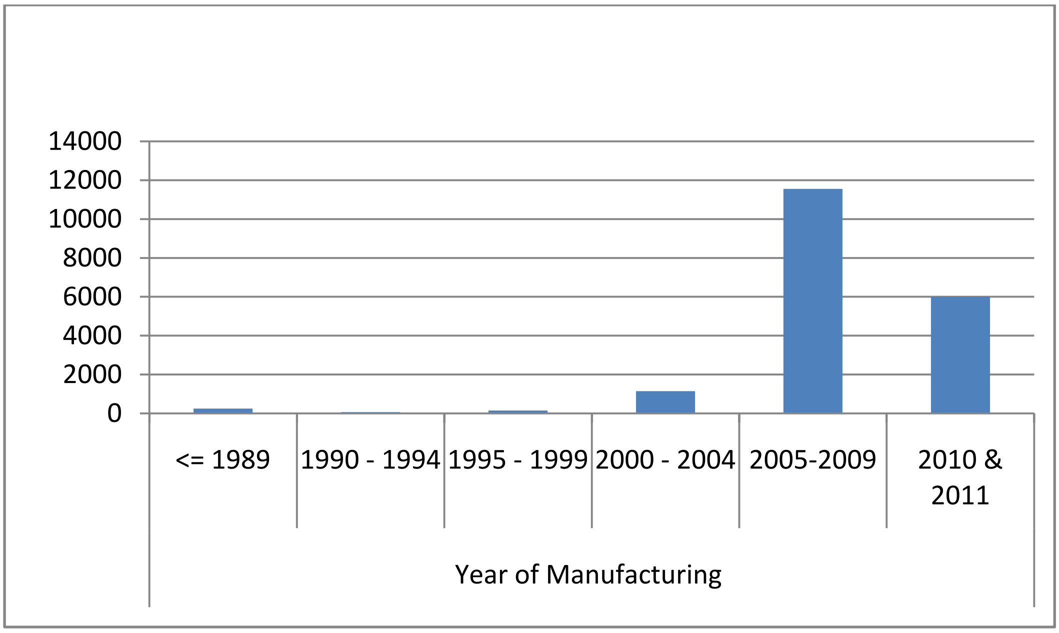


Fig 4.2 Distribution of motorcycles and tricycles in Ethiopia by year of manufacture

c) Fuel type vs fuel economy

Figure 4.3 shows the distribution of motorcycles and tricycles by fuel type in number in Ethiopia. Almost all motorcycles and tricycles across the country use gasoline fuel. Since diesel vehicles are fuel efficient, the use of 2-stroke cycle gasoline engines results in more fuel consumption. It is recommended to introduce more 4-stroke cycle gasoline engines, although they are relatively expensive.

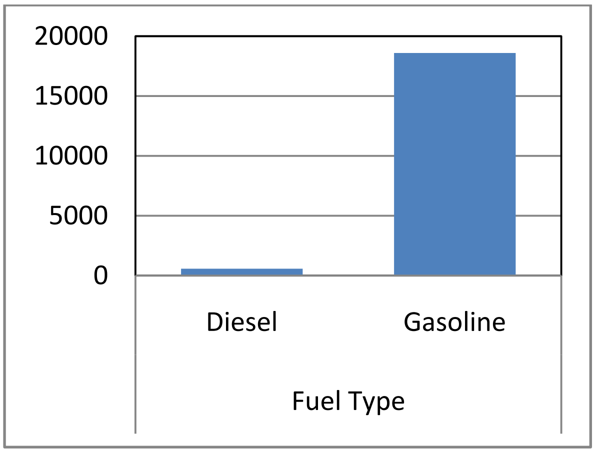


Fig 4.3 Distribution of motorcycles and tricycles by fuel type

4.4.2 Gasoline Vehicles

a) Engine capacity vs fuel economy

Figure 4.4 shows the distribution of gasoline vehicles by engine capacity in number in Ethiopia. Most gasoline vehicles in Addis Ababa and some regions have medium engine capacity (1001-1300 cc). Since gasoline vehicles are not fuel efficient as compared to diesel vehicles, high population of medium engine capacity gasoline vehicles contributes to low fuel consumption and better fuel economy.

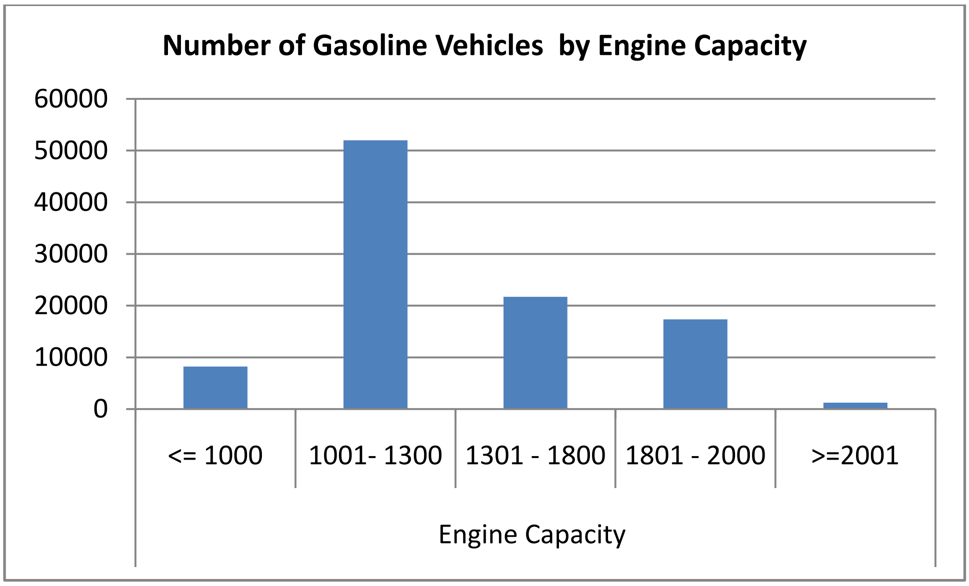


Fig 4.4 Distribution of gasoline vehicles by engine capacity

b) Year of manufacture vs fuel economy

Figure4.5 shows the distribution of gasoline vehicles in Ethiopia by year of manufacture in number. Many gasoline vehicles available in Ethiopia are manufactured during the period 1982-1989 which is more than 23 years ago. Unless these vehicles are properly maintained and their engines are overhauled, they are not fuel efficient. Moreover, the fuel efficiency mainly depends on the type of air fuel mixture formation.

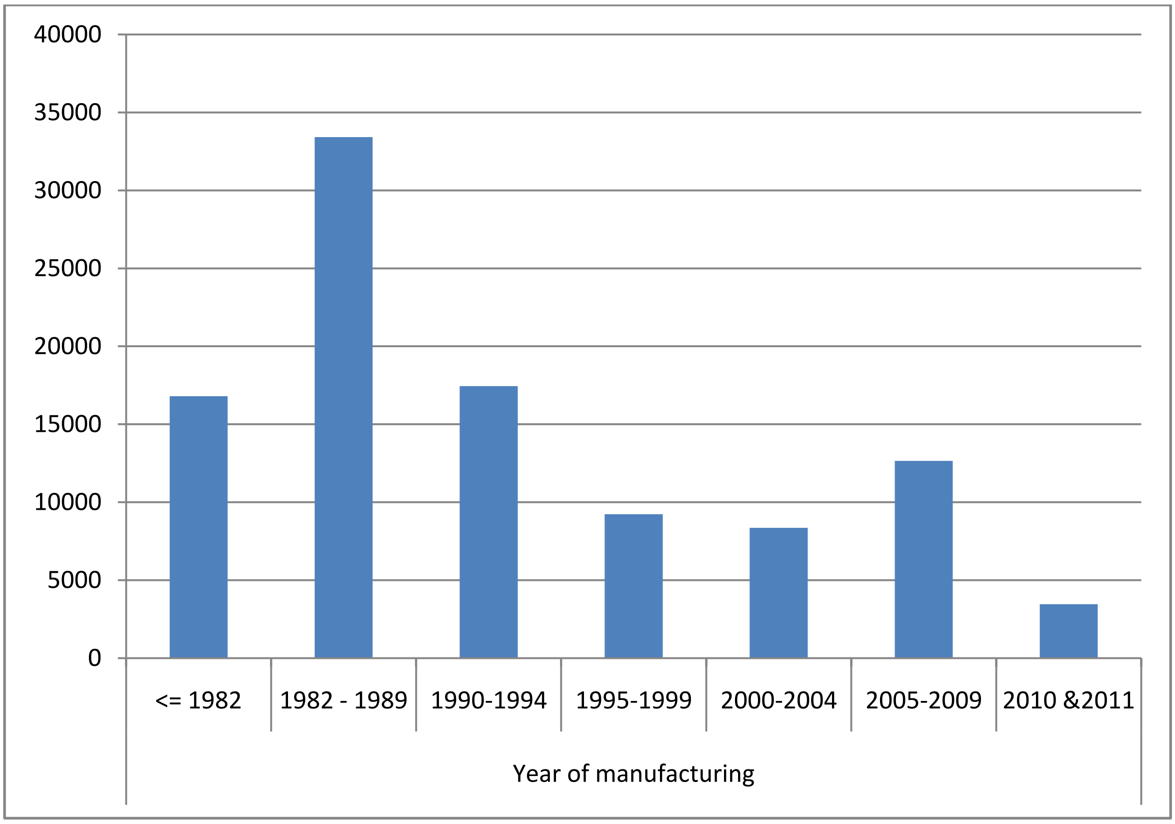


Figure 4. 5 Summary of gasoline vehicles distribution by year of manufacture

c) Type of air-fuel mixture formation vs fuel economy

Figure4.6 shows the distribution of gasoline vehicles in Ethiopia by type of air fuel mixture formation in number. The number of gasoline vehicles with Electronic Fuel Injection system (EFI) is greater than that of the conventional carburetor systems. This is recommended for better fuel efficiency.

4.4.3 Diesel Vehicles

Diesel vehicles (generally comprised of light duty vehicles, heavy trucks (cargo) and buses) are more fuel-efficient compared to petrol vehicles, and that emit less CO2. There are other factors that contribute to high fuel consumption such as body type, engine capacity, year of manufacture and type of fuel injection systems. As it is discussed in the previous sections, the raw data collected from regional governments does not have complete information to analyze the influence of various factors on fuel economy. Therefore, this section only addresses the effect of year of manufacture and fuel system on fuel economy.

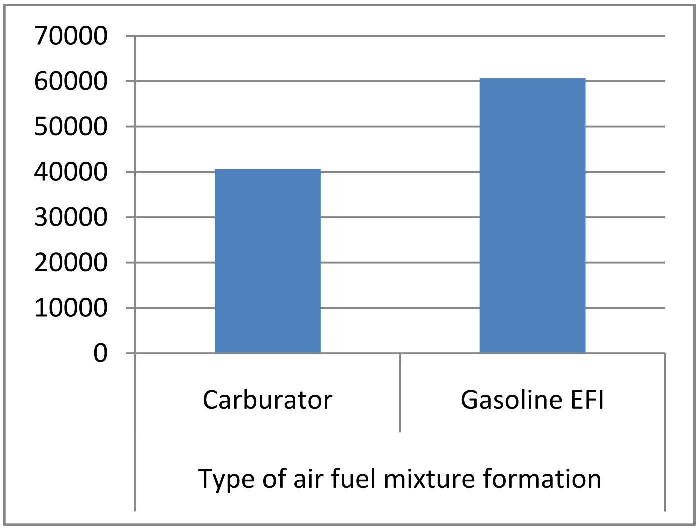


Figure 4.6 Summary of gasoline vehicles distribution by type of air fuel mixture formation

a) Year of manufacture vs fuel economy

Figure 4.7 shows the distribution of diesel vehicles in Ethiopia by year of manufacture. The number of new diesel vehicles imported to Ethiopia increases gradually from time to time. Most diesel vehicles available in Ethiopia were manufactured in the range of 2005-2009. This indicates that the old heavy duty trucks and busses are being replaced by the new ones. This trend will encourage the use of new diesel vehicles for better fuel economy.

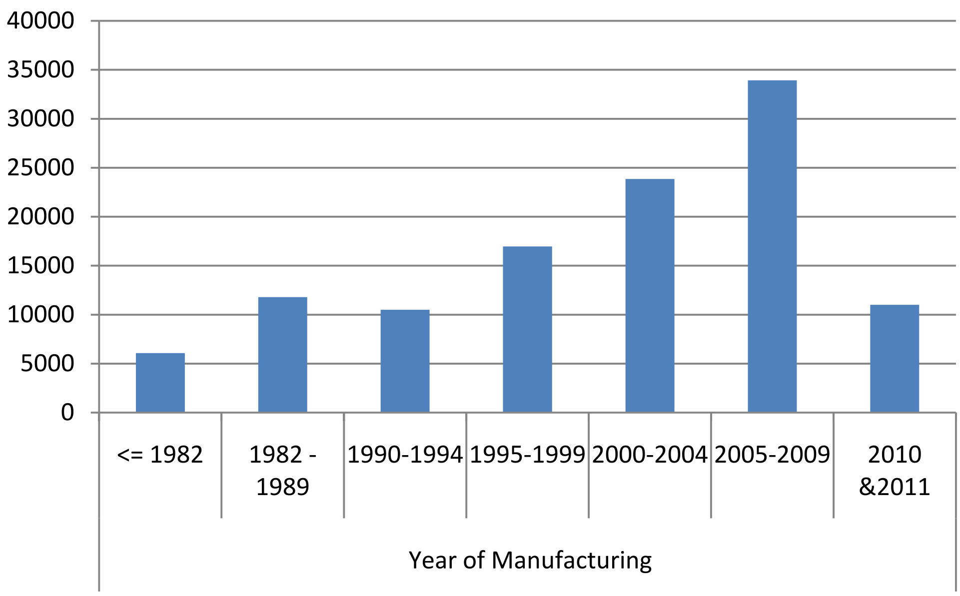


Figure4. 7 Summary of diesel vehicles distribution by year of manufacture

b) Type of air-fuel mixture formation vs fuel economy

Figure 4.8 shows the distribution of diesel vehicles in Ethiopia by type of fuel system. The number of diesel vehicles with Electronic Injection system (EI) is twice greater than that of the conventional Mechanical Injection systems. Since most diesel vehicles were manufactured after 2005, they are equipped with electronic injection system. Therefore, the use of more diesel vehicles with Electronic Injection system improves fuel economy.

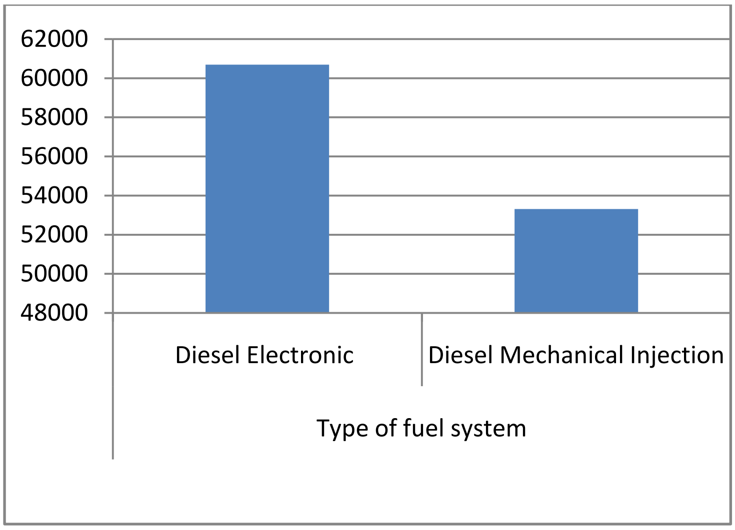


Figure 4. 8 Summary of diesel vehicles distribution by type of fuel system

5. FUEL QUALITY REVIEW AND IMPROVEMENT OF FUEL STANDARD

5.1 Fuel Utilization Policy and Consumption

The economic development of a country along with infrastructure expansion and shifts to industrialization is exacerbating the demand for fuel. For instance, Ethiopia imports fuel on average that costs about 768 million USD per annum and this covers 77% of the total export earnings (MM and E, 2007). The demand is expected to increase with the economic and population growth of the country. The economic changes are associated with changes in economic sectors such as transport sector which uses only commercial energy such as gasoline and diesel as opposed to noncommercial forms of energy. Therefore, the share of commercial energy in the development process will increase because of rapid growth of inherently modern fuel using sectors such as transport sector of the economy (Mosse, 2002).

The transport energy policy of Ethiopia emphasizes ensuring efficient utilization of energy and partially substituting by local products, to save scarce foreign exchange to achieve sustained and continued economic and social development of the country (MW and E, 2010). The policy emphasis is that the energy must be friendly to the environment through adopting different technology intervention to reduce petroleum fuel consumption products in the transport sector and substituting wherever possible to new non petroleum fuels.

5.1.1 Diesel and Gasoline Consumption in Ethiopia from (2006-2012)

Petroleum is one of the valuable commodities in the world. It is used to generate power to drive the science-invented tools of Transport, Industry, Agriculture and Communication that touches every aspect of our daily life (World Bank, 1999). The level of petroleum consumption is directly related to economic development and the number of population (Mosse, 2002). The data of the Ethiopian Petroleum Enterprise shows that Ethiopia consumes petroleum products, gasoline and diesel, which has were increased during the year 2006 - 2012 (Table 5.1). During these years diesel had the largest share compared to gasoline. This shows that diesel consuming transport activities has constituted the largest share and increase.

In these years, gasoline consumption increased by 27.9%, whereas that of diesel was 35.61%. During all those years, diesel oil has been the dominant fuel demand of the total consumption (Table 5.1 and Figure 5.1). As the economic growth of the country is expected to continue even at higher rate, the demand for gasoline and diesel is expected to continue rising rapidly.

Table 5.1 Petroleum product sales (consumption) quantity in metric ton

Product type	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Diesel	851,381	927,939	1,107,193	1,199,673	1,250,641	1,154,560	1,232,894
Gasoline	147,514	144,637	143,024	149,966	162,070	151,634	154,238

Source: Ethiopian Petroleum Supply Enterprise

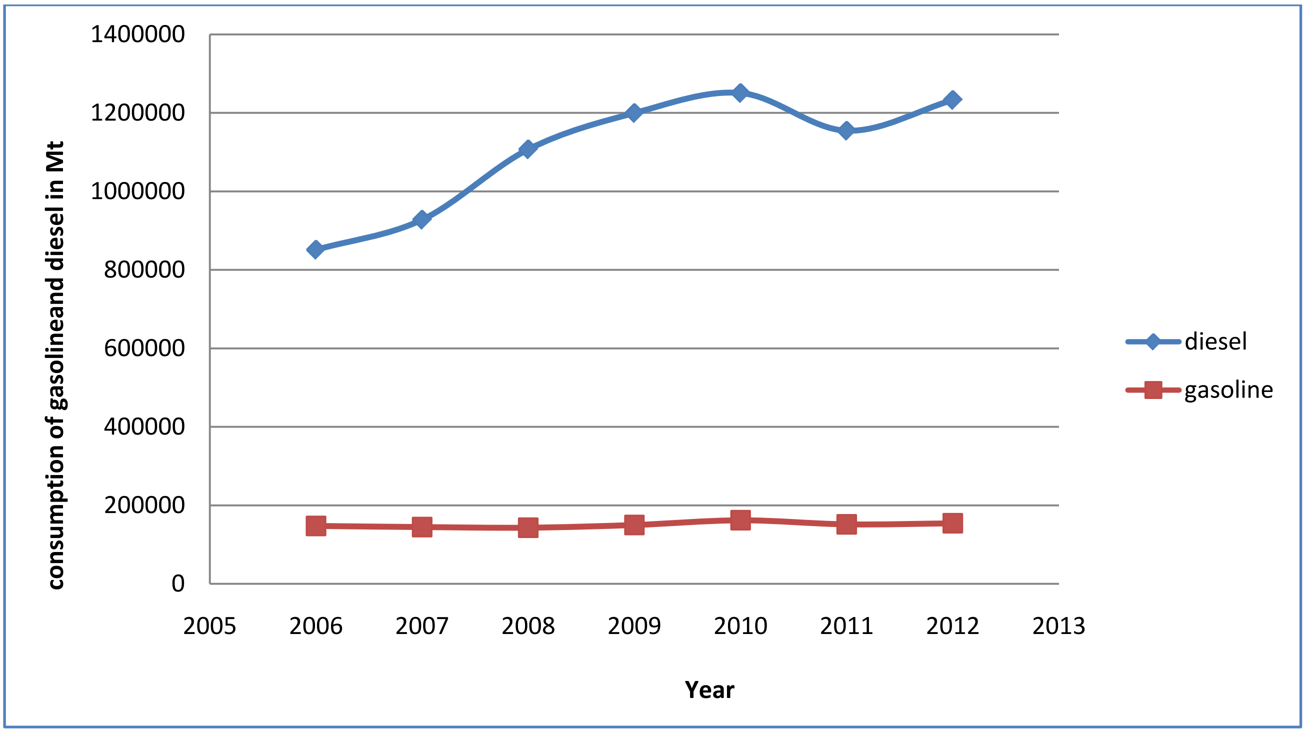


Figure 5.1 Trend of gasoline and diesel consumption

5.1.2 The Biofuel Development and Utilization Strategy in Ethiopia

In order to ensure the countries continued development program and the national fuel security, it is important to increase fuel utilization and substitution by locally produced fuels such as biofuel. The "Ethiopian Biofuel Development and Utilization Strategy'' is targeted for supply of fuels from locally produced biofuel with the objective of the strategy being to ensure the production of biofuel without affecting food self sufficiency, enable import substitution and improve balance of payment (MM and E, 2007).

Fuel demand is getting higher while the supply is getting less. The oil price increase, which is the result of the mismatch between the demand and supply, is becoming a barrier for stable and sustainable economic development for many countries, particularly for developing countries like Ethiopia. In order to address these fossil fuel constraint shortage realities, the Ethiopian government has formulated a bio-fuel strategy for the energy sector. The strategy is expected to satisfy the demand for fuel by undertaking projects that accelerate bio-fuel development activities in the country. This will enable the country to withstand the challenges of unexpected fossil fuel price increase, to save foreign earnings, and even earn produce foreign currency (MM and E, 2007).

The biofuel development strategy paper (2007) by ministry of water resources and energy indicates that the production of ethanol in the medium and long term development can grow to 1 billion liters (1 million m^3) through agro-processing industry integrated development, in particular sugar industry, by cultivating 700,000 ha suitable land for sugar cane plantation. The sugar corporation agency of Ethiopia planned to produce 128,165,000 liters (128,165m^3) of ethanol from four sugar industries namely Fincha, Metehara, Wonji and Tendaho at the end of 2012 though Tendaho sugar factory has not yet started production (Guta, 2012).

Local production and utilization of ethanol has already been started as a blending to gasoline (B5) which has been upgraded to (B10). Data obtained from Ministry of Water Resources and Energy indicates that a total of 5,880,294.00 liter has been blended in 2012 which shows an increment of 4,231,961 liter compared to 2008. The blend of ethanol with gasoline shows an increment from year to year but the share of the blend compared to gasoline and diesel consumption is insignificant (Table 5.2 and 5.3).

Although the production of bio-diesel is not yet started, the country possesses ample potential for production of this fuel. The country has promoted production mainly of three feedstock, Castor crop, Jatropha curcas, and palm tree. In light of this, at national level, the country has allocated 23.3million ha to feedstock production (Guta, 2012).

By considering diverse potential energy sources and commitment of the government in creating enabling policies and legal grounds to facilitate the utilization of these resources as opportunity, it is possible to produce much more bio-fuel.

Table 5.2 Total amount of ethanol blending from 2008-2012

S/N	Year	Total Blending(Lt)	Remark
1	2008	1648333	
2	2009	5146642	
3	2010	6110936	
4	2011	2827372	Incomplete data
5	2012	5880294	

Source: Ministry of Water and Energy Bio Fuel Development Coordination July, 2012

Table 5.3 trend of Total blend of ethanol, Gasoline and Diesel (2008-2012)

Year	Total blend(m^3)	Gasoline(m^3)	Diesel(m^3)
2008	1648.333	194004.503	1244037.078
2009	5146.642	203420.959	1347947.191
2010	6110.936	219839.396	1405214.606
2011	2827.372	205683.513	1297258.427
2012	5880.294	209215.702	1387521.347

5.2 International and National Fuel Quality Standards

5.2.1 Parameters Included In the Fuel Quality Studies

The fuel quality parameters which are included in the discussion of fuel quality studies are discussed below. Some of the parameters have an impact on air pollution and/or motor vehicle emissions while others are related to motor vehicle performance (ORBITAL & CSIRO, 2008).

a) Gasoline Fuel Quality Parameter

(i) Octane is a measure of petrol's ability to resist auto-ignition, which can cause engine knock. There are two laboratory test methods to measure petrol octane numbers: one determines the Research Octane Number (RON) and the other is the Motor Octane Number (MON). RON correlates best with low speed, mild-knocking conditions and MON correlates with high-temperature knocking conditions and with part-throttle operation. Vehicles are designed and calibrated for a certain octane value. When a customer uses petrol with an octane level lower than that required, knocking may result, which could lead to severe engine damage. Engines equipped with knock sensors can handle lower octane levels by retarding the spark timing. However, fuel consumption and power suffer at very low octane levels and knock may still occur. Using petrol with an octane rating higher than that required will not improve the vehicle's performance. Most Euro-compliant engines are designed for 95 RON. In Europe, the min RON is 95, while in USA and Ethiopia is 91.

(ii) Sulfur: Sulfur naturally occurs in crude oil. If the sulfur is not removed during the refining process it will contaminate the vehicle fuel. Sulfur has a significant impact on vehicle emissions by reducing the efficiency of catalysts. Sulfur also adversely affects heated exhaust gas oxygen sensors. Reductions in sulfur will provide immediate reductions of emissions from all catalyst-equipped vehicles on the road.

(iii) Lead: Unleaded petrol is necessary to support vehicle emission control technologies such as catalytic converters and oxygen sensors. As vehicle catalyst efficiencies are increased, tolerance to lead contamination decreases. Even slight lead contamination can destroy a modern catalysts. The phase out of lead is supported but consideration must be given to the existing vehicle fleet as some older vehicles may require lead (or lead replacement additives) for engine protection.

(**iv)Volatility:** Sufficient volatility of petrol is critical to the operation of spark ignition engines with respect to both performance and emissions. Volatility is characterized by two measurements, vapor pressure and distillation**.** The vapor pressure of petrol should be controlled seasonally to allow for the differing volatility needs of vehicles at different temperatures. Lower vapor pressure is required at higher temperatures to reduce the possibility of hot fuel handling problems and to reduce evaporative emissions.

b) Diesel Fuel Quality Parameters

(i) Cetane Number/Cetane index: Cetane index is the ‘natural’ Cetane of the fuel, which is calculated based on measured fuel properties. The Cetane number is measured on a test engine and reflects the effects of Cetane improver additives. To avoid excessive additive dosage, a minimum difference between Cetane index and Cetane number must be maintained. Increasing the Cetane number improves fuel combustion, reduces white smoke on startup, and tends to reduce NOx and PM emissions. NOx seems to be reduced in all engines, while PM reductions are engine-dependent. These Cetane number effects also tend to be non-linear in the sense that increasing the Cetane number produces the greatest benefit when starting with a relatively low Cetane number fuel.

(ii) Density and Viscosity: Variations in fuel density (and viscosity) result in variations in engine power and, consequently, in engine emissions and fuel consumption. Changes in fuel density affect the energy content of the fuel brought into the engine at a given injector setting. Reducing fuel density tends to decrease NOx emissions in older technology engines that cannot compensate for this change.

(iii) Sulfur in Diesel: Diesel fuel sulfur contributes significantly to fine particulate matter (PM) emissions, through the formation of sulfates both in the exhaust stream and, later in the atmosphere. Sulfur can lead to corrosion and wear of engine systems. Furthermore the efficiency of some exhaust after-treatment systems is reduced as fuel sulfur content increases, while others are rendered permanently ineffective through sulfur poisoning.

5.2.2 International Fuel Quality Standards

In 2007, the European Commission undertook a review of these fuel quality requirements. The review addressed fuel specifications meeting stricter EU air quality targets and future auto emissions requirements, and also greenhouse gas (GHG) emissions from transportation fuels (International Fuel Quality Center, 2012). The review outcome was incorporated in a new directive as shown in the Table 5.4

Table 5.4: Gasoline and Diesel specifications (applicable in Europe 2009-2012)

Parameter		**Limits**
	Gasoline	
RON		Min 95
MON		Min 85
Sulfur		Max 10 ppm
Aromatics		Max 35 vol%
Oxygen		Max 2.7wt%
	Diesel	
Cetane number		Min51
Cetane index		Min 46
Sulfur		Max 10 ppm
Flashpoint		Min 55^{o}C
Density at 15^{o}C		820 kg/m^{3}-845kg/m^{3}

Source: International Fuel Quality Center compiled from Directive 98/70/EC as amended and EN 228:2008 and EN, 590:2009

In USA, **t**he EPA imposed a drastic reduction in the permitted lead level in petrol, from 0.13 g/L in 1985 and then to 0.026 g/L from January 1986. This was considered to be the lowest lead level that would allow continued operation of older engines. Finally ``sales of leaded petrol were banned from January 1995. The current American gasoline fuel specification is shown in the Table 5.5(ORBITAL & CSIRO, 2008).

Gasoline Sulfur Content: the maximum allowable sulfur limits in national standards, sulfur limits in local/regional standards (such as specifications for cities/states) of United States is 11-99ppm as shown in table 5.5 and Fig 5.3 (International Fuel Quality Center, 2012).

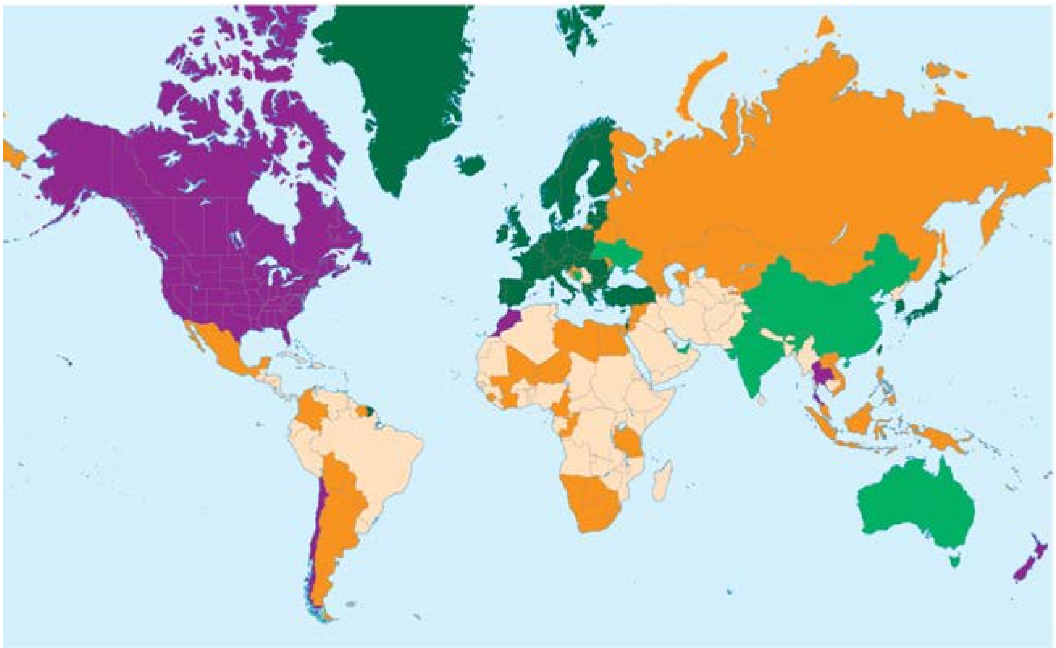


Figure 5.2 Global maximum gasoline sulfur content (source: www.ifqc.org)

Table 5.5 ASTM Specifications for Gasoline and Diesel (2012)

Parameter		**Limits**	**Test methods**
	Gasoline		
RON		Min. 91	ASTM D 2699
Total Sulfur µg/g		Max.11-99	
Density @ 15 ^{O}C.(g/ml)		0.705-0.74	ASTM D 1298
Lead Content, g/L		Max. 0.013	IP 352
	Diesel		
Cetane number		Min 40	D 643
Cetane index		Min 40	D976-80
Sulfur, ppm(µg/g),max % mass, max % mass, max		15 0.05 0.50	D5453 D2622 D129
Flashpoint		Min 55^{o}C	

5.2.3 Over View of Ethiopian Fuel Specifications

Fuel quality in Ethiopia is maintained through a regulation of Ethiopian petroleum supply enterprise and specifications made by Ethiopian quality and standards authority. Ethiopian quality and standards authority has established national fuel quality specifications based on Ethiopian standard which in most cases is in agreement with American Society of Testing and Materials (ASTM) Standard (Table 5.6).

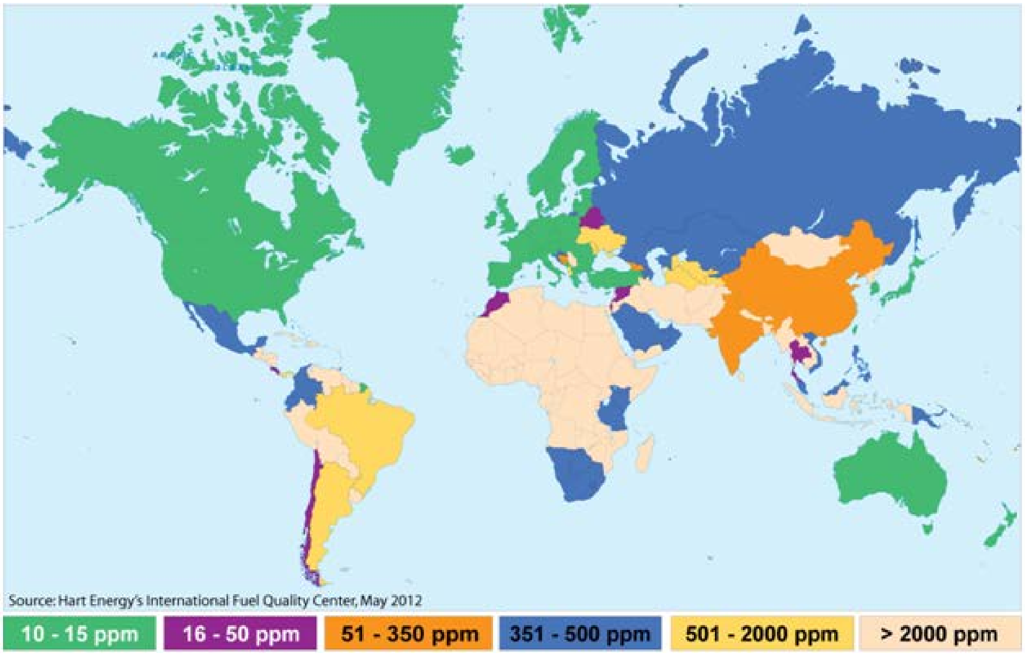


Figure 5.3 Global maximum sulfur content of diesel (source: www.ifqc.org)

Table 5.6 Ethiopian Specifications for Gasoline and Diesel 2012

Parameter		**Limits**	**Test methods**
	Gasoline		
RON		Min. 91	ASTM D 2699
MON		-	
Total Sulfur(µg/g)		Max (1000 ppm)	ASTM D 4294
Density @ 15 ^{O}C.(g/ml)		0.705-0.74	ASTM D 1298
Lead Content, g/L		Max. 0.013	IP 352
	Diesel		
Cetane number		-	-
Cetane index		Min 48	ASTM D 976
Total Sulfur % Weight		Max 0.50(5000ppm)	ASTM D 1552 ASTM D 4294
Flashpoint		Min 52^{o}C	ASTM D 93

Source: Ethiopian Petroleum Supply Enterprise June, 2012

***Gasoline lead content*:** as it can be noticed from national fuel specification (Table 5.6) and historical data from Ethiopian petroleum supply the maximum allowable lead content is 0.013g/L which is unleaded.

***Gasoline sulfur content*:** Ethiopian standards authority set the maximum allowable sulfur content gasoline to be 1000ppm (Table 5.6 and Fig 5.3) which is by far greater than current standards of USA and Europe.

***Diesel sulfur content*:** Standard diesel sulfur content is specified at max 5000 ppm which will be a bottle neck to apply emission control technologies (Table 5.6 and Fig 5.4).

5.3 Data Collected on Fuel Quality (historical data)

The data for selected parameters were collected from the data base of Ethiopian Petroleum Enterprise and compiled into excel file for analysis purpose. The data were compiled for the last 8 years. The average, minimum, and maximum values of these data were evaluated for

Table 5.7 Summary of Gasoline Fuel Quality in 2011

Test/parameter	Specification	Test method	Average	Min	Max
Research Octane Number (RON)	Min. 91	ASTM D 2699	90.52	90	91.8
Density @ 15 ^{O}C.(g/ml)	0.705-0.74	ASTM D 1298	0.721	0.711	0.739
Total Sulfur % Weight	Max. 0.10	ASTM D 4294	0.0244	0.004	0.1
Lead Content, g/L	Max. 0.013	IP 352	0.007	0.007	0.007

Table 5.8 Summary of Diesel Fuel Quality in 2011

Test/parameter	Specification	Test method	Average	Min	Max
Density @15^{o}C(g/ml)	Report	ASTM D4052	0.861	0.844	0.865
Total Sulfur % weight	Max 0.5	ASTM D 1552 ASTM D 4294	0.469	0.402	0.5
Flash point Pensky-Martens Closed cup, ^{O}C	Min 52	ASTM 93	77.94	63	89
Kinematic Viscosity Centistokes @37.8 ^{O}C	Min 1.9 Max 4.1	ASTM D445	3.686	2.9	4
Cetane index	Min 48	ASTM D97	49.18	48	56
Carbon residue Rams bottom10% (% weight)	Max 0.35	ASTM D524	0.123	0.03	0.2

each year to compare with the standards as shown in Tables (5.7 to 5.10 for three consecutive years) while summary of the date for the year 2004 to 2010 are shown in the annex. The review indicates the imported gasoline is unleaded gasoline but has very high sulfur content.

Table 5.9 Summary of Gasoline Fuel Quality in 2010

Test/parameter	Specification	Test method	Average	Min	Max
Research Octane Number (RON)	Min. 91	ASTM D 2699	90.18	90	91.3
Density @ 15 Deg. C.(g/ml)	0.705-0.74	ASTM D 1298	0.724	0.722	0.738
Total Sulfur % Weight	Max. 0.10	ASTM D 4294	0.012	0.004	0.06
Lead Content, g/L	Max. 0.013	IP 352	0.007	0.007	0.007

Table 5.10 Summary of Diesel Fuel Quality in 2010

Test/parameter	Specification	Test method	Average	Min	Max
Density @15°C(g/ml)	Report	ASTM D4052	0.856	0.834	0.866
Total Sulfur % weight	Max 0.5	ASTM D 1552 ASTM D 4294	0.458	0.340	0.50
Flash point Pensky-Martens Closed cup, Deg.C	Min 52	ASTM 93	76.71	57	89
Kinematic Viscosity Centistokes @37.8 Deg.C	Min 1.9 Max 4.1	ASTM D445	3.53	2.4	4
Cetane index	Min 48	ASTM D97 (calc)	49.71	41	55
Carbon residue Rams bottom10% Distillation Residue % weight	Max 0.35	ASTM D524	0.121	0.09	0.17

5.3.1 Global and National Sulfur Levels in Fuels

Global levels of sulfur in fuels differ greatly, by country and region. Depending on the crude oil used and the refinery configurations, sulfur levels in petrol range from a value less than 10 ppm to as high as 1000 ppm or more (Figure 5.2). In diesel fuel, levels range from a value less than 10 ppm to more than 10,000 ppm (Figure 5.3). Europe, the US, and Japan have put in place measures to reduce sulfur to lower levels (below 10-15 ppm), often along with emission standards that require advanced emission control technologies that cannot be used with higher sulfur fuels (UNEP, 2006).

Around the world, many countries are lowering the limit of allowable sulfur in fuels and adopting tailpipe emission standards to reduce vehicle pollution (UNEP, 2006). However, the global picture is mixed. As shown in Figures 5.2 and 5.3, the sulfur levels in both gasoline and diesel in the majority of developing countries of Africa, including Ethiopia, is very high. The data acquired from Ethiopian Petroleum Supply Enterprise showed that the max allowable sulfur level in gasoline is 1000 ppm whereas the maximum allowable sulfur level in diesel is 5000ppm. The Ethiopian Petroleum Supply Enterprise is very stringent in maintaining the set standards especially from 2006 onwards **(**Table 5.11, Figure 5.4 and 5.5). Different researches conducted on vehicle emission and engine operability indicate that fuel quality intimately affects vehicle emissions as the vehicle and its fuel (and oil) form an integrated system (Blumberg *et al*., 2003). The vehicle-fuel system determines the quality and amount of emissions and the extent to which emission control technologies will be able to reduce the emissions. Reducing sulfur levels in fuels is especially important in reducing the smallest particles and can reduce vehicle emissions in general (UNEP, 2006). This demonstrates that there are substantial emission reductions to be achieved when sulfur in diesel is reduced from very high levels that are common in many developing countries like Ethiopia, which have more than 5,000 ppm in diesel fuels, to very low levels (50 ppm and less). This, not only reduces PM emissions further but also enables the introduction of emission control technologies that provide even greater emission reductions.

Table 5.11 Sulfur content of imported Diesel for the previous 8 years

Year	**Average**	**Minimum**	**Maximum**
2004	0.913	0.70	0.99
2005	0.610	0.31	0.97
2006	0.499	0.14	3.9
2007	0.448	0.28	0.48
2008	0.481	0.40	0.93
2009	0.477	0.38	0.48
2010	0.458	0.34	0.50
2011	0.469	0.40	0.50
2012	0.475	0.47	0.48

NB: specification (total sulfur % by weight 0.5 or 5000ppm)

Table 5.12 Sulfur content of imported gasoline (From 2004-2011)

Year	**Average**	**Minimum**	**Maximum**
2004	0.061	0.004	0.09
2005	0.015	0.004	0.09
2006	0.056	0.02	0.09
2007	0.075	0.07	0.08
2008	0.0391	0.004	0.09
2009	0.038	0.004	0.09
2010	0.012	0.004	0.06
2011	0.0244	0.004	0.1

NB: specification (total sulfur % by weight 0.1 or 1000ppm)

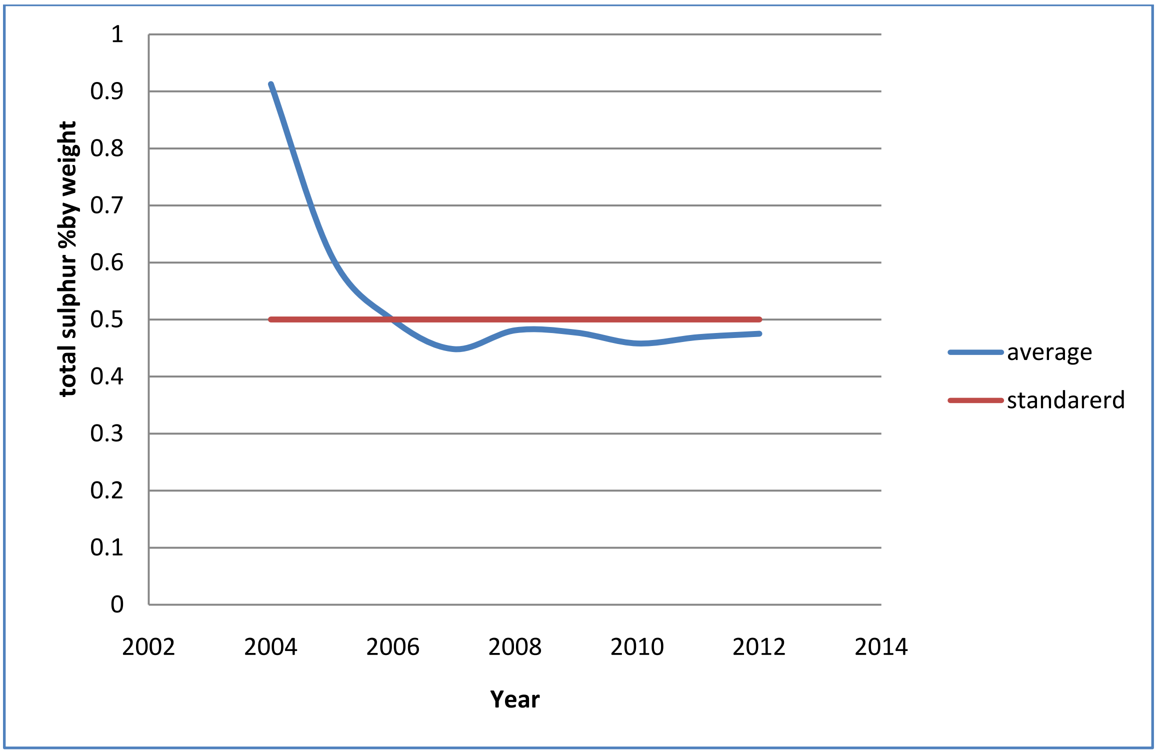


Figure 5.4 Trend of sulfur content of diesel

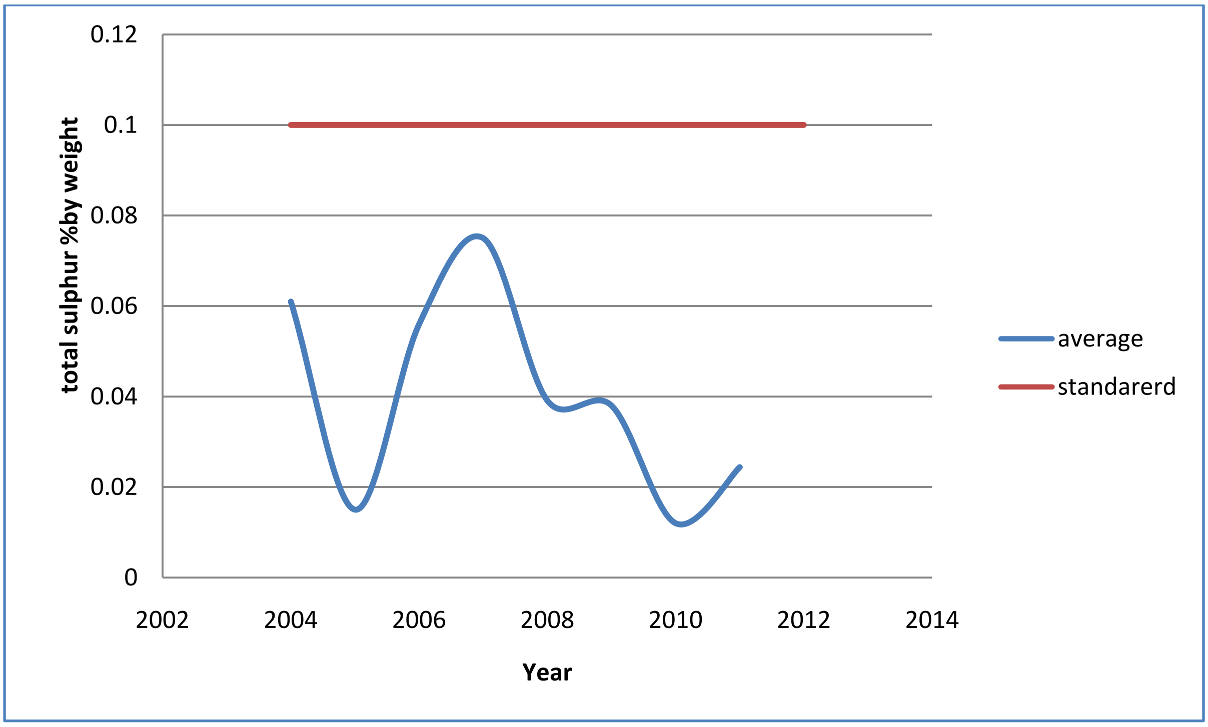


Figure 5.5 Trend of sulfur content of gasoline

5.4 Conclusions and Recommendations

Ethiopia imports its entire petroleum fuel requirement, and the demand for petroleum fuel is rising rapidly due to a growing economy and expanding infrastructure. By 2012 Ethiopia has imported 1,232,894.00 Mton of diesel and 154,238.00Mton diesel while the total blend of ethanol with gasoline was 5,880,294.00 Lt. Report from Ministry of Water Resources and Energy indicates that Ethiopia imports fuel on average at the expense of 768 million USD per annum and this covers 77% of the total export earnings. Given the current and expected oil price trends and volatility, the gradual substitution of imported petroleum fuels by biofuel and a diversification of energy sources will rapidly gain macroeconomic importance. In order to ensure the continued development program and the national fuel security, the government of Ethiopia has set a clean energy plan to increase fuel efficiency and substituting fossil fuel demand by locally produced fuels such as biofuel.

The historical data obtained from petroleum supply of Ethiopia demonstrates the fuel parameters of the imported gasoline and diesel comply with the set standards but as stated in section 5.3, the sulfur content of gasoline and diesel are 1000ppm and 5000ppm, respectively.

This is categorized under high sulfur content of fuel. The high sulfur content of fuel reduces the vehicle efficiency and affects the environment and human health. With high sulfur fuel, it will also make the application of vehicle emission control technologies difficult.

As can be noted, in Ethiopia, vehicle numbers are increasing rapidly from time to time. Hence, the high-sulfur fuels continue to be the norm and to inhibit the introduction of new vehicle technologies. Therefore in order to allay the mounting human health impacts of increasing vehicle numbers and reduce the burden associated with cleaning up existing vehicles, Ethiopia needs to institute policies earlier to lower sulfur levels to 50ppm which allows for the further benefit of advanced control technologies for diesel vehicles. Studies show the benefits of sulfur reduction far outweigh the costs. The U.S. EPA found human health and environmental benefits due to sulfur reduction was ten times higher than the costs. Furthermore the considerable potential for greenhouse gas emission reductions adds further to the health, environmental, and social benefits of sulfur reduction (Blumberg et al., 2003).

6. ANALYSIS OF IMPACT OF VEHICLE EMISSION ON AIR POLLUTION

6.1 Introduction

Air pollution is the presence of pollutants in the ambient air in such concentration as to harm human, plant, or animal life, cause damage to materials and structures, cause climate or weather change. Urban air pollution usually occurs when a high level of emission (from vehicles or other combustion sources), combines with poor dispersion conditions. Meteorological and topographic conditions affect dispersion and transport of these pollutants.

Motor vehicles are sources of a number of air pollutants, such as carbon monoxide, nitrogen oxides, un-burnt hydrocarbons, suspended particulate matter, sulfur dioxide and volatile organic compounds. Nearly 50% of global carbon monoxide (CO), hydrocarbons (HCs) and nitrogen dioxide (NO_2) emissions from fossil fuel combustion come from petrol and diesel engines. In city centers and congested streets, traffic can be responsible for about 80-90% of these pollutants and this situation is expected to be severe in cities in developing countries where vehicle emission monitoring is not in place. Vehicle emissions mainly result from fuel combustion or evaporation. The major pollutants emitted from gasoline fueled vehicles are CO, HCs, and NOx (oxides of nitrogen), whereas the presence of sulfur compounds in diesel fuel results in sulfur dioxide (SO_2) and particulate matter (PM) emissions.

Diesel exhaust emission usually contains particles in the size range between 50nm and 100nm. Particulates from gasoline vehicle exhaust emission are well below 40nm in diameter, with large proportion of this being in the order of 10 nm. Particles with diameter below 0.1μm are ultrafine particles. Particles between 0.1 and about 1μm in diameter are typically formed from ultrafine particles by coagulation and adsorption of gaseous material in the atmosphere onto preexisting particles. These particles can remain suspended in the air for long period of time (several weeks). These particles and the ultrafine particles are also known as fine particles ($PM_{2.5}$), i.e. particles with an aerodynamic diameter of less than 2.5μm [Bacha, 2007; Tiagarajam, 2004; Farnlund, 2001].

According to the WHO assessment, diseases associated to air quality deterioration have been responsible for millions of premature deaths, majority of which is in the developing countries.

Local pollutants such as carbon monoxide, air toxins and particulates, tend to concentrate adjacent to busy roadways, especially where geographic and climatic conditions trap pollution and produce ozone [www.vtpi.org].

Air pollution is a serious environmental concern in large cities. Often, a significant portion of city residents are exposed to poor air quality. Childhood cancers are frequent in households living adjacent to high traffic roads [www.vtpi.org]. In addition, as shown in Figure 6.1 people who travel by car are exposed to more air pollution than people traveling by other modes. According to a study, road pollution emissions in Austria, France and Switzerland cause significant increases in bronchitis, asthma, hospital admissions and premature deaths.

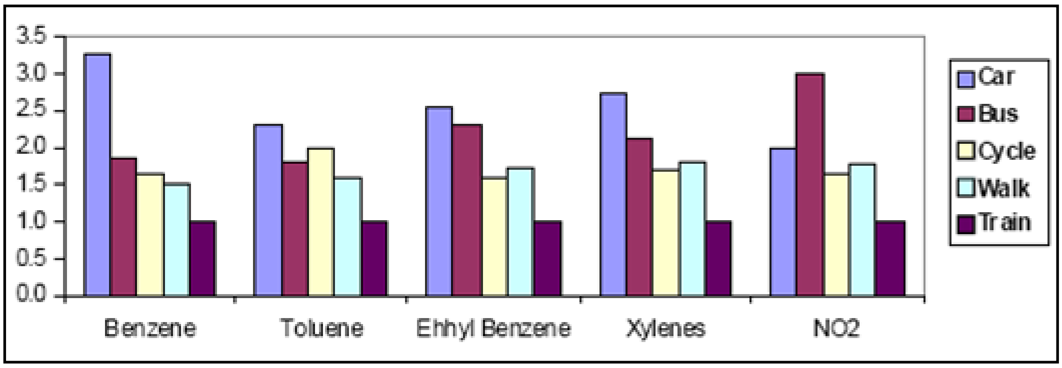


Figure 6.1 Relative air pollutants (HC& NO_2) exposure by transportation mode [www.vtpi.org]

Air quality limit values are designed, and set to serve as guidance in reducing human health impacts of air pollution. In order to reduce the impact of air quality deterioration, it is necessary to know the state of the ambient air quality. Accordingly, this part of the study deals with the measurement and assessment of common air pollutants related to motor vehicle emissions in the Addis Ababa City.

6.2 Methodology

This section deals with the methodological aspects of air quality measurement. The methodology followed in this part of the study includes literature review, measuring method and instruments, measuring site selection and evaluation of the results. Collected primary and secondary data were analyzed by comparing against WHO guidelines and EPA Ethiopia guidelines given in Table 6.1.

Table 6.1 EPA Ethiopia and WHO air quality guidelines [EPA, 2003; WHO, 2005]

Pollutant	**EPA Ethiopia guideline**		**WHO guideline**	
	Guideline value (μg/m^3)	**Average time**	**Guideline value (μg/m^3)**	**Average time**
Sulfur dioxide	500	10 minutes	500	10 minutes
	125	24 hours	20	24 hours
	50	1year	50	1 year
Nitrogen dioxide	200	1 hour	200	1 hour
	40	1 year	40	1 year
Carbon monoxide	100,000	15 minutes	100,000	15 minutes
	60,000	30 minutes	60,000	30 minutes
	30,000	1 hour	30,000	1 hour
	10,000	8 hours	10,000	8 hours
Particulate matter				
$PM_{2.5}$	65	24 hours	25	24 hours
	15	1 year	10	1year

6.2.1 Literature Review

There is very little information available concerning urban air pollution in Addis Ababa city. A study was conducted on the magnitude and variation of CO pollution due to vehicle emissions in Addis Ababa city by Abera Kume at 40 different sites (Kume, 2010). According to this study none of the sampling sites showed CO concentrations above WHO guideline limit. The result indicated that the mean value for 15 minutes CO concentration was found to be 2.1 ppm and 2.8 ppm for wet and dry seasons, respectively.

6.2.2 Measuring Methods and Instruments

In this study, only the measurements of common vehicle emissions/pollutants viz. carbon monoxide, (CO), particulate matter ($PM_{2.5}$), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) were carried out mainly due to time limitation and shortage of available resources including measuring instruments and associated technical problems.

CO and $PM_{2.5}$ measurement were carried out employing continuous measuring instruments comprising of uninterrupted recording of concentrations throughout the measurement period.

The measurements of NO_2 and SO_2 were carried out using non-continuous measuring instruments.

Two sampling periods, dry and wet seasons, were selected. All measurements were taken during working days from 8:30 am to 5:30 pm local time. The measuring instruments were fixed at the edges of the roads at a height of 1 meter above ground.

a) Carbon Monoxide Measurement

HOBO model CO data logger was used to measure the level of CO in the ambient air at all selected sites. The instrument was calibrated as per the specification of the manufacturer before commencing the intended measurements. Measurements were conducted by placing the instrument 1 meter above the ground at the edge of the selected road. The instrument was set at a sampling interval of 1 minute during the whole period of the study lasting from 8:30 AM to 5.30 PM. Measured data were evaluated and presented.

b) Particulate Matter Measurement

Particles between 0.1 and about 1µm in diameter are typically formed from ultrafine particles by coagulation and adsorption of gaseous material in the atmosphere onto preexisting particles. These particles can remain suspended in the air for long period (several weeks). These particles and the ultrafine particles are also known as fine particles ($PM_{2.5}$), i.e., particles with an aerodynamic diameter of less than 2.5µm.

In this work, the measurement of $PM_{2.5}$ was carried out mainly because of the fact that most particulate matter associated with vehicular emissions are fine particles of less than 2.5µm in diameter.

Concentration of fine particulate matter was measured using the University of California Berkeley Particle Monitor (UCB PM Monitor). The UCB Particle Monitor can detect particles with aerodynamic diameter of 2.5 microns ($PM_{2.5}$) and less. Measurements were conducted by placing the instrument 1 meter above the ground at the edge of a road. The instrument was continuously recording the concentration of fine particles in the ambient air from 8:0 am to 5.30 pm.

c) *Nitrogen Dioxide Measurement*

The measurements of nitrogen oxides concentration in the ambient air were carried out using Oldham Multi-gas detector. Measurements were performed at different time intervals on discrete basis.

d) *Sulfur Dioxide (SO_2) Measurement*

SO_2 concentration in the ambient air was measured using Crown Gasman detector. On-road measurements were performed at different time intervals on discrete basis.

Table 6.2 Measurement sites and location

Site		**GPS location**
Code	**Name**	
S1	Aduwa Square (Megenagna)	N 09^{o} 00.145’; E 038^{o} 47.560’
S2	Arada (Arada building)	N 09^{o} 01.977’; E 038^{o} 45.187’
S3	Betel	N 09^{o} 00.225’; E 038^{o} 41.515’
S4	Bob Marley Square (Imperial Hotel)	N 09^{o} 00.156’; E 038^{o} 48.005’
S5	Bole Bridge	N 08^{o} 59.351’; E038^{o} 47.550’
S6	Bus Station (Addis Ketema)	N 09^{0} 02.038’; E038^{o} 43.947’
S7	Entoto (St. Mary Church)	N 09^{0} 05.182’; E 038^{o} 45.735’
S8	Kaliti Road Intersection (Traffic light)	N08^{o}55.967’; E038^{o} 46.002’
S9	La gare Traffic Light	N 09^{o} 00.701’; E 038^{o} 45.192’
S10	Mexico Square	N 09^{o} 00.638’; E 038^{o} 44.699’
S11	Teklehaimanot Square	N 09^{o}01.728’; E038^{o} 44.583’
S12	Urael Traffic Light	N 09^{o} 00.659’; E 038^{o} 46.503’

6.3 Measurement Sites

Given the limitation in time and resource, only 12 sampling sites were selected. In line with the objective of the project, which aimed at assessing the severity of air pollution due to vehicle emission, on-road measurements were carried out at selected sites (road junctions, roundabouts and squares). The criteria used for site selection were:

- congested traffic area suspected of high fleet pollutant emissions
- high population density relative to receptor-dose levels, both short- and long-term (permanent/residence)

- atmospheric considerations such as spatial and temporal variability of pollutants and their transport
- height and density of buildings
- building use
- traffic frequency and composition
- background pollution

The selected measurement sites in Addis Ababa city are shown Table 6.2.

6.4 Results

6.4.1 Carbon Monoxide

Figure 6.2 and Figure 6.3 show the variation of CO concentration with time as recorded by the instrument in the interval of time shown for two representative sites (Bole bridge and Teklehaimanot Square). The site at Bole Bridge hosts high traffic intensity of light vehicles since the circulation of vehicles above 3t is restricted in this area while the site at Teklehaimanot Square is a commercial area that hosts heavy traffic of different vehicle categories. According to Figure 6.2 higher levels of CO are observed in the morning up to lunch time in Bole bridge and this level decreases very gradually in the afternoon.

The tendency at Teklehaimanot looks different. The CO level was seen to increase in the morning until around 12:00am when the highest peak was observed. Lowest values were seen between 12:00am and 13:30pm (lunchtime). The level of CO afterwards showed more or less a regular pattern oscillating around a mean value. The maximum recorded value of CO at this site for the dry season is 16.4ppm.

Nevertheless, as can be seen from Table 6.3, none of the averages are greater than the values indicated in the WHO guideline. Only two sites (S6 and S11) show values greater than 50% of the WHO guideline for 8-hour average. Particular to these two sites is the relatively higher circulation level of diesel vehicles.

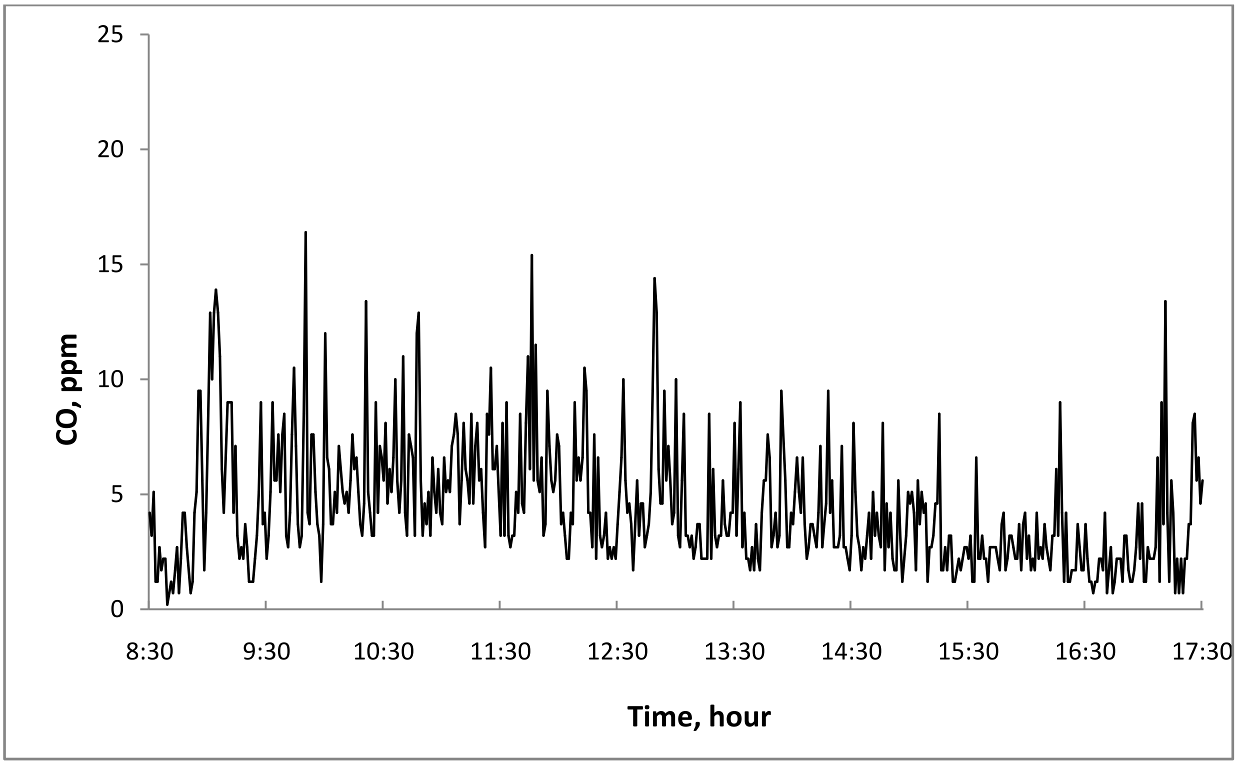


Figure 6.2 Measured CO concentration at Bole Bridge during the dry season

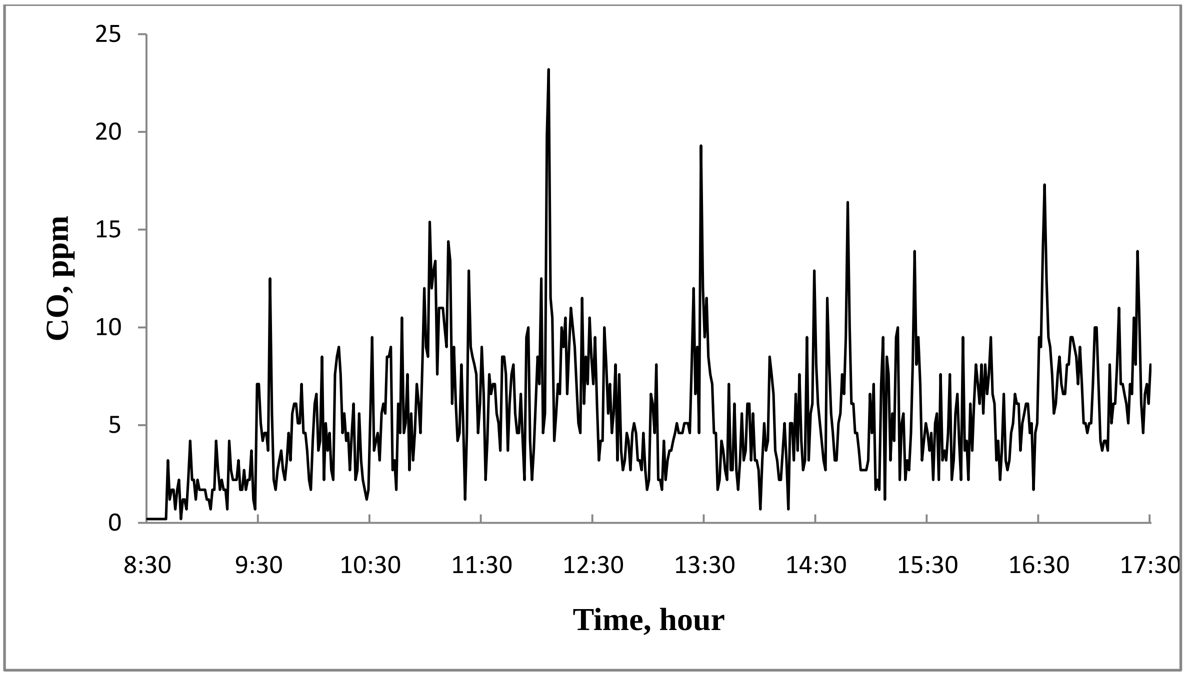


Figure 6.3 Measured CO concentration at Teklehaimanot Square during the dry season

Table 6.3 CO concentrations at different sites collected during the dry season

Site		CO Concentration, ppm				
Code	**Name**	**Max 15-minute average**	**Max 30-minute average**	**Max 1-hour average**	**8-hour average**	**Maximum**
S1	Aduwa Square (Megenagna)	7.1	7.1	6.0	3.8	15.9
S2	Arada (Arada building)	3.8	3.0	2.8	2.2	12.5
S3	Betel	4.4	4.3	3.7	2.5	12.5
S4	Bob Marley Square (Imperial Hotel)	6.9	6.3	4.9	3.7	13.4
S5	Bole Bridge	15.0	10.7	6.1	4.4	16.4
S6	Bus Station (Addis Ketema)	15.0	7.8	7.1	**5.9**	20.8
S7	Entoto (St. Mary Church)	0.2	0.2	0.2	0.2	0.2
S8	Kaliti Road Intersection	15.0	5.1	4.8	3.9	11.0
S9	La gare Traffic Light	6.3	5.8	4.8	3.6	14.4
S10	Mexico Square	9.9	7.6	7.3	3.7	17.7
S11	Teklehaimanot Square	16	9.0	7.5	**5.2**	23.2
S12	Urael Traffic Light	5.3	5.1	4.8	3.2	12.9
Average		8.7	6.0	5.0	3.5	14.2

WHO guideline for CO: 15minute = 90ppm; 30 minute = 50ppm; 1hr =25ppm; 8hr = 10ppm

EPA guideline for CO: 15minute = 90ppm; 30 minute = 50ppm; 1hr = 25pp; 8hr = 10ppm

Measurement of CO concentrations during the wet season was conducted only for three representative sites due to time constraints. The result of measurements is given in Table 6.4.

Table 6.4 Wet season CO concentration level at different sites

Site	CO concentration, ppm				
	Max 15-minute average	**Max 30-minute average**	**Max 1-hour average**	**8-hour average**	**Maximum**
Bus station (Addis Ketema)	37.4	23.4	17.2	2.8	44.2
Mexico Square	14.5	13.1	8.1	4.9	22.7
Teklehaimanot Square	17.2	13	8.0	1.5	24.2

As can be seen from Table 6.4 the results obtained for the wet season at the same sites are slightly higher than those of the dry season.

6.4.2 Particulate Matter

Figure 6.4 shows that the $PM_{2.5}$ concentration builds up in the morning attaining a maximum around 9:30 am after which the concentration gradually drops and remains at relatively low level until it starts to increase after lunch time reaching a maximum around 15:00 pm. It can be said that this observed pattern is related to the traffic intensity during the rush hours.

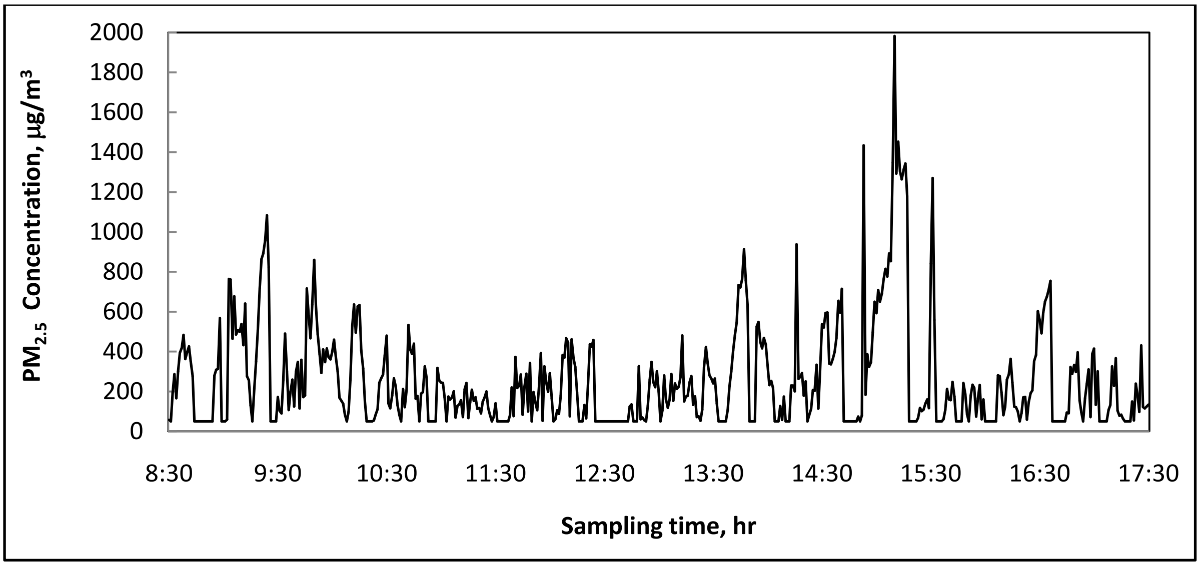


Figure 6.4 $PM_{2.5}$ concentrations at Bole Bridge

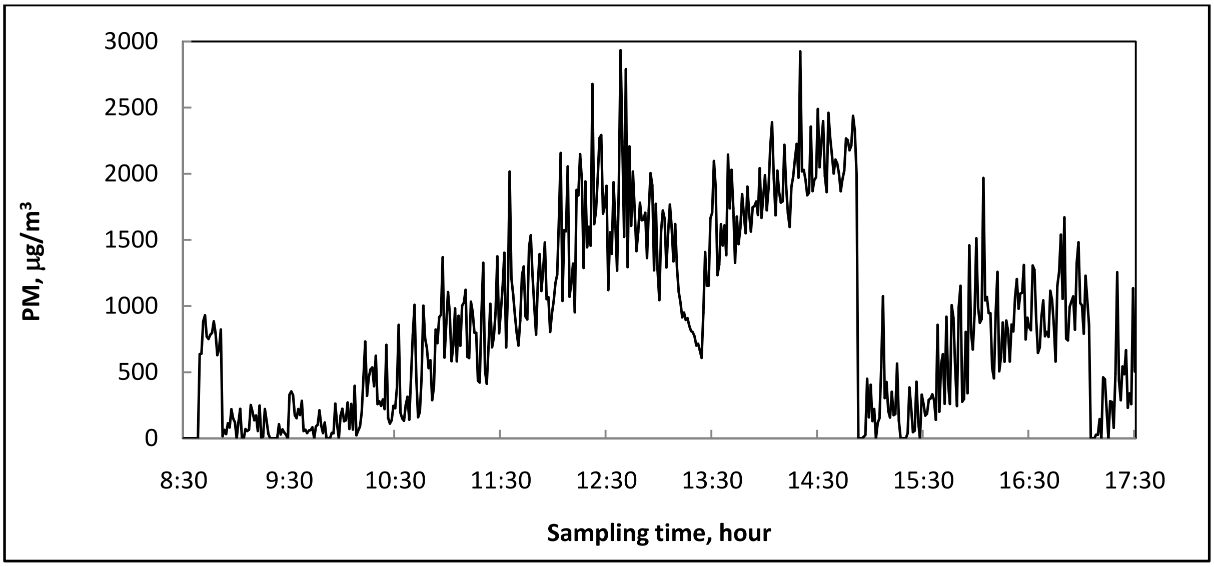


Figure 6.5 $PM_{2.5}$ concentrations at Teklehaimanot Square

In the case of Figure 6.5, one can observe that the concentration builds up until 15:00 pm, in line with the traffic intensity associated with the commercial activities of the area.

Table 6.5 gives 24-hour averages and maximum levels of $PM_{2.5}$ for the dry season. As can be seen in the table, the measured values at all sites are higher than the WHO guideline limit. On the other hand, except sites S1, S2, S4 and S7, all other sites show values greater than the Ethiopian EPA guideline limit. If one considers the maximum for the different sites, both limit values are highly exceeded in all 12 sites.

Consequently, people residing and working along roads and those frequently using passenger vehicles are expected to encounter severe health effects due to such high level of $PM_{2.5}$ in the ambient air.

Table 6.5 $PM_{2.5}$ concentration data for different sites during the dry season.

Site		**$PM_{2.5}$ Concentration, µg/m^3**	
Code	**Name**	**24-hour average**	**Maximum**
S1	Aduwa Square (Megenagna)	**54.8**	4471.9
S2	Arada (Arada building)	**30.7**	624.0
S3	Betel	135.6	6576.4
S4	Bob Marley Square (Imperial Hotel)	**43.6**	511.1
S5	Bole Bridge	97.3	1982.6
S6	Bus Station (Addis Ketema)	70.4	1827.5
S7	Entoto (St. Mary Church)	**27.2**	808.5
S8	Kaliti Road Intersection (Traffic light)	271.4	9082.6
S9	La gare traffic light	83.5	3268.8
S10	Mexico Square	228.6	17169.3
S11	Taklehaimanot Square	342.1	2933.7
S12	Urael Traffic Light	165	1837.5

WHO guideline for $MP_{2.5}$: 24 hr average = 25µg/m^3

EPA Ethiopia guideline for $PM_{2.5}$: 24 hr average = 65µg/m^3

The measurement of fine particulate matter ($PM_{2.5}$) concentration levels in the ambient air during the wet season was conducted at selected three sites. The results of measurement are presented in Table 6.6.

Table 6.6 $PM_{2.5}$ concentration levels at the three sites during the wet season

Site	**$PM_{2.5}$ concentration, μg/m^3**	
	24-hour average	Maximum
Bus station (Addis Ketema)	34.6	4824.6
Mexico Square	59.3	1529.6
Teklehaimanot Square	60.9	3531.6

WHO guidelines for $PM_{2.5}$: 24 hr average = 25 μg/m^3 ; EPA (Ethiopia) Guideline for $PM_{2.5}$: 65μg/m^3

It can be seen from the data in Tables 6.5 and 6.6 that the results obtained for $PM_{2.5}$ during the wet season is lower than those obtained during the dry season for the same sites. This difference arises as a result of agglomeration and wet precipitation of fine particles. In addition, horizontal wind enhances dispersion of fine particles decreasing their concentration in the ambient air.

6.4.3 Nitrogen Oxide (NOx)

The level of nitrogen dioxide concentrations in the ambient air was not detected by the instrument during the field survey at all selected sites. This indicates that the concentration of NO_2 in the ambient air is relatively low in the Addis Ababa city. The instrument used for NO_2 concentration level measurement can detect values less 0.1ppm, which is lower than the WHO and EPA Ethiopia guideline limit value of 0.11ppm (200μg/m^3). The low level of NO_2 may be attributed to variety of factors including combustion flame temperature, residence time of the nitrogen gas in the peak temperature zone of combustion flame, and the amount of oxygen present in the peak temperature zone of the flame. Oxides of nitrogen are invariably produced in any combustion process involving air containing high proportion of nitrogen. The rate of formation of oxides of nitrogen is dependent on the pressure and temperature, with high temperatures being conducive to higher formation rates provided that the residence time and oxygen available are sufficient. However, the rate of formation of nitrogen oxides can be suppressed by the presence of hydrocarbons (HCs) and carbon monoxide. This would result in low NOx emissions.

In addition, the atmospheric life time of NO_2 is relatively short. Nitrogen dioxide transforms in the air to gaseous nitric acid and toxic organic nitrates. It plays a major role in the atmospheric reaction of ozone formation, a major component of smog. Nitrogen dioxide is also a precursor of nitrates, which contributes to increased respiratory fine particulate matters in the atmosphere. This transformation and dispersion of NO_2 in the atmosphere would account for the low concentration level of this pollutant in the ambient air.

6.4.4 Sulfur Dioxide

The concentration of SO_2 in the ambient air was not detected by the instrument (Crown Gasman detector) at all measurement sites during the study period. This indicates that SO_2 concentration in the ambient air is low. Sulfur oxides formed during fuel combustion are further oxidized to solid sulfates, to a certain extent within the engine and completely in the atmosphere. The low level of SO_2 concentration would arise from the transformation and dispersion factors as it is released from the exhaust tailpipe. Its lifetime in the atmosphere depends strongly on meteorological conditions and is usually short. It is highly soluble in water, forming weak sulfurous acid. In the presence of excess oxygen, SO_2 is oxidized to sulfur trioxide (SO_3) in the atmosphere. The SO_3 rapidly combines with water forming sulfuric acid. Generally, SO_2 is further oxidized to sulfuric acid and sulfates, in the atmosphere, forming an aerosol often associated with other pollutants in droplets or solid particles extending over wide range sizes. Sulfur dioxide and its oxidation products are removed from the atmosphere by wet and dry deposition. Sulfur dioxide can also be removed from the atmosphere through condensation and precipitation. Under favorable meteorological conditions SO_2 released from the vehicle exhaust system to the atmosphere can be diluted by dispersion and transportation thereby maintaining low level concentration in the ambient air.

The volume and composition of vehicle emission is affected by many factors such as the size of the engine, the age of the vehicle, the air-to-fuel ratio, etc.

The higher the size (capacity) of the engine that powers a vehicle, the higher will be the fuel per km consumption and hence the greater the volume of the emissions. The age of a vehicle closely correlates to the type of emissions control equipment installed in the vehicle. Older vehicles tend to have traveled a greater number of kilometers, which causes both engines and emission control equipment to wear.

In general, a petrol engine operating with a fuel-air ratio greater than the stoichiometric will produce more products of incomplete combustion, such as carbon monoxide (CO), hydrocarbons (HC) from unburned fuel and particulate emissions. If the mixtures is slightly lean, the formation of NOx (mainly NO and a smaller proportion of NO_2) is favored. The formation of NOx increases strongly with peak flame temperatures if sustained long enough in the presence of oxygen. Thus, particulates can be reduced through higher temperature and faster combustion, whereas reductions in NOx emissions require reduced combustion temperature.

In Addis Ababa, most of the circulating vehicles are old vehicles. This means vehicles with old engines and poor emission controls are in circulation. In addition, there is lack of proper instrumentation and expertise to tune engines of vehicles for optimum conditions (acceptable emission levels and power output).

Altitude is also an important factor. Fuel combustion efficiency of motor vehicles declines with altitude resulting in increased pollutant emission, particularly CO. Addis Ababa is located between 2200 and 2800 meter above sea level. For vehicles circulating in the city, unless properly tuned the air-fuel mix becomes rich (more fuel than the stoichiometric), due to the less amount of oxygen available, thus favoring less complete combustion, i.e., more CO, more HC and more particulate and less NOx.

Therefore, based on the foregoing discussion, it is reasonable to expect high amount of CO, HC and particulate matter in Addis Ababa.

However, the level of pollutant concentration in ambient air is also highly affected by dispersion factors like the meteorological and physiographical conditions of a city (wind speed and direction, precipitation). According to a study [Faiz, 1996], most air pollution disasters have occurred in areas where natural air ventilation is restricted by terrain.

Addis Ababa borders to the north with Entoto Mountain which is about 3000 (meters above sea level) masl and slopes down to the south, south-east and south-west.

In addition the city, which is stretched horizontally, is characterized by very low vertical density. It occupies an estimated area of 54 thousand hectares. Low rising buildings occupy a significant proportion of the city while the high rising buildings are mostly located parallel to main roads.

The city is often regarded as one having three major seasons: the dry season from October to January, the small rainy season from February to May and the heavy rainy season from June to September. As can be seen in Table 6.7, the city gets rain for more than half of the year (132 days).

Table 6.7 Climate data for Addis Ababa (Source: Ethiopian National Meteorological Agency)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average max temperature, ^{0}C	23.2	24.7	26.6	25.2	25.2	25.6	21.2	21.3	22.9	23.0	23.9	22.2	
Average min. temperature, ^{0}C	9.0	10.0	11.9	12.0	12.0	12.3	11.5	11.5	12.0	10.5	6.0	8.5	2009
Rainfall, mm	19.5	2.7	28.4	80.6	80.6	82.0	349.9	387.6	112.7	45.8	4.4	65.0	
Average max temperature, ^{0}C	23.8	23.6	23.5	24.1	24.1	22.8	20.4	20.9	21.3	23.5	22.5	22.8	
Average min. temperature, ^{0}C	9.6	12.2	12.3	13.3	13.5	11.9	11.6	12.2	11.7	11.2	9.5	8.9	2010
Rainfall, mm	2.6	79.2	55.5	97.6	24.0	231.1	313.9	205.3	237.8	1.8	25.7	14.5	
Average max temperature, ^{0}C	24.0	25.0	24.6	25.9	26.0	24.0	22.0	21.2	21.8	23.0	23.0	27.0	
Average min. temperature, ^{0}C	10.0	10.0	11.5	13.4	13.0	12.0	12.0	11.8	11.7	10.0	11.0	7.0	2011
Rainfall, mm	14.1	13.1	44.5	17.0	50.0	180.0	56.0	195.9	184.5	0.0	32.4	0.0	
Average max temperature, ^{0}C	25.0	26.0	26.6	25.0	27.0	25.0	21.0	21.3	21.3	23.0	24.5	23.0	
Average min. temperature, ^{0}C	8.0	8.0	10.8	12.0	13.0	13.0	12.0	11.8	11.3	10.0	9.6	10.0	2012
Rainfall, mm	0.0	0.0	16.0	41.0	57.0	49.0	324.0	293.0	202.9	2.0	0.8	10.0	

Thus, the variation of elevation within the city by favoring natural ventilation, the low height of most buildings in city by offering little or no obstacle to flow of air, and the light and heavy rainy seasons by washing air pollutants contribute to the dispersion deposition of pollutants from vehicle emissions in the city.

The observed low level of CO during this study, in spite of all the factors indicating the opposite, can only be explained by the meteorological and physiographical conditions of the city which contribute towards the dispersion of CO.

Moreover, the removal and dispersion seems to be less efficient in case of $PM_{2.5}$. This is also reasonable, since $PM_{2.5}$ has the tendency to remain suspended in the air for longer times due to their smaller size. Fine particulate matters have low removal tendency by precipitation and deposition owing to their size, and hence have long residence time in the air. This is one of the main reasons for observed elevated concentration of $PM_{2.5}$ in the ambient air during the study period.

According to the 2007 population census, the city has a population of 3,384,569. There is an increased economic activity in the city now. More and more people move from one part of the city to the other during working days for work, study, etc. The shortage of transportation is evident. Many people can be seen queuing at bus and taxi stops at peak hours. This implies more and more people are exposed to air pollutants (especially to $PM_{2.5}$), the exposure time depending on the time spent in queue and travel.

6.5 Trend Projection

The estimated mileage and corresponding annual fuel consumption in Addis Ababa for the Ethiopian year 2003 (2010/11) are given in Table 6.8.

Table 6.8 Mileage and fuel consumption per vehicle category in Addis Ababa (2010/2011)

Vehicle category		No of Vehicles	Annual Mileage[km/yr]
passenger cars	Petrol without catalyst	85,786	2,058,864,000
	Petrol with 3-way catalyst	40,677	976,248,000
	Diesel- OLD-without PM filter	3,401	81,624,000
	Diesel- with PM filter	38,376	921,024,000
Light Duty Trucks and Buses	Light Duty-pre Euro	3,928	196,400,000
	Light Duty-Euro I+II	24,130	1,206,500,000
	Light Duty-Euro III+IV	8,466	423,300,000
Heavy Duty Trucks and Buses	Heavy Duty-pre Euro	682	34,100,000
	Heavy Duty-Euro I+II	5,160	258,000,000
	Heavy Duty-Euro III+IV	1,669	83,450,000
	Bus pre-Euro	524	26,200,000
	Bus Euro I+II	2,503	125,150,000
	Bus Euro III+IV	961	48,050,000

This estimation was made assuming that annual mileage of passenger cars, trucks and buses are 24,000, 50,000 and 50,000kms, respectively. In addition, 50% of the vehicles with ET plates were assumed to circulate in Addis Ababa.

Following, the estimated amount of the different pollutants per vehicle category were calculated using the emission factors of Nairobi [UNEP] and shown in Table 6.9. Furthermore, it was attempted to estimate the GHG emission as expressed in Million ton of CO_2e using the indicated conversion factors. Since these conversion factors were derived based on transport conditions in developed countries, the actual emission values of these pollutants are expected to be higher.

Table 6.9 Annual emissions of pollutants per vehicle category in Addis Ababa (2010/2011)

Vehicle category		**Annual Emission [kg/yr]**				
		CO	**VOC**	**NO_X**	**SOx**	**PM10**
Passenger cars	Petrol without catalyst	109,120	18,217	5,188	103	21
	Petrol with 3-way catalyst	17,572	761	1,142	49	10
	Diesel- OLD-without PM filter	295	153	136	18	18
	Diesel- with PM filter	3,325	17	820	147	74
Light Duty Trucks and Buses	Light Duty-pre Euro	709	369	328	57	53
	Light Duty-Euro I+II	4,343	229	1,979	314	157
	Light Duty-Euro III+IV	1,524	80	694	106	55
Heavy Duty Trucks and Buses	Heavy Duty-pre Euro	293	56	523	24	23
	Heavy Duty-Euro I+II	2,216	426	3,873	178	173
	Heavy Duty-Euro III+IV	446	96	768	58	24
	Bus pre-Euro	348	66	624	26	56
	Bus Euro I+II	1,477	317	2,553	121	168
	Bus Euro III+IV	278	76	481	47	31
Total		**141,947**	**20,864**	**19,108**	**1,200**	**862**

According to the Climate Resilient Green Economy Strategy of Ethiopia [FDRE, 2011], the total GHG emission of the country from the transport sector in 2010 was estimated at 5 Million ton CO_2e. With business-as-usual-scenario, the GHG emission from this sector is expected to reach 40 Mt CO_2e in 2030 which is an 800% increase. Similarly, the GHG emission in Addis Ababa can be expected to increase by the same percentage if not more. Hence, the air quality in the city will deteriorate unless proper mitigation measures are introduced in time.

6.6 Mitigation Measures and Conclusion

6.6.1 Recommendation on Mitigation Measures

Mitigation measures refer to programs or strategies designed to reduce vehicular emissions for a particular region or area and are necessary to maintain or improve air quality. There is a global interest towards developing mitigation measures, which can reduce vehicle emissions either directly (e.g., by tightening emission standards, retrofitting, and introducing fuel reformulations) or indirectly (e.g., by relieving traffic congestion, encouraging ride share, and shifting private vehicle use to non-auto travel or public transport modes). In order to reduce the impact of air pollution caused due to vehicular fleet, appropriate mitigation measures need to be considered and applied. Regulatory guidelines are important to effectively control and reduce vehicular emissions. Moreover emissions are generally regulated based on the available standards that establish limit values for each type of pollutants released to the ambient air.

a) Vehicle Emission Standards

Emission standards set limits on the amount of specific pollutants that vehicles can release into the environment. The pollutants usually regulated include NOx, CO, HC and particulate matter (PM). Unfortunately there are no universally accepted standards.

Most countries are adopting European Union Emission Standards as their national vehicle emission standard. European Union vehicle emission standard started in early 1990s with Euro I and reached Euro III at 2000. Then, it developed to Euro IV in 2005. While the current standard is Euro V, it will be updated to Euro VI starting 2014. In order to control vehicular emissions and reduce air pollutions in Ethiopia, it is necessary to draft and implement emission standards as soon as possible. Since new vehicles imported from China and locally assembled ones meet Euro III standards it is recommended to adopt and enforce Euro III on newly registered vehicles emission in the country. European regulations introduce different emission limits for diesel and petrol/gasoline vehicles. Emission standards for passenger cars are defined by vehicle driving distance, g/km. But for heavy duty vehicles (eg., trucks and buses) standards are defined by engine energy output, g/kWh. Table 6.10 shows Euro III vehicle emissions standard.

Emission standards for trucks and buses are defined by engine energy output, g/kWh. Table 6.12 shows Euro III standard for trucks and buses.

Table 6.10 Euro II Emission standards in the European Union for passenger cars and light duty vehicles, g/km) [Saint Gobain, 2011]

Vehicle Category	**Engine type**	**Pollutants**				
		CO	**THC**	**NOx**	**HC+NOx**	**PM**
Passenger cars	Diesel	0.64	-	0.5	0.56	0.05
	Petrol	2.3	0.2	0.15	-	-
Light-commercial vehicles ≤ 1305 kg	Diesel	0.64	-	0.50	0.56	0.05
	Petrol	2.3	0.20	0.15	-	-
Light-commercial vehicles 1305-1760 kg	Diesel	0.8	-	0.65	0.72	0.07
	Petrol	4.17	0.25	0.18	-	-
Light-commercial vehicles >1760max3500	Diesel	0.95	-	0.78	0.86	0.10
	Petrol	5.22	0.29	0.21	-	-

Table 6.11 Euro III emission standard for heavy duty diesel vehicles, g/kWh [Wikipedia 2007],

Vehicle category	**CO**	**HC**	**NOx**	**PM**
Trucks and buses	2.1	0.66	5.0	0.1
Heavy duty cargo vehicles (2000kg and above)	2.1	0.66	5.0	0.1

The emission limit values specified in standards should not be exceeded in order to avoid air pollution. Regulatory guidelines require that new vehicles should be fitted with catalytic converters in order comply with the emission limit values defined by the standards.

Moreover, fuel quality also plays a major role in controlling emissions and performance of the converter. High sulfur content fuel can cause catalyst poisoning thereby reducing its effectiveness. Catalytic converters are considered to be effective and viable measures to achieve emissions reduction and improve ambient air quality. High sulfur has also a potential to produce high emission of sulfur oxides. It is therefore necessary that refined low sulfur fuel be used to control vehicle emissions.

b) Catalytic Converter

Catalytic converter is a vehicle emissions control device which converts toxic byproducts of combustion to less toxic substances by catalyzed chemical reactions before they leave vehicles exhaust system [Wikepdea, 2012]. This device reduces vehicular emissions by chemical reactions performed on the surface of catalyst fitted in a housing through which exhaust gas is passed.

The rising air pollution in Addis Ababa requires that vehicles should have calataytic converter corresponding to the standard.

7. TECHNOLOGY OPTIONS AND POLICY MEASURES FOR FUEL EFFICIENT VEHICLES

7.1 Technology Options for Fuel Efficient and Clean Vehicles

7.1.1 Technology Options for Increasing Fuel economy

The gasoline engine, which was invented by Nicolas Augusto Otto, was operating with only incremental improvement since 1876. To make these engines fuel efficient, new technologies such as electronic ignition and electronic injection were introduced in 1970s and made the carburetor and conventional ignition systems obsolete to cope with escalating fuel prices caused by Arab-Israel war. All passenger cars with gasoline engines manufactured after 1990s have electronic injection system and ignition system. As a result, incremental change in vehicle fuel economy was obtained. A shift from mechanical individual fuel injection system to common rail electronic injection system was also observed in diesel engines. Although some success was obtained in increasing fuel economy of the reciprocating internal combustion engine, with the incorporation of more improvements the limit will be approached. A better result in fuel economy was obtained by using new concepts such as hybrid, electric and fuel cell engines.

The technological options and their limitations for increasing fuel economy to improve fuel economy are discussed in this section and reported in literature [Lipman, 2003],(IEA,2008].

a) Hybrid electric vehicle (HEV)

This is a vehicle that is powered by an on-board internal combustion engine which is complemented by an electric motor that is driven by a battery, charged by electricity recovered via regenerative braking. The braking energy that could otherwise be lost as heat is recovered by driving an electric motor as a generator and stored by charging batteries. Any excess power and braking power while a hybrid vehicle travels downhill, will be used for driving a generator. The engine and the electric motor of hybrid vehicles can be in a series or parallel configured as sown in Figure 7.1. In series configuration, the engine drives an electric motor that delivers power to the wheels and in parallel configuration, both can provide power directly to the wheels. Hybrid vehicles use an electric motor to start and drive at low speed range. Hence, the engine can be stopped when the car is idling at traffic light. The vehicle will restart by electric motors and then the gasoline engine will be engaged after takeoff. Moreover the electric motor will operate besides the internal combustion engine when the vehicle has to climb uphill at peak load. As the internal combustion is not operated during idling and low load, hybrid vehicles have better fuel economy in urban driving condition. In addition, hybrid vehicles have a continuously variable transmission (CVT), which makes the engine to operate at optimum efficiency at different vehicle speeds. Hybrid vehicles can significantly reduce fuel consumption in city driving.

The new generation plug-in hybrid electric vehicles (PHEV) have high capacity batteries that can be charged by plugging them into an electrical outlet or charging station. PHEVs can store enough electricity from the power grid to significantly reduce their petroleum consumption under typical driving conditions. Hence, fossil fuel consumption is insignificant.

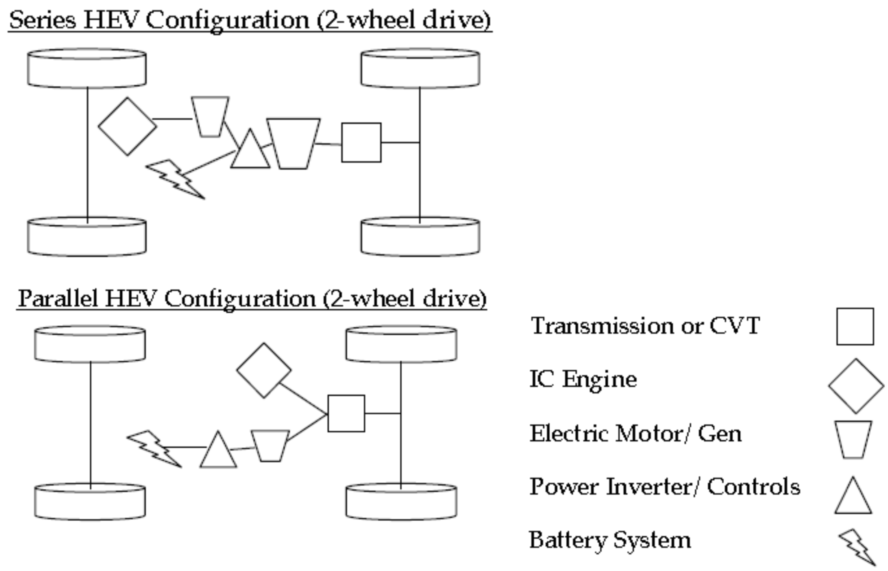


Figure 7.1 Drive system of Hybrid vehicles

b) Electric vehicle (EV)

A battery electric vehicle, shown in Figure 7.2, is driven by an electric motor powered by electricity stored in onboard battery pack which is charged by plugging into the grid. An electric vehicle has no engine. Electric vehicles plug into a wall socket or other source of electricity to recharge the batteries. The vehicle can travel only 60-120 km between recharge. Another disadvantage of electric cars is that they require long period to recharge the battery. Using DC fast charging, the battery pack can be charged to 80% capacity in about 30 minutes. However the cost of such a charger was around USD16, 800 in May 2010 and the fast charger will also gradually degrade the battery capacity. 10-20 % loss is expected in a 10-year period. By increasing considerably the electrical energy that can be stored in the battery and cutting the battery cost, the technology can be made reliable to compete with conventional vehicles.

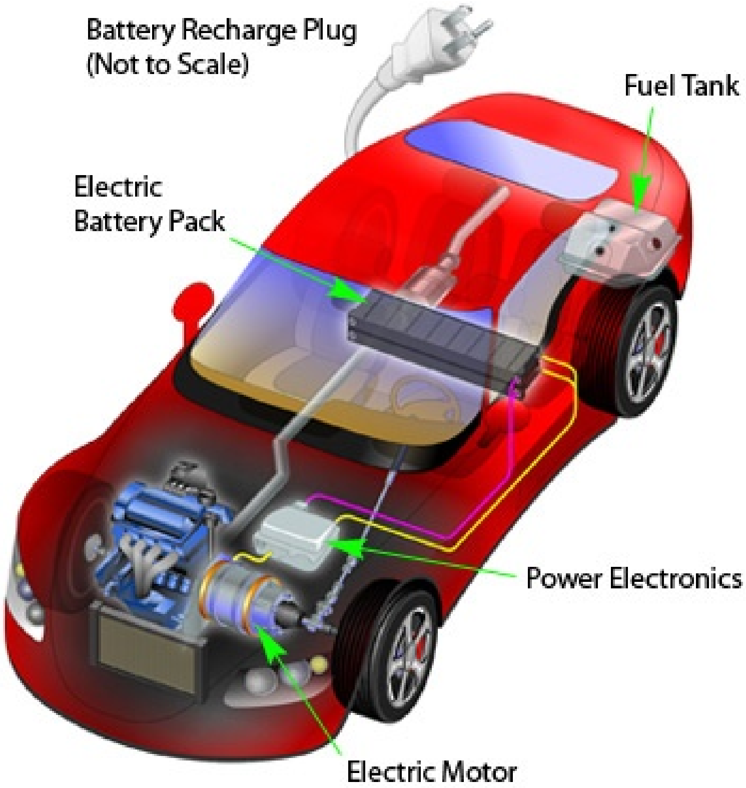


Figure 7.2 Battery pack of electric vehicle under the body

Electric vehicles and plug-in hybrid vehicles have high potential to significantly reduce fuel consumption which can benefit to achieve fuel sustainability and reducing emissions of pollutants and CO_2. In Ethiopia where electricity is generated without direct CO_2 emission or with small life cycle GHG emission, electric vehicles can contribute 100 % in direct fuel savings and about 85 % life cycle CO_2 emission reduction per vehicle

Electric and plug-in hybrid electric vehicles are developed by large number of vehicle manufacturers in different countries. They are viewed as a breakthrough in reducing GHG emission in the transport sector and strong dependence on fossil fuels.

There are several barriers that shall be addressed before mass-market penetration can be achieved. These barriers include:

- Limited vehicle travel distance between recharge

- High initial cost due to high costs of batteries
- Limited availability of recharging infrastructure.

It is hoped that some of the major barriers will be overcome up to 2020 and the electric vehicle and plug-in hybrid vehicles will penetrate the market in significant number beyond 2020.

c) Fuel efficiency improvement of conventional passenger cars

It is believed that the efficiency of conventional vehicles will increase with the incremental approach by making combustion more efficient, reducing engine and valve gear friction, making the body compact and reducing the engine size. Improvements to gasoline engines injection system using injection engine is estimated to attain 18% reduced fuel consumption. Cylinder shutoff during low load conditions and improved valve timing and lift controls are some of the measures to improve fuel efficiency of passenger cars. (SAE International, 2003a)

d) Proper maintenance of old vehicles and gradual replacement

The study on vehicle fleet classification in Ethiopia indicated that the majority of saloon and compact passenger cars are older than 15 years and their fuel efficiencies are low. The fuel economy of these vehicles is less than 8 km/liter for city driving. New vehicles with equivalent power have fuel economy off 12-15 km/liter. Hence, enhancing the replacement of the old vehicles, higher fuel economy can be achieved. In countries like Ethiopia, where the vehicle engines are not tuned optimally, proper maintenance of vehicles by availing spare-parts and tools is expected to improve fuel economy by about 10-20 % per vehicle older than 15 years. Some studies indicate that proper vehicle engine tuning can yield 10% decrease in fuel consumption (IPCC, 1996). Replacement of bias (cross-ply) tires with radial tires can reduce fuel consumption by about 10%. In Ethiopia, considerable portion of cars use bias tires. Hence, regular tire inspection and maintenance as well as replacement of bias tires can increase fuel economy.

e) Reducing traffic congestion by road improvement and use of mass transit

Traffic congestion will cause a car to idle and consume fuel while not travelling or travelling at low speed. Even though the number of vehicles in Addis Ababa is about quarter a million, traffic congestions happen in some part of the city. Construction of over and underpasses at some road junctions and implementation of the planned light rail and bus rapid transit can contribute to improvement of fuel economy

f) Popularization of EC0-driving habit

Eco driving or driving habit with high acceleration and braking will result in higher fuel economy. Hence, Eco driving has to be popularized by distributing flyer and launching demonstrating video on TV.

Some of the rules of ECO driving are:

- Start slowly, avoiding rapid acceleration.
- Use the highest gear possible, and lower the engine speed.
- Maintain a constant speed during travelling
- Anticipate traffic conditions, and accelerate and decelerate smoothly – it is safer, uses less fuel, and reduces brake wear.
- Drive at road posted speed limits.
- Avoid idling for any stop of longer period reduces fuel consumption and carbon dioxide emissions.
- Check the tire pressure monthly with cold tires.
- Replace air filters regularly - saving up to 10% fuel consumption.

7.1.2 Emission Control Technologies

a) Catalytic Converters of Gasoline Engines

Two-way catalytic converter: It oxidizes carbon monoxide to carbon dioxide and hydrocarbons unburned or partially burned during combustion, present in the exhaust gas, to carbon dioxide and water over a platinum or palladium catalyst. The catalyst aids the reaction of carbon monoxide and hydrocarbons with the remaining oxygen in the exhaust gas. *Three-way catalytic converter*: The reduction catalyst is the first stage of this catalytic converter (Figure 7.3). It uses rhodium catalyst coating to reduce the NOx to nitrogen. In the second stage carbon monoxide and hydrocarbons are oxidized to carbon dioxide and water in the same way as in two way catalytic converter.

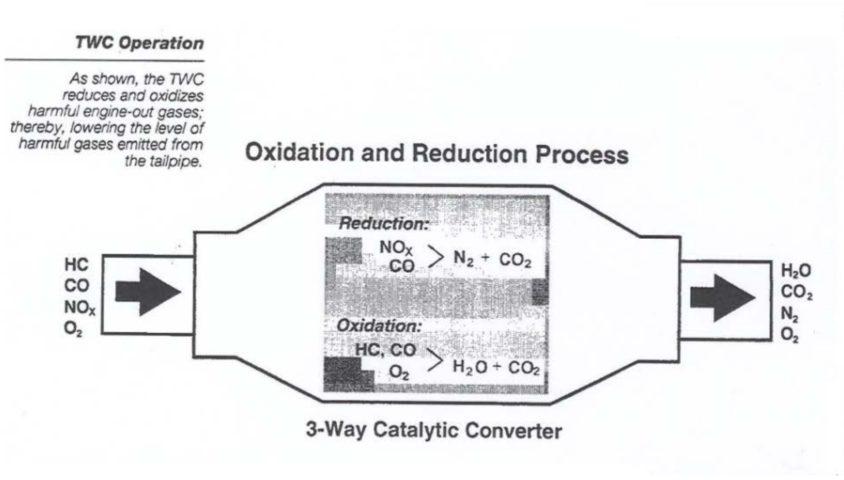


Figure 7.3 Three way catalytic converter

Two way catalyst converters became obsolete since they do not reduce NOx emission. At present all vehicles with petrol engines have three way catalytic converters. The price of such type of catalytic converters starts with USD 200.

b) Catalytic Converters for Diesel Engines

Diesel Oxidation Catalyst:- It is the most commonly used catalytic converter is the compression ignition engine. This catalyst converter oxidizes carbon monoxide and hydrocarbons in the exhaust by excess oxygen in the exhaust.

Diesel particulate filter:- Catalytic converters cannot clean up soot or elemental carbon. Hence particulates are cleaned up by diesel particulate filter. Particulate filter efficiency is adversely affected by sulfur dioxide in the flue gas, which by oxidation in the catalytic converter and combining with water, converts to sulfuric acid. Low sulfur fuel is a prerequisite for efficient and sustainable performance of diesel particulate filters.

Hence there is a need to shift to gasoil with 50 ppm maximum sulfur. The price difference between the Standard Diesel grade (500 ppm) and the low sulfur diesel grade (50 ppm) is said to be about 1%.

7.1.3 Alternative Fuels

Bio-fuels have the potential to replace a significant part of gasoline and gasoil used in the transport sector. According to Climate Resilient Development Plan of Ethiopia, biofuels share of transport fuels shall increase to about 15% for gasoline engines and 5 % for diesel engines by 2030. With expansion of sugar industries, Ethiopia will not only have sufficient ethanol to blend with gasoline in 15-85 % proportion, but also can produce bioplastics such as polyethylene and pet from ethanol. Hence, the plan in CRDGA for ethanol-gasoline blending can be easily achieved. With regard to biodiesel, numerous foreign companies with local partners have acquired investment licenses. For example, Global Energy Ethiopia (GEE) is planting a castor and jatropha to process 40,000 tons per annum. GEE leased 30,000 hectares of land in Wolaita Soddo in the Southern Nations Nationalities and Peoples Regional State for this purpose. Therefore, it will be reasonable to assume the share of biodiesel in reduction of gasoil will reach 10 % by 2050. Averaging the share of ethanol in reducing gasoline and that of biodiesel in reducing gasoil and noting that the heating value of ethanol is two third of that of gasoline, the replacement of fossil fuels with bio-fuels will reach 10 % by 2050.

7.2 Policy Measures for Promoting Cleaner and Efficient Vehicles

Some of the policy measures in this section are discussed in the literatures {GEFI,2010]

7.2.1 Enhancing Vehicle Efficiency Improvement

a) Mandatory requirement of fuel efficiency and emission certificate for vehicles to be imported or assembled in the country.

In addition to this all vehicles for sale shall post fuel economy value on display.

b) Banning of import of old second hand vehicles

Although the initial price of old second hand vehicles is low, the operating costs are high due to excessive fuel consumption caused by the deterioration of the engine due to aging and hih frequency of maintenance. New vehicles and relatively newer second hand vehicles require only servicing that is replacement of air filter, fuel filter, engine oil and oil filter often every 5000 km. Second hand vehicles might require the following types of maintenance as soon as bought.

- Front brakes have to be replaced every 40,000 km and rear every 70,000 km
- Require replacement shock absorbers, batteries and tires
- Vehicles that travelled 200,000 km require engine overhaul and other accessories.
- If the body is corroded, the corroded part has to be removed and welded and the it must be repainted.

Hence, old second hand vehicles have high operating costs. In addition when a vehicle has to be maintained, the user needs to rent another car or use taxi (especially for business purpose). This cost is called downtime costs which increase as the vehicle becomes older.

Experience from other African that legislated policy on second hand-vehicles indicate that the maximum age limited to maximum of ten years as follows.

- Algeria - -3 years.
- South Africa – new only
- Sudan - new (except migrants)
- Kenya - 8 years
- Lesotho - 8 years
- Gabon - 5 years
- Mozambique cars – 5 Vans -9
- Niger - 5 years

From the economic analysis conducted in this study in next chapter and lessons learnt from bench marked countries, it is recommended to limit the age of second hand vehicles to be imported to Ethiopia 8-10 years.

Banning import of vehicles older than 8-10 years, will contribute to increase fuel economy due to newer vehicles with improved technology and higher efficiency.

c) Introduction of hybrid and electric vehicle

Duty free import for pilot introduction of electric and hybrid electric vehicles is essential as a transfer program. The pilot technology transfer program can be carried as follows;

- 200 hybrid vehicles (duty free) in public enterprise or as hotel taxi fleet
- 50 electric vehicles such as service vehicles in premises of Ethiopian airlines

In addition, legislation for total exemption of excise tax of hybrid vehicles and plug-in electric vehicles is necessary to enhance dissemination of these fuel efficient vehicles. It is hoped that after 2020, these vehicles will penetrate the market and become considerable after 2030.

d) Improvement of maintenance infrastructure of vehicles and increasing awareness

In order to improve condition of vehicles, it is necessary to avail more spare parts and tools by reducing import duty tax. It also necessary to control vehicle condition during annual inspection, initiate certification of vehicle maintenance workshops and increase awareness on fuel economy. Drivers shall also be aware of not to accelerate and brake frequently too, select less congested route and time.

7.2.2 Use of cleaner fuels

Although, the sulfur content of the imported diesel fuel in Ethiopia has recently decreased appreciably to 500 ppm and below, the high sulfur content of the fuel is still an obstacle for effectiveness of particulate matter removal from diesel engine exhausts.

With regard to sustainable use of biofuel, major achievement was scored in using gasoline ethanol blend. However, commercial production of biodiesel has not commenced as expected. The investors did not go beyond pilot plantation.

Hence, the following courses of actions are recommended to promote cleaner fuels

- Amending the Ethiopian standard for limiting sulfur to 50 ppm maximum in diesel fuel by 2015 so that modern vehicles with diesel engines with lower particulate emissions can effectively use particulate filter for cleaning exhaust.
- Preparation of incentive package to promote biodiesel production such as VAT exemption
- In addition, improvement of EPE and Ethiopian Standard laboratory infrastructure are recommended.

Although some vehicles in Ethiopia are fitted with catalytic converters, most of the catalytic converters are ineffective due to use of unleaded gasoline in earlier years (old vehicles), high sulfur content in the fuel and no replacement of damaged units.

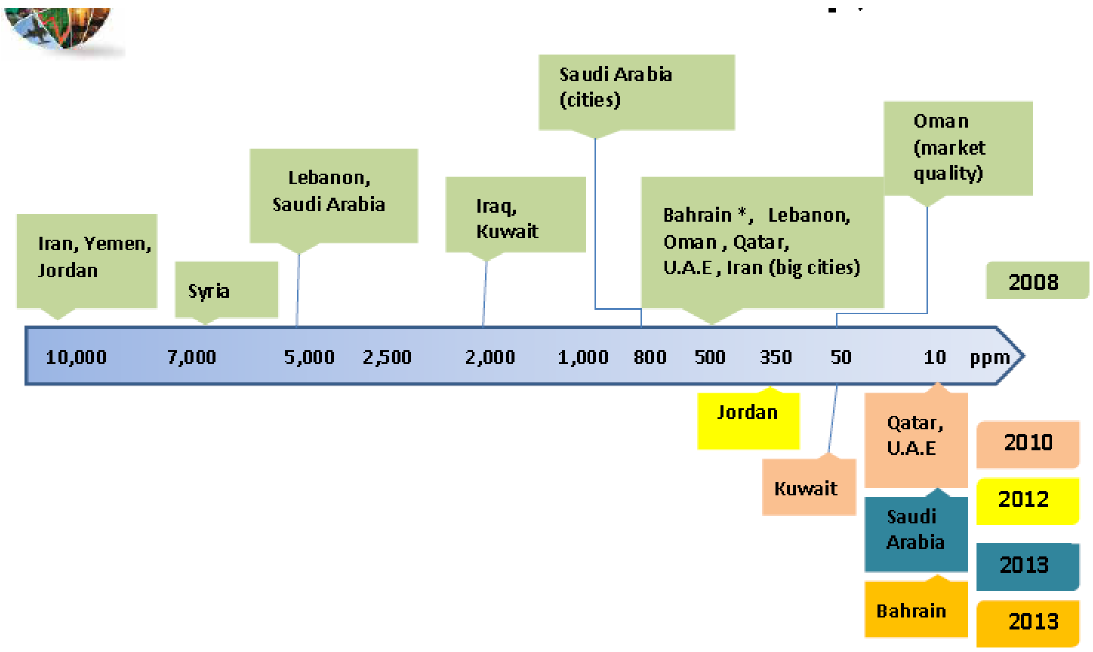


Figure 7.4 Availability and enforcement of low sulfur diesel in Middle East

7.2.3 Emission Control

The high level of CO and PM emission in traffic congestion areas of Addis Ababa, although the vehicle stock is very low even compared to African cities such as Nairobi, indicates that the necessity of functional and effective catalytic converters for every vehicle.

As the sulfur content of the fuel is 500 ppm at present, diesel particulate filter will not become fully effective unless stringent vehicle emission standards such as Euro IV and above are implemented. However, implementation of Euro III with maximum 150 ppm sulfur content in the fuel will considerably reduce particulate matter emission. The transition to Euro IV emission standard has to be delayed as some of the vehicles imported from china will be able to conform to it only in 2013 and until the maximum sulfur content in the fuel is limited to 50 ppm. It is recommended that Ethiopia shall adopt Euro III emission standard in 2015 and move to Euro IV in 2017. The availability of low sulfur diesel is not a problem as most of the Gulf States are going for low sulfur diesel as shown in Figure 7.4

The emission standard shall incorporate the following

- All vehicles to be imported or assembled in the country after January, 2015 except three wheel vehicles shall have catalytic converters that confirm at least to Euro III emission standard and after January 2017 to Euro IV emission standard.

- All three wheels vehicle to be imported after January 1st, 2015 shall have four stroke engines and a catalytic converter.
- All vehicles imported after 2015, without functional catalytic converters shall be penalized upon annual inspection after 2015.

The above policy measures which have to be formulated in legislation are given as draft legislation given in Appendix 1.

7.3 Targets for Fuel Economy Improvement and Average Fuel Economy

In order to determine the targets for fuel economy improvement, the light duty vehicles population in Ethiopia was projected with the assumption that the present growth rate will prevail and the high taxes on light duty vehicles, high fuel prices and improvement in public transport with introduction of light transit train in Addis Abba will continue to encourage use of public transportation and discourage owning of personal cars. The projection of light duty vehicles is shown in Figure 7.5. If the vehicle population increases at faster rate, it means vehicles with newer technology with lower fuel consumption will be more in proportion and higher improvement in fuel economy can be achieved. The fuel economy for the baseline year or 2005 is 11.5 km/liter for new vehicles and 9 km/liter for the fleet as a whole.

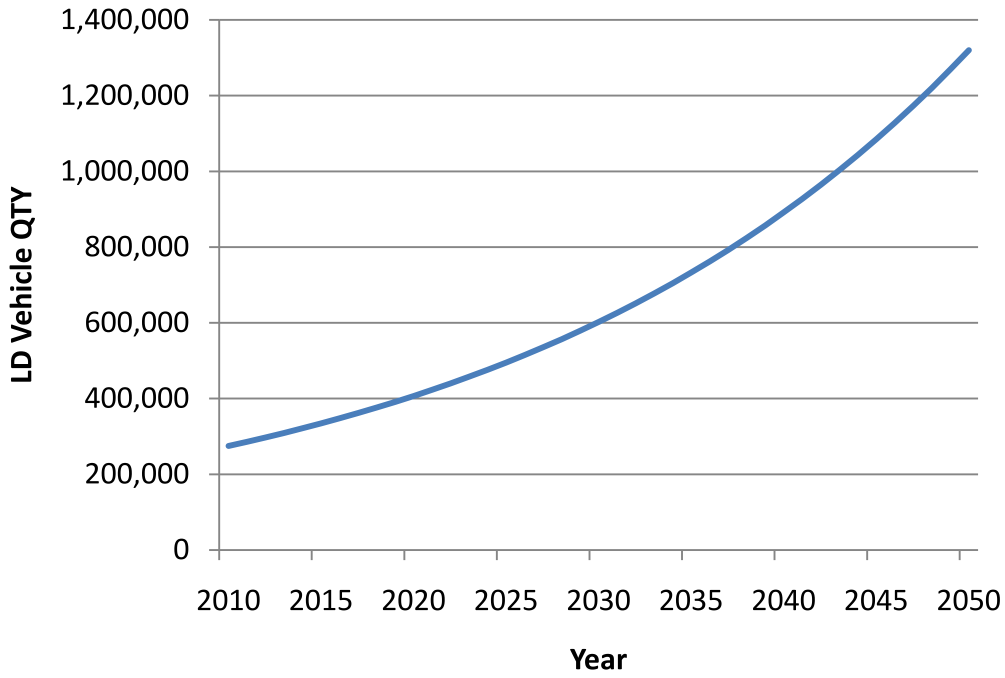


Figure 7.5 Forecasted LD vehicle at present actual growth rate.

7.3.1 Target for 2020

It is assumed that 60 % of the vehicles in 2020, which will be registered between 2010 and 2020, will have an average fuel economy of 13 km/liter in city driving due to improved polices and technology. The old vehicles, which were registered before 2010, are assumed to have 9 km/liter fuel economy and account to 40 % of the fleet. The target fuel economy for new vehicles and the vehicle stock is given in Figure 7.1.

Table 7.1 Fuel Economy Target for 2020

	Improvement measure	**Fossil Fuel Economy Improvement**
1	Preventive maintenance of vehicle and awareness	5 %
2	Vehicles fleet efficiency improvement	17.5 %
3	Bio-fuels	2.5%
	Total	**25%**
	Average fuel economy target of new vehicles	*6.25 L/100 km (16 km/L)*
	Average fuel economy target of the fleet	*9.05 L/100 km (11.05 km/L)*

7.3.2 Target for 2030

Table 7.2 Fuel Economy Target for 2030

	Improvement Measure	**Fossil Fuel Economy Improvement**
1	Preventive maintenance of vehicle and awareness	5 %
2	Vehicles fleet efficiency improvement	25 %
3	Hybrid vehicles	2.5%
4	Bio-fuels	7.5%
	Total	**40%**
	Average fuel Economy target of new vehicles	*5 L/100 km (20 km/L)*
	Average fuel economy target of the fleet	***7.6 L/100 km (13.05 km/L)***

In this case, it is assumed that 50 % of the vehicles in 2030, which will be registered between 2020 and 2030, will have average fuel economy of 17 km/liter in city driving due to improved polices and technology. Vehicles registered between 2010 and 2020 will account 30 % of the fleet and will have fuel economy of 12 km/liter. The old vehicles, which were registered before 2010, are assumed to have 9 km/liter fuel economy and account to 20 % of the fleet. The targets to be met are shown in table 7.2.

7.3.2 Target for 2050

Here it is assumed that 45 % of the vehicles registered before 2030 will have fuel economy of 12.5 km/liter and 45 % of vehicles are registered after 2030 with average fuel economy 20 km/liter. In addition 12 % vehicles (9% hybrid vehicles and 3 % electric vehicles) will be electric and plug-in hybrid vehicles saving 7 % of fuel consumed. Table 7.3 shows the obtained targets

Table 7.3 Fuel economy target for 2050

	Efficiency Improvement	**Fossil Fuel Economy Improvement**
1	Vehicles fleet efficiency improvement	30 %
2	Hybrid and electric vehicles	7%
3	Bio-fuels	7.5%
	Total	**44.5 %**
	Average fuel economy target of the fleet	***6.05 L/ 100 km (16.6 km/L)***

The comparison of projected fuel economy of new vehicles of Ethiopia with the European Union and China shows that Ethiopia will still lag behind the world average by 2030 as shown in Figure 7.5. However compared to the benchmark year 2005, it comes near to achieving targets set by GFEI by partially substituting petroleum by bio-fuel in addition fuel economy improvement obtained due to incremental technology improvement of conventional vehicles and introduction of new technologies such as hybrid and electric vehicles starting 2020.

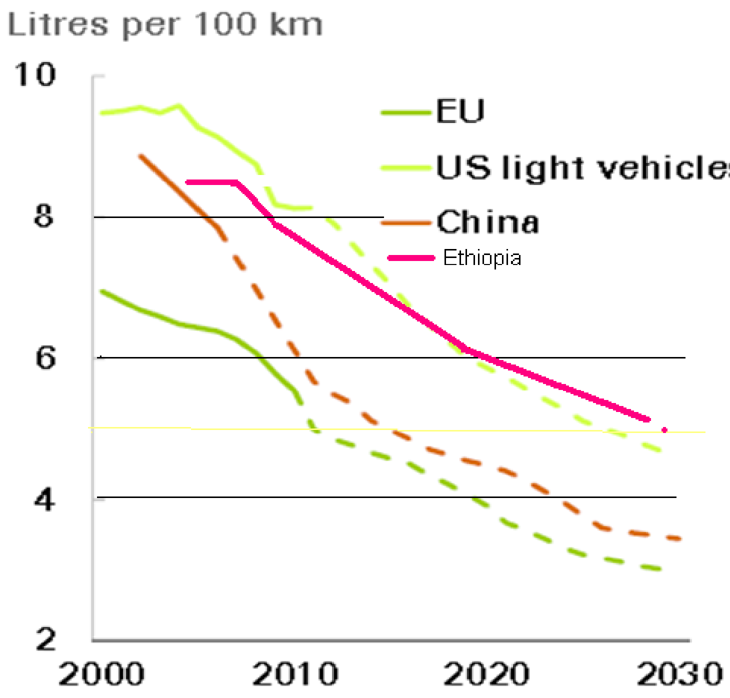


Figure 7.5 Target average fuel economy of new vehicles of Ethiopia compared to other countries

8. COST BENFIT ANALYSIS OF POLICY MEASURES

8.1 Scope of the Life Cycle Cost Analyses

The objective of the analyses is to compare available vehicle technologies with respect to possibility of private end users making economically rational decision toward cleaner technology when purchasing a new car. Therefore, the life cycle cost methodology has been chosen to determine and quantify the cost of each vehicle technology. The first goal is to develop a life cycle cost model and to calculate the private end users costs associated with owning and operating conventional and cleaner vehicles.

The life cycle cost model is based on forecasts of various vehicle operating costs. The values of these operating costs are estimated based on the most probable forecasts, which cover a long period of time. The values of these variables for the most probable outcome scenario may be influenced by many factors and the actual values may differ considerably from the forecast values depending on future events. It is therefore necessary to consider the sensitivity of the life cycle cost model to potential changes in key variables. Accordingly, life cycle cost analyses under different scenarios is also carried out.

Finally, the tax structure of vehicles in Ethiopia is analyzed and the impact of a new fiscal system based on the environmental performance of vehicles on making cleaner technologies economically competitive with conventional vehicles is analyzed.

8.2 Assumptions and Specifications

Within the life cycle cost analysis, several parameters have to be defined. In this section, the main assumptions are briefly explained.

8.2.1 Definition of Functional Unit

A functional unit is a quantified description of the performance of product systems, for use as a reference unit. It allows comparing two or several product systems on the basis of a common provided service. Within this study, the functional unit will be defined in such a way that all the life cycle phases of vehicles will be taken into account in the analysis.

Accordingly it has been assumed that the vehicle lifetime is 10 years, with an annual driving range of 25.000 km or 250,000 km lifetime travel.

8.2.2 Financial Parameters

The financial parameters that will be taken into account can be divided into the vehicle initial financial costs and the operating costs related to the use of the car. Vehicle initial costs comprise the initial investment cost, freight and taxes. Operating costs are the future expenses related to the use of the car. Operating costs can be divided into fuel operating costs and the non fuel operating costs (lubricant, tyre , battery, repair and maintenance, vehicle registration and insurance).

In order to accurately combine the initial expenses with the future costs, the present value of all expenses must be determined. Vehicle initial costs occur at the same time, so there is no need to calculate their present value. Their present value is equal to their actual cost. The operating costs are in contrast time dependent costs and their present value has to be calculated. In other words annual operating costs during the life of the vehicle will be adjusted to reflect the time value of money. Discounting is a technique or a process by which one can reduce future costs to their present worth or present value.

Operating costs are discounted by a factor that reflects the rate at which today's value of a monetary unit decreases with the passage of every time unit. The factor used to discount operating costs is called the discount rate and is expressed as a percentage.

For the purpose of this study a discount rate of 10% is used and to determine the present value of future operating costs, the following formula is used

$$PV = A_0 \cdot \frac{(1+I)^T - 1}{I * (1+I)^T}$$

Where:

PV = Present Value
A_0 = Amount of recurring cost
I = Real Discount Rate
T = Time (expressed as number of years)

8.2.3 Technical Specification of Vehicles

The following vehicle technologies were included in the life cycle cost analysis.

a) Toyota Yaris conventional specification

Prime mover	Petrol engine
Engine power	74 kW
Engine Disp. volume	1500 c.c.

No of cylinders 4

Transmission 4 speed automatic or 5 manual

Average fuel consumption 13.5 km/l

CO_2 emissions 79 g/km

Figure 8.1 *Toyota Yaris*

b) Toyota Yaris Hybrid specifications.

Prime mover petrol engine and battery powering the electrical motor

Engine power 55 kW

Engine Disp. volume 1500 c.c.

No of cylinders 4

Transmission 4 speed automatic

Engine power 55 kW

Total maximum power 74 kW

Average fuel consumption 28.5 l/ km

CO_2 emissions of only 79 g/km,

c) Nissan Leaf Electric Vehicle

Prime mover Electric motor

Power 80 kW

Torque 280 N·m

Drive: Front-mounted synchronous electric motor driving the wheels,

Battery: 24 kilowatt-hours (86 MJ) lithium ion battery pack

Battery weight 300 kilograms

Cost of battery: US$18,000

Energy consumption: 765 kJ/km (34 kWh/100 miles)

Life span of battery: 10 years or minimum160,000 km

Interval between charges: 117 km

Cost USD 27,000

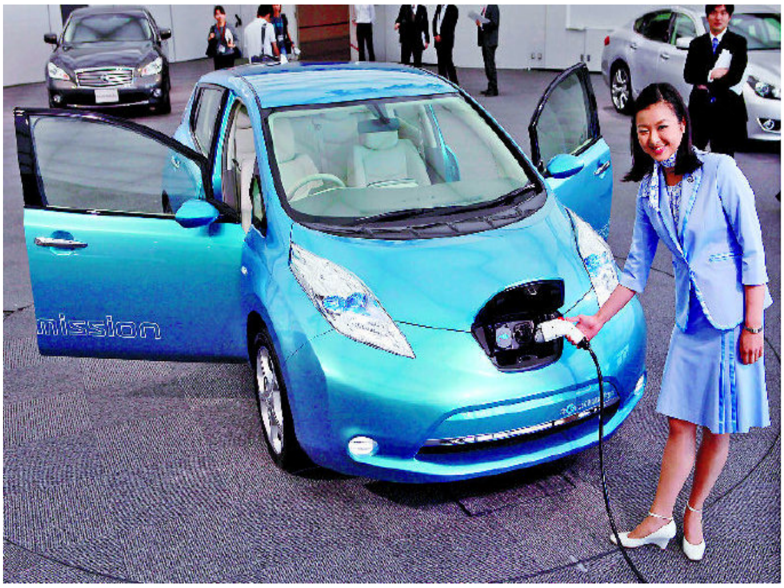


Figure 8.2 Nissan Leafi

8.2.4 Current Tax Regime for Importing Vehicles

In Ethiopia imported vehicles are liable to five different taxes. These taxes are assigned priority levels and are calculated in a sequential order. These taxes, in their sequential order, are Customs Duty, Excise Tax, VAT, Surtax and Withholding Tax. The rates applied especially for Excise Tax differ from vehicle to vehicle based on the horse power of the vehicle. For the type of vehicles under consideration the rates are as followed;

- Duty (35% of CIF)
- Excise (50 % of CIF + Duty)
- Sur Tax (10% of CIF + excise +duty)
- VAT (15% of CIF + excise + duty + sur tax)
- With hold (3% of CIF)

8.3 Results of Life Cycle Cost Analyses

8.3.1 Base Case

Under the base case scenario the current tax regime is considered. The current price of fuel is assumed to increase by 5% annually. The cost of electrical energy is assumed to be Birr 0.65 per kwh. Total mileage traveled per vehicle per year is considered to be 24,000 km. The battery for electric vehicles is assumed to be replaced every 166,000 km.

Based on the above assumptions under the base case scenario the life cycle cost of conventional, hybrid and electric vehicles is Birr 745,539, Birr 826,643 and Birr 1,243,680, respectively (see Figure 8.3 and for details see Appendix.)

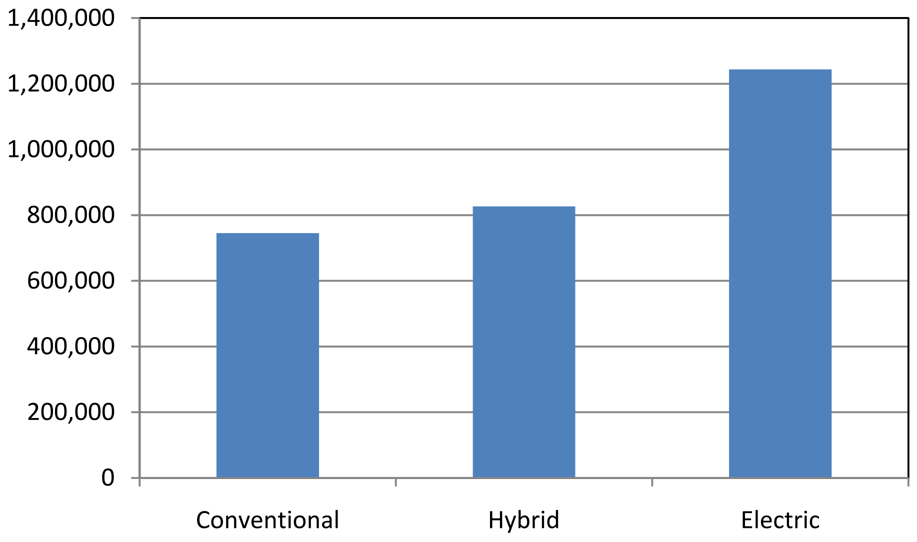


Figure 8.3 Life cycle cost of the vehicles with the existing tax regime in Birr

However, when the mileage traveled per vehicle per year is considered to be 36,000 km/year a different picture immerges where new conventional vehicles followed by five year old conventional second hand vehicles and hybrid vehicles will become the least expensive (see Table 8.1). As compared to a mileage of 24,000 km/year when a 36,000 km/year mileage is considered the life cycle cost for conventional second hand 10 year and 5 year old vehicles has increased by 26% and 20% respectively while for hybrid and electric vehicles the increase is only by 8% and 1% respectively.

Table 8.1: Life cycle cost of the vehicles for the existing tax regime

Assuming 36,000 km/year mileage **Type of vehicles**	**LCC in Birr**
Conventional (new)	851,209
Hybrid	891,528
Electric	1,255,014

Moreover, assuming that the cost of fuel will increase by 10% annually and the cost of energy will increase to 1.30 per kwh the total life cycle cost (assuming 24,000 km mileage) will become Birr 792,144 Birr 855,444 and Birr 1,266,347 for conventional, hybrid and electric vehicles respectively (see Table 8.2.)

Table 8.2: Life cycle cost of the vehicles for 24,000 km/y mileage and 10 % fuel inflation and cost of electricity increase 1.3 Birr/kWh

Type of vehicles	**(in Birr)**
Conventional (new)	792,444
Hybrid	855,444
Electric	1,266,347

8.3.2 With Tax incentive for cleaner vehicles

In this scenario it is assumed that for hybrid and electric vehicles excise and surtax will be exempted. Accordingly, other assumptions being similar to base case scenario the life cycle cost of conventional, hybrid and electric vehicles is Birr 745,539, Birr 586,887 and Birr 884,028 (see Figure 8.4.)

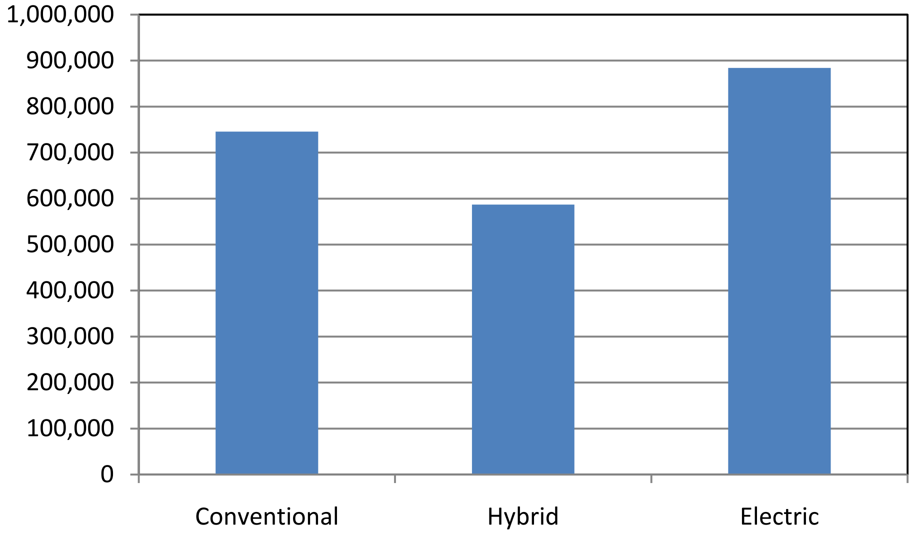


Figure 8.4 Life cycle cost of vehicles with excise and sur tax exemption

8.3.3 Second Hand Vehicles

To compare the live cycle cost of new conventional with imported second hand vehicles, Toyota corolla 1992, Toyota corolla 2007 model and Toyota Corolla 2002 models have been considered. The prices of the second hand vehicles were collected from second hand car dealers and for the new model it was calculated from CIF prices using the cost build up due to transportation and various taxes. The fuel consumption per 100 km is taken 6, 7, 8.5 and 10 for new, 5 years old, 10 years old and 11 years old vehicles respectively, considering improvements in technology and efficiency reduction due to depreciation. It was assumed that each vehicle will change oil every 5000 km. In addition fixed time replacement of batteries and tires were considered and the cost was apportioned to mileage. For annual maintenance cost, Birr 3000 was estimated for new vehicle and to increase by 10 % with age. The 20 year old vehicle certainly will require engine over hauls and replacement of engine and vehicle accessories. Hence, the average annual maintenance cost was relatively high.

The analysis with existing fuel price and annual mileage of 24,000 is given in table 8.3 and Figure 8.5. The results show that the 10 year old vehicle is more economical for the user. In strict sense, 8 years old would have the least life cycle cost. If the annual mileage increases to 36,000 km, then a vehicle upto five year old will be economical to the user.

Table 8.3: Life cycle cost of vehicles of different ages under existing fuel price and 5% annual fuel inflation under consideration assuming annual mileage of 24,000 km

Age of Vehicle	LCC in Birr
20	743,362
10	707,132
5	722,589
New	743,362

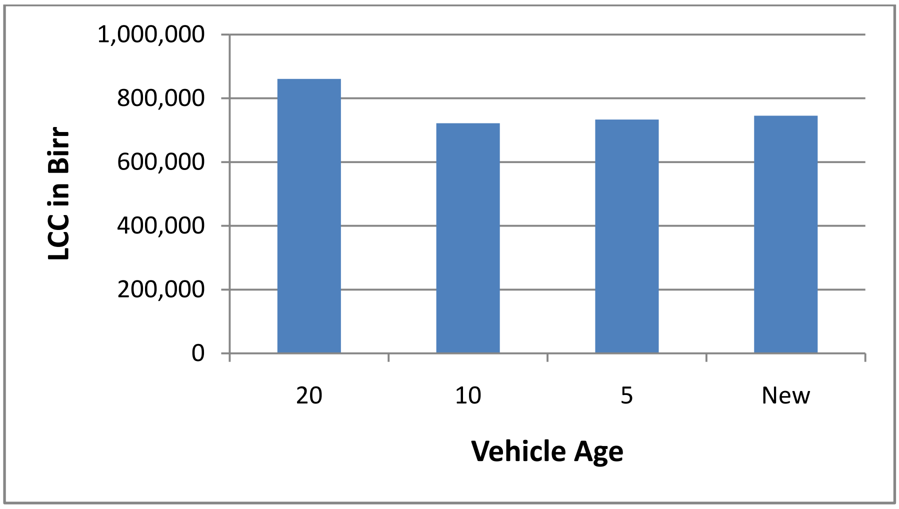


Figure 8.5 Comparison of Life cycle cost of different ages under existing fuel price and 5% annual fuel inflation.

Table 8.4: Life cycle cost of vehicles of different ages under existing fuel price and 5% annual fuel inflation under consideration assuming annual mileage of 36,000 km

Age of Vehicle	LCC in Birr
20	1,083,697
10	907,536
5	892,464
New	890,5849

The above analysis does not include down time cost of an old vehicle during maintenance which hast to replaced by rented vehicles temporarily. Hence, it is conclude 8- 10 year old vehicles are economical for personal cars with less annual mileage and 0-5 year old vehicles are economical for business application with increased annual mileage.

8.3.4 Impact off Tax Incentives for Cleaner Vehicles inn Government Revenue

Assuming that in 2030 the total light duty vehicle population of the country will become 600,000 and the share of hybrid and electric vehicles from the total will be 3% or 18,000 vehicles and considering the average excise and sur tax the government collects from the hybrid and electric vehicles under consideration (Birr 390,918) the total amount of tax income loss for the government for introducing tax exemption for cleaner vehicles by 2030 is estimated at Birr 7.021 billion or Birr 413.9 million annually.

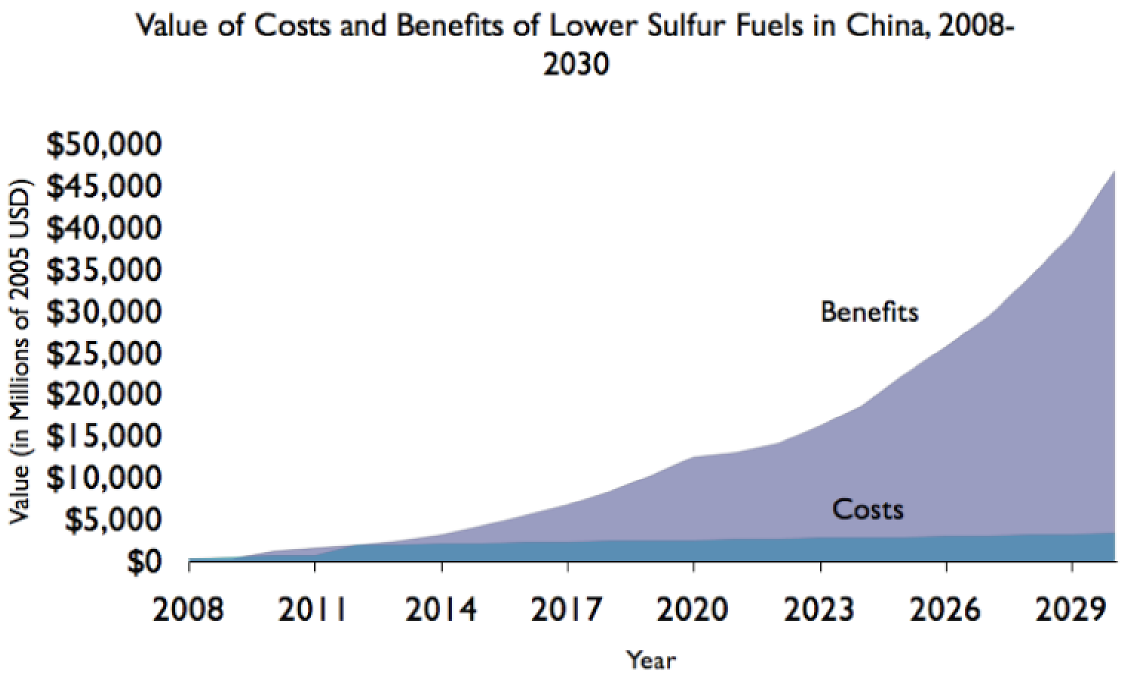
8.3.5 Conclusion

Under the current tax system, the life cycle costs is significantly lower for conventional vehicles compared to other vehicle technologies. The main reason for this advantage is the high initial price for both hybrid and electric vehicles and the ensuing high tax and for electric vehicles also the high battery replacement costs. However, with excise and sur tax exemption for hybrid electric vehicles their life cycle cost will be lower than the conventional vehicles. Hence, private end users cannot make rational decision, based on economical aspect, toward cleaner technology when purchasing a new vehicle under the current tax regime for vehicles. Although the life cycle cost of electric vehicles is high, breakthrough through in battery technology will bring drastic decrease in initial cost in the near future. Hence, the technology transfer activity has to begin for both vehicles.

8.4 Benefits and costs associated with sulfur reduction in fuel

Experience of countries like USA, China, Mexico, Europe and studies conducted on African refineries showed that the average consumer cost of reducing sulfur levels to 15 ppm is from 3.66 to 7 USD cents per liter (Sandy Thind, 2000, Abidjan, 2009). Hence, reduction of sulfur content of a fuel from 5000 to 150 ppm in Ethiopia, for instance, will not add more than 5 USD cents per liter. Accordingly, if the petroleum enterprise of Ethiopia reduces the sulfur content of the Diesel from 5000 to 150 ppm and even down to 50 ppm, the incremental cost is expected to be around 5 USD cents per litter cost on the current market price of the fuel. Ethiopia has imported 1,232,894 ton (1,450,463,529.42 liter) of diesel fuel in 2012 (Ethiopian PE, 2012). The cost of importing of diesel fuel would have increased form around USD 1,289,300,915.037 to USD 1,360, 535,728.588, if low sulfur fuel were imported in the same year to Ethiopia. Definitely, as most countries will go for low sulfur diesel option in the future, the incremental cost will lower due to economy of scale.

Lowering the sulfur content of diesel fuel has a lot of economic benefits though the price seems to be high at first. Benefits will overtake costs in years as it has been witnessed by tangible researches conducted in US, Europe, China and Mexico as shown in Figure 8.6. In summarizing the complex costs and benefits of low sulfur diesel, it was estimated that the annual monetized net benefits would be $66.2 billion due to the thousands of avoided hospital admissions, asthma emergencies, lost work days, chronic pulmonary ailments, other health impacts, reduced agricultural crop and commercial forest damage (U.S. EPA, 2007). The same patterns were seen in Mexico, Europe and other countries (ICCT, 2009).



Source: Costs and Benefits of Reduced Sulfur Fuels in China,(ICCT, 2006).

Figure 8.6 Projected incremental cost and benefits of low sulfur fuel in China

Using low-sulfur diesel offers economic benefits beyond the obvious public health and environmental improvements. Low-sulfur diesel can reduce maintenance costs over the life of a vehicle because it reduces engine corrosion and makes engine lubricating oil less prone to acidification and this leads to longer maintenance intervals and lower maintenance costs.

9. CONCLUSION AND RECOMMENDATION

The study compiled and used data of registered vehicles and annual inspected vehicles in Ethiopia, scanned parameters of imported gasoline and gasoil, reviewed legislation and regulation of relevant to vehicle import registration, inspection and vehicle emission, conducted measurement of ambient air quality at 12 selected sites in Addis Ababa, reviewed new vehicle technologies and conduct cost benefit analysis of measures that require introduction of new technologies. Finally policy recommendations to promote efficient and cleaner vehicles and draft legislation on vehicle emission standard and related were prepared.

Major finding of the study can be concluded as follow.

- Gasoline engine vehicles in Ethiopia are aging consuming more fuel and with increased emissions
- The relatively low average fuel economy indicates importation of old second hand vehicles has to be stopped and minimum fuel economy standard for different class of vehicles has to beset
- The high-level of particulate matter emission indicates that vehicle emission standard implementation is crucial.
- Implementation of vehicle emission standard will require radical reduction of sulfur content of the fuel. Hence, Ethiopian fuel standard has to be revised.
- New vehicle technologies that promote fuel efficiency and emissions reduction has to be introduced into the country at first and disseminated. Toward this, incentives packages have to be prepared and maintenance support has to be arranged.

In addition to this, the following recommendations are made to facilitate the implementation of the study:

- As the particulate matter emission is alarming, detailed ambient air quality study has to be conducted at least for a year for more sites in Addis Ababa and other cities with high traffic.
- Task forces shall be formed from the stakeholder including from Ministry of Transportation to implement the different aspects of the study.

- ECRA shall revise its newly registered vehicle database so that it can facilitate tracking of vehicle fuel efficiency similar to the cleaned vehicle database in this study
- Computerized vehicle inspection data recording has to be improved to facilitate classification of vehicle stock and implemented in regions where it is absent.
- The laboratory infrastructure of EPE has to be strengthened.

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APPENDIX 1: DRAFT REGULATION

Federal Negarit Gazeta

Of the Federal Democratic Republic of Ethiopia

Council of Ministers (draft) Regulations No. /2012

Council of Ministers Regulations to Provide Vehicular Emission Standard & Incentive for Fuel Efficient & Environmental Friendly Vehicles

These Regulations are issued by the Council of Ministers pursuant to Article 5 of Proclamation No. 691/2010 of the Definition of Powers & Duties of the Executive Organs of the Federal Democratic Republic of Ethiopia, and Article 20 of the Environmental Pollution Control Proclamation No. 300/2002, and Article ? of the Environmental Pollution Control (Amendment) Proclamation No. / .

Article 1: Short Title

These Regulations may be cited as "Regulations to Provide Vehicular Emission Standard & Incentive for Fuel Efficient & Environmental Friendly Vehicles Council of Ministers Regulations No. /2012"

Article 2: Definitions

Unless the context requires otherwise, in these Regulations:

(1) "Incentive" means the exemption from any applicable import related tax (es) on imported or assembled vehicles, wholly or partly.

(2) "Person" means any natural person or juridical entity which has been bestowed with legal existence, rights & obligations by law.

(3) "Pollution" shall have the meaning as provided under Article 2(12) of the Environmental Pollution Control Proclamation No. 300/2002.

(4) "Tax Payer" means a person who imports taxable vehicles to Ethiopia or purchases assembled vehicles in Ethiopia.

(5) "Vehicle" means any type of wheeled motor vehicle except defense & three wheel vehicles, for use on roads classified as carriage.

(6) "Vehicular Emission" means pollutants emitted from vehicles exhaust.

Article 3: Scope of Application

These Regulations shall:

(1) apply within the territory of Federal Democratic Republic of EthiopiaCity of Addis Ababa;
(2) apply on new or second hand vehicles imported to Ethiopia on or after the effective date of these Regulations;
(3) apply on new vehicles assembled in Ethiopia on or after the effective date of these Regulations;
(4) apply on any tax payer or person by virtue of being a purchaser of assembled vehicle in Ethiopia or importer of vehicle to Ethiopia;
(5) not apply on defense vehicles & three wheel vehicles including on those vehicles exempted under Article 5 & Article 26 of Proclamation No. 681/2010.

Article 4: Vehicular Emission Standard

(1) The Vehicular Emission Standard is hereby provided in the Schedule which forms an integral part of these Regulations.
(2) All vehicles, with four or more wheels, to be imported to Ethiopia or assembled in Ethiopia on or after effective date of these Regulations shall have catalytic converter that conform to the Vehicular Emission Standard provided hereof.
(3) All vehicles to be imported to Ethiopia or assembled in Ethiopia after January 1 2015 shall have catalytic converter that confirm to Euro III emission standard.
(4) Euro IV vehicular emission standard shall be updated with Euro IV standard as of September 2017.
(5) Conformance to the Vehicular Emission Standard may not be mandatory to all three wheel vehicles. However, they shall have four stroke petrol engines with catalytic converters.

Article 5: Importation of New Vehicles

(1) No tax payer or person is allowed to import new or second hand vehicles in to Ethiopia which shall not comply with the Vehicular Emission Standard as provided in these Regulations.
(2) No tax payer or person shall be allowed to import in to Ethiopia second hand vehicle older than 5 years of its make.
(3) No person is allowed to assemble vehicles in Ethiopia which shall not conform to the Vehicular Emission Standard provided hereof.

Article 6: Incentives

(1) A tax payer or person who imports new or second hand vehicle to Ethiopia & such vehicle which conforms to the Vehicular Emission Standard, shall be granted import tax related incentive(s) as provided in the Incentive Schedule which forms an integral part of these Regulations.
(2) A tax payer or person, who purchases assembled vehicle in Ethiopia & such vehicle which conform to the Vehicular Emission Standard, shall be granted import tax related

incentive(s) as provided in the Schedule which forms an integral part of these Regulations.

Article 7: Implementation

All relevant federal & the Addis Ababa City Government institutions shall undertake their respective obligations as originate from the implementation of these Regulations, based on their respective legal framework & power.

Article 8: Power to Issue Directives

The Transport Authority may issue directives for the better implementation of these Regulations.

Article 9: Duty to Cooperate

Any person shall have the obligation to cooperate for the implementation of these Regulations**.**

Article 10: Inapplicable Laws

Any regulations or directives or practice which is inconsistent with these Regulations shall not be applicable for matters provided hereof.

Article 11: Effective Date

These Regulations shall come in to force on January 1, 2015.

Done at Addis Ababa, this day of , 2013

…

Prime Minister of the Federal Democratic Republic of Ethiopia

Schedule 1:

Vehicular Emission Standard for Passenger Vehicles, g/km

Vehicle Category	**Engine type**	**Pollutants**				
		CO	**THC**	**NOx**	**HC+NOx**	**PM**
Passenger cars	Diesel	0.64	-	0.5	0.56	0.05
	Petrol	2.3	0.2	0.15	-	-
Light-commercial vehicles ≤ 1305 kg	Diesel	0.64	-	0.50	0.56	0.05
	Petrol	2.3	0.20	0.15	-	-
Light-commercial vehicles 1305-1760 kg	Diesel	0.8	-	0.65	0.72	0.07
	Petrol	4.17	0.25	0.18	-	-
Light-commercial vehicles >1760max3500	Diesel	0.95	-	0.78	0.86	0.10
	Petrol	5.22	0.29	0.21	-	-

Schedule 2:

Vehicles Emission Standard for Heavy Duty Diesel Vehicles, g/kWh

Vehicle category	**CO**	**HC**	**NOx**	**PM**
Trucks and buses	2.1	0.66	5.0	0.1
Large good vehicles (2000kg and above)	2.1	0.66	5.0	0.1

Schedule 3:

Incentives for Fuel Efficient Vehicles to be imported to or assembled in Ethiopia

The following exemptions have been granted if not already provided by other applicable import related tax laws.

No	**Category of Vehicles**	**VAT**	**Excise Tax**	**Import Sur Tax**
I.	Hybrid vehicles	15 %	Exempted	Exempted
II.	Electric vehicles	15 %	Exempted	Exempted

APPENDIX 2: LIFE CYCLE COST ANALYSES (BASE CASE)

CONVENTIONAL VEHICLE

a) Capital Cost

1	**Purchase price**	**Cost**
1.1	in USD	12,007
1.2	in Birr	216,126
2	**Cost of freight, insurance and port handling**	
2.1	in USD	2,500
2.2	in Birr	45,000
	Total CIF cost	
	in USD	**14,507**
	in Birr	**261,126**
3	**Tax (in Birr)**	
3.1	Duty (35% of CIF)	91,394
3.2	Excise (50% of CIF + Duty)	176,260
3.3	Sur Tax (10% of CIF + excise +duty)	52,878
3.4	VAT (15% of CIF + excise + duty + sur tax)	87,249
	Total tax in Birr	**407,781**
	Total capital cost (Birr)	**668,907**
4	Salvage value (Birr)	222,969
	Grand total capital cost (Birr)	**445,938**

b) Operating cost

Sr. No	Description	Year/ cost in Birr									
1	**Fuel**	1	2	3	4	5	6	7	8	9	10
1.1	Mileage travelled per year	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000
1.2	Fuel consumption (per 100 km)	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
1.3	Amount of fuel required (lit/annum)	1,368	1,368	1,368	1,368	1,368	1,368	1,368	1,368	1,368	1,368
1.4	Unit Cost of fuel (per lit)	18.88	19.82	20.82	21.86	22.95	24.10	25.30	26.57	27.89	29.29
	Annual Cost of fuel (in Birr)	**25,828**	**27,119**	**28,475**	**29,899**	**31,394**	**32,964**	**34,612**	**36,342**	**38,159**	**40,067**
2	**Lubricant**										
2.1	Mileage travelled per year	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000
2.2	Number of Lubricant change (every 5000 km)	5	5	5	5	5	5	5	5	5	5
2.3	Average Amount of lubricant required (kg)	29	29	29	29	29	29	29	29	29	29
2.4	Average Unit cost of lubricant (per kg)	100	105	110	116	122	128	134	141	148	155
	Annual Cost of Lubricant (in Birr)	**2,880**	**3,024**	**3,175**	**3,334**	**3,501**	**3,676**	**3,859**	**4,052**	**4,255**	**4,468**
3	**Tyre and battery (every 24,000 km)**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**
4	**Maintenance and Repair Costs**	**3,000**	**3,600**	**4,320**	**5,184**	**6,221**	**7,465**	**8,958**	**10,750**	**12,899**	**15,479**
5	**Vehicle registration and insurance cost**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**
	Total operating cost	**34,508**	**36,543**	**38,770**	**41,217**	**43,915**	**46,904**	**50,229**	**53,944**	**58,114**	**62,815**

c) Life Cycle Cost

Year	Actual cost (in Birr)	Discounting Factor (10%)	Discounted cost (in Birr)
Capital cost	445,938	1	445,938
1	34,508	1	34,508
2	36,543	0.909	33,218
3	38,770	0.826	32,024
4	41,217	0.751	30,954
5	43,915	0.683	29,994
6	46,904	0.621	29,128
7	50,229	0.564	28,329
8	53,944	0.513	27,673
9	58,114	0.467	27,139
10	62,815	0.424	26,633
	Total Life Cycle Cost (in Birr)		**745,539**

HYBRID VEHICLE

a) Capital Cost

1.1	**Purchase price**	**Cost**
1.1.1	in USD	17,299
1.1.2	in Birr	311,382
2	**Cost of freight, insurance and port handling**	
2.1	in USD	2,500
2.1	in Birr	45,000
3	**Total CIF cost**	
3.1	**in USD**	**19,799**
3.2	**in Birr**	**356,382**
4	**Tax (in Birr)**	
4.1	Duty (35% of CIF)	124,734
4.2	Excise (50% of CIF + Duty)	240,558
4.3	Sur Tax (10% of CIF + excise +duty)	72,167
4.4	VAT (15% of CIF + excise + duty + sur tax)	119,076
	Total tax	**556,535**
5	**Total capital cost (Birr)**	**912,917**
6	Salvage value (Birr)	304,306
	Grand total capital cost (Birr)	**608,611**

b) Operating cost

Sr. No	Description	Year/ cost in Birr									
1	**Fuel**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1.1	Mileage travelled per year	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000
1.2	Fuel consumption (per 100 km)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
1.3	Amount of fuel required (lit/annum)	840	840	840	840	840	840	840	840	840	840
1.4	Unit Cost of fuel (per lit)	18.88	19.82	20.82	21.86	22.95	24.10	25.30	26.57	27.89	29.29
	Annual Cost of fuel (in Birr)	**15,859**	**16,652**	**17,485**	**18,359**	**19,277**	**20,241**	**21,253**	**22,315**	**23,431**	**24,603**
2	**Lubricant**										
2.1	Mileage travelled per year	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000
2.2	Number of Lubricant change (every 5000 km)	5	5	5	5	5	5	5	5	5	5
2.3	Average Amount of lubricant required (kg)	29	29	29	29	29	29	29	29	29	29
2.4	Average Unit cost of lubricant (per kg)	100	105	110	116	122	128	134	141	148	155
	Annual Cost of Lubricant (in Birr)	**2,880**	**3,024**	**3,175**	**3,334**	**3,501**	**3,676**	**3,859**	**4,052**	**4,255**	**4,468**
3	**Tyre and battery (every 24,000 km)**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**
4	**Maintenance and Repair Costs**	**3,000**	**3,600**	**4,320**	**5,184**	**6,221**	**7,465**	**8,958**	**10,750**	**12,899**	**15,479**
5	**Vehicle registration and insurance cost**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**
	Total operating cost	**24,539**	**26,076**	**27,780**	**29,677**	**31,798**	**34,181**	**36,870**	**39,917**	**43,386**	**47,350**

c) Life Cycle Cost

Year	Actual cost	Discounting Factor (10%)	Discounted cost
Capital cost	608,611	1	608,611
1	24,539	1	24,539
2	26,076	0.909	23,703
3	27,780	0.826	22,946
4	29,677	0.751	22,287
5	31,798	0.683	21,718
6	34,181	0.621	21,227
7	36,870	0.564	20,795
8	39,917	0.513	20,478
9	43,386	0.467	20,261
10	47,350	0.424	20,076
	Total Life Cycle Cost		**826,643**

ELECTRIC VEHICLE

a) Capital Cost

1	**Capital Cost**	**Cost**
1.1	Purchase price	
1.1.1	in USD	27,200
1.1.2	in Birr	489,600
2	**Cost of freight, insurance and port handling**	
2.1	in USD	2,500
2.2	in Birr	45,000
2.3	**Total CIF cost**	
2.3.1	**in USD**	**29,700**
2.3.2	**in Birr**	**534,600**
3	**Tax (in Birr)**	
3.1	Duty (35% of CIF)	187,110
3.2	Excise (50% of CIF + Duty)	360,855
3.3	Sur Tax (10% of CIF + excise +duty)	108,257
3.4	VAT (15% of CIF + excise +duty+ sur tax)	178,623
	Total tax	**834,845**
4	**Total capital cost (Birr)**	**1,369,445**
5	Salvage value (Birr)	456,482
6	**Grand total capital cost (Birr)**	**912,963**

b) **Operating cost**

Sr. No	Description	Year 1	2	3	4	5	6	7	8	9	10
1	**Energy**										
1.1	Mileage travelled per year	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000
1.2	Energy consumption (kwh/km)	0.215	0.215	0.215	0.215	0.215	0.215	0.215	0.215	0.215	0.215
1.3	Amount of energy required (kwh/annum)	5,160	5,160	5,160	5,160	5,160	5,160	5,160	5,160	5,160	5,160
1.4	Unit Cost of energy (Birr/ per kwh)	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
	Annual Cost of energy (in Birr)	**3,354**	**3,354**	**3,354**	**3,354**	**3,354**	**3,354**	**3,354**	**3,354**	**3,354**	**3,354**
2	**Lubricant**										
2.1	Mileage travelled per year	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000
2.2	Number of Lubricant change (every 5000 km)	4.80	4.80	4.80	4.80	4.80	4.80	4.80	4.80	4.80	4.80
2.3	Average Amount of lubricant required (kg)	14.40	14.40	14.40	14.40	14.40	14.40	14.40	14.40	14.40	14.40
2.4	Average Unit cost of lubricant (per kg)	100	105	110	116	122	128	134	141	148	155
	Annual Cost of Lubricant (in Birr)	**1,440**	**1,512**	**1,588**	**1,667**	**1,750**	**1,838**	**1,930**	**2,026**	**2,128**	**2,234**
3	**Tyre (every 24,000 km)**	**900**	**900**	**900**	**900**	**900**	**900**	**900**	**900**	**900**	**900**
4	**Battery (every 160,000 km)**							**461,953**			
5	**Maintenance and Repair Costs**	**1,500**	**1,800**	**2,160**	**2,592**	**3,110**	**3,732**	**4,479**	**5,375**	**6,450**	**7,740**
6	**Vehicle registration and insurance cost**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**
	Total operating cost	**8,194**	**8,566**	**9,002**	**9,513**	**10,115**	**10,824**	**473,616**	**12,655**	**13,831**	**15,228**

c) Life Cycle Cost

Year	Actual cost	Discounting Factor (10%)	Discounted cost
Capital cost	912,963	1	912,963
1	8,194	1	8,194
2	8,566	0.909	7,786
3	9,002	0.826	7,435
4	9,513	0.751	7,144
5	10,115	0.683	6,908
6	10,824	0.621	6,722
7	473,616	0.564	267,119
8	12,655	0.513	6,492
9	13,831	0.467	6,459
10	15,228	0.424	6,456
	Total Life Cycle Cost		**1,243,680**

APPENDIX 3: NEW AND SECOND VEHICLES LIFE COST ANALYSIS

A2.1 New Vehicle

1	**Capital Cost**	
		Birr
1.1	Purchase price	600,000
1.2	**Total capital cost (Birr)**	**600,000**
1.3	Salvage value (Birr)	200,000
1.4	**Grand total capital cost (Birr)**	**400,000**

		1	2	3	4	5	6	7	8	9	10	Total
2	**Operating cost**											
2.1	**Fuel**											
2.1.1	Mileage travelled per year	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	
2.1.2	Fuel consumption (per 100 km)	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	
2.1.3	Amount of fuel required (lit/annum)	1,440	1,440	1,440	1,440	1,440	1,440	1,440	1,440	1,440	1,440	
2.14	Unit Cost of fuel (per lit)	18.88	20.77	22.84	25.13	27.64	30.41	33.45	36.79	40.47	44.52	
	Annual Cost of fuel (in Birr)	**27,187**	**29,906**	**32,897**	**36,186**	**39,805**	**43,785**	**48,164**	**52,980**	**58,278**	**64,106**	**433,294**
2.2	**Lubricant**											
2.2.1	Mileage travelled per year	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	
2.2.2	Number of Lubricant change (every 4000 km)	5	5	5	5	5	5	5	5	5	5	
2.2.3	Average Amount of lubricant required (kg)	19	29	29	29	29	29	29	29	29	29	
2.2.4	Averege Unit cost of lubricant (per kg)	100	105	110	116	122	128	134	141	148	155	
	Annual Cost of Lubricant (in Birr)	**1,920**	**3,024**	**3,175**	**3,334**	**3,501**	**3,676**	**3,859**	**4,052**	**4,255**	**4,468**	**35,264**
2.3	**Tyre and battery (every 24,000 km)**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**18,000**
2.4	**Maintenance and Repair Costs**	**3,000**	**3,300**	**3,630**	**3,993**	**4,392**	**4,832**	**5,315**	**5,846**	**6,431**	**7,074**	**47,812**
2.5	**Vehicle registration and insurance cost**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**10,000**
	Total operating cost	**34,907**	**39,030**	**42,502**	**46,313**	**50,498**	**55,092**	**60,138**	**65,679**	**71,764**	**78,448**	**544,371**

3. **Life Cycle Cost**

Year	**Actual cost**	**Discounting Factor (10%)**	**Discounted cost**
Capital cost	400,000	1	400,000
1	34,907	1	34,907
2	39,030	0.909	35,478
3	42,502	0.826	35,106
4	46,313	0.751	34,781
5	50,498	0.683	34,490
6	55,092	0.621	34,212
7	60,138	0.564	33,918
8	65,679	0.513	33,693
9	71,764	0.467	33,514
10	78,448	0.424	33,262
	Total Life Cycle Cost		**743,362**

A2.2 Five Year Old Vehicle

1.	**Capital Cost**	
1.1	Purchase price	480,000
1.2	**Total capital cost (Birr)**	**480,000**
1.3	Salvage value (Birr)	160,000
1.4	**Grand total capital cost (Birr)**	**320,000**

		1	2	3	4	5	6	7	8	9	10	Total
2.	**Operating cost**											
2.1	**Fuel**											
2.1.1	Mileage travelled per year	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	
2.1.2	Fuel consumption (per 100 km)	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	
2.1.3	Amount of fuel required (lit/annum)	1,680	1,680	1,680	1,680	1,680	1,680	1,680	1,680	1,680	1,680	
2.14	Unit Cost of fuel (per lit)	18.88	20.77	22.84	25.13	27.64	30.41	33.45	36.79	40.47	44.52	
	Annual Cost of fuel (in Birr)	**31,718**	**34,890**	**38,379**	**42,217**	**46,439**	**51,083**	**56,191**	**61,810**	**67,991**	**74,790**	**505,510**
2.2	**Lubricant**											
2.2.1	Mileage travelled per year	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	
2.2.2	Number of Lubricant change (every 4000 km)	5	5	5	5	5	5	5	5	5	5	
2.2.3	Average Amount of lubricant required (kg)	19	29	29	29	29	29	29	29	29	29	
2.2.4	Averege Unit cost of lubricant (per kg)	100	105	110	116	122	128	134	141	148	155	
	Annual Cost of Lubricant (in Birr)	**1,920**	**3,024**	**3,175**	**3,334**	**3,501**	**3,676**	**3,859**	**4,052**	**4,255**	**4,468**	**35,264**
2.3	**Tyre and battery (every 24,000 km)**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**18,000**
2.4	**Maintenance and Repair Costs**	**4,392**	**4,832**	**5,315**	**5,846**	**6,431**	**7,074**	**7,781**	**8,559**	**9,415**	**10,357**	**70,002**
2.5	**Vehicle registration and insurance cost**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**10,000**
	Total operating cost	**40,831**	**45,546**	**49,669**	**54,197**	**59,170**	**64,632**	**70,632**	**77,222**	**84,462**	**92,415**	**638,776**

3. Life Cycle Cost

Year	Actual cost	Discounting Factor (10%)	Discounted cost
Capital cost	320,000	1	320,000
1	40,831	1	40,831
2	45,546	0.909	41,401
3	49,669	0.826	41,027
4	54,197	0.751	40,702
5	59,170	0.683	40,413
6	64,632	0.621	40,137
7	70,632	0.564	39,836
8	77,222	0.513	39,615
9	84,462	0.467	39,444
10	92,415	0.424	39,184
	Total Life Cycle Cost		**722,589**

A3.3 Ten Year Old Vehicle

1	**Capital Cost**	
1.1	Purchase price	
1.2	**Total capital cost (Birr)**	**325,000**
1.3	Salvage value (Birr)	**108,333**
1.4	**Grand total capital cost (Birr)**	**216,667**

		1	2	3	4	5	6	7	8	9	10	**Total**
2.	**Operating cost**											
2.1	**Fuel**											
2.1.1	Mileage travelled per year	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	
2.1.2	Fuel consumption (per 100 km)	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	
2.1.3	Amount of fuel required (lit/annum)	2,040	2,040	2,040	2,040	2,040	2,040	2,040	2,040	2,040	2,040	
2.14	Unit Cost of fuel (per lit)	18.88	20.77	22.84	25.13	27.64	30.41	33.45	36.79	40.47	44.52	
	Annual Cost of fuel (in Birr)	**38,515**	**42,367**	**46,603**	**51,264**	**56,390**	**62,029**	**68,232**	**75,055**	**82,561**	**90,817**	**613,833**
2.2	**Lubricant**											
2.2.1	Mileage travelled per year	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	
2.2.2	Number of Lubricant change (every 3,333 km)	5	5	5	5	5	5	5	5	5	5	
2.2.3	Average Amount of lubricant required (kg)	19	19	19	19	19	19	19	19	19	19	
2.2.4	Averege Unit cost of lubricant (per kg)	100	105	110	116	122	128	134	141	148	155	
	Annual Cost of Lubricant (in Birr)	**1,920**	**2,016**	**2,117**	**2,223**	**2,334**	**2,450**	**2,573**	**2,702**	**2,837**	**2,979**	**24,150**
2.3	**Tyre and battery (every 24,000 km)**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**18,000**
2.4	**Maintenance and Repair Costs**	**7,074**	**7,781**	**8,559**	**9,415**	**10,357**	**11,392**	**12,532**	**13,785**	**15,163**	**16,680**	**112,739**
2.5	**Vehicle registration and insurance cost**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**10,000**
	Total operating cost	**50,309**	**54,964**	**60,080**	**65,702**	**71,881**	**78,672**	**86,137**	**94,342**	**103,361**	**113,275**	**778,721**

3. **Life Cycle Cost**

Year	Actual cost	Discounting Factor (10%)	Discounted cost
Capital cost	216,667	1	216,667
1	50,309	1	50,309
2	54,964	0.909	49,962
3	60,080	0.826	49,626
4	65,702	0.751	49,342
5	71,881	0.683	49,095
6	78,672	0.621	48,855
7	86,137	0.564	48,581
8	94,342	0.513	48,397
9	103,361	0.467	48,270
10	113,275	0.424	48,029
	Total Life Cycle Cost		**707,132**

A2.4 Twenty Year Old Vehicle

1.	**Capital Cost**	
1.1	Purchase price	280,000
1.2	**Total capital cost (Birr)**	280,000
1.3	Salvage value (Birr)	70,000
1.4	**Grand total capital cost (Birr)**	**210,000**

		1	2	3	4	5	6	7	8	9	10	**Total**
2.	**Operating cost**											
2.1	**Fuel**											
2.1.1	Mileage travelled per year	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	
2.1.2	Fuel consumption (per 100 km)	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	
2.1.3	Amount of fuel required (lit/annum)	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	
2.14	Unit Cost of fuel (per lit)	18.88	20.77	22.84	25.13	27.64	30.41	33.45	36.79	40.47	44.52	
	Annual Cost of fuel (in Birr)	**45,312**	**49,843**	**54,828**	**60,310**	**66,341**	**72,975**	**80,273**	**88,300**	**97,130**	**106,843**	**722,157**
2.2	**Lubricant**											
2.2.1	Mileage travelled per year	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	
2.2.2	Number of Lubricant change (every 3,333 km)	5	5	5	5	5	5	5	5	5	5	
2.2.3	Average Amount of lubricant required (kg)	19	19	19	19	19	19	19	19	19	19	
2.2.4	Averege Unit cost of lubricant (per kg)	100	105	110	116	122	128	134	141	148	155	
	Annual Cost of Lubricant (in Birr)	**1,920**	**2,016**	**2,117**	**2,223**	**2,334**	**2,450**	**2,573**	**2,702**	**2,837**	**2,979**	**24,150**
2.3	**Tyre and battery (every 24,000 km)**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**1,800**	**18,000**
2.4	**Maintenance and Repair Costs**	**15,163**	**16,680**	**18,348**	**20,182**	**22,201**	**24,421**	**26,863**	**29,549**	**32,504**	**35,755**	**241,666**
2.5	**Vehicle registration and insurance cost**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**10,000**
	Total operating cost	**65,195**	**71,339**	**78,092**	**85,515**	**93,676**	**102,647**	**112,509**	**123,351**	**135,271**	**148,376**	**1,015,972**

3 Life Cycle Cost

Year	Actual cost	Discounting Factor (10%)	Discounted cost
Capital cost	210,000	1	210,000
1	65,195	1	65,195
2	71,339	0.909	64,847
3	78,092	0.826	64,504
4	85,515	0.751	64,222
5	93,676	0.683	63,981
6	102,647	0.621	63,744
7	112,509	0.564	63,455
8	123,351	0.513	63,279
9	135,271	0.467	63,172
10	148,376	0.424	62,912
	Total Life Cycle Cost		**849,310**

Emission standards in the **European Union** for passenger cars and light duty vehicles

Table 1: EU emission standards for passenger cars (Category M1*), g/km

Emissions stage	Implementation date: new types	CO	NO_x	Particulate matter limit	Particle number limit
Euro 1	07/1992	2.72	–	0.14	
Euro 2	01/1996	1.00	–	0.08	
Euro 3	01/2000	0.64	0.50	0.05	
Euro 4	01/2005	0.50	0.25	0.025	
Euro 5a	09/2009	0.50	0.18	0.005	
Euro 5b	09/2011	0.50	0.18	0.0045	6×10^{11} #/km
Euro 6	09/2014	0.50	0.08	0.0045	6×10^{11} #/km

Table 2: EU emission standards for light commercial vehicles, g/km

Category	Emissions stage	Implementation date: new types	NO_x	Particulate matter limit	Particle number limit
N_1, Class I ≤ 1305 kg	Euro 1	10/1994	–	0.140	–
	Euro 2	01/1998	–	0.080	–
	Euro 3	01/2000	0.500	0.050	–
	Euro 4	01/2005	0.250	0.025	–
	Euro 5a	09/2009	0.180	0.005	–
	Euro 5b	09/2011	0.180	0.045	6×10^{11} #/km
	Euro 6	09/2014	0.080	0.045	6×10^{11} #/km
N_1, Class II 1305-1760 kg	Euro 1	10/1994	–	0.190	–
	Euro 2	01/1998	–	0.120	–
	Euro 3	01/2001	0.650	0.070	–
	Euro 4	01/2006	0.330	0.040	–
	Euro 5a	09/2010	0.235	0.005	–
	Euro 5b	09/2011	0.235	0.045	6×10^{11} #/km
	Euro 6	09/2015	0.105	0.045	6×10^{11} #/km
N_1, Class III > 1760 kg	Euro 1	10/1994	–	0.250	–
	Euro 2	01/1998	–	0.170	–
	Euro 3	01/2001	0.780	0.100	–
	Euro 4	01/2006	0.390	0.060	–
	Euro 5a	09/2010	0.280	0.005	–
	Euro 5b	09/2011	0.280	0.045	6×10^{11} #/km
	Euro 6	09/2015	0.125	0.045	6×10^{11} #/km
N_2	Euro 5a	09/2010	0.280	0.005	–
	Euro 5b	09/2011	0.280	0.045	6×10^{11} #/km
	Euro 6	09/2015	0.125	0.045	6×10^{11} #/km

* Category M_1: Vehicles designed and constructed for the carriage of passengers and comprising no more than eight seats in addition to the driver's seat.

Category N_1: Vehicles designed and constructed for the carriage of goods and having a maximum mass not exceeding 3.5 tons.

Category N_2: Vehicles designed and constructed for the carriage of goods and having a maximum mass exceeding 3.5 tons but not exceeding 12 tons.

European Union emission regulations for new light duty vehicles (cars and light commercial vehicles) were originally introduced by the Directive 70/220/EEC, followed by a number of amendments. Following are some of the most important steps in the emission regulations:

- **Euro 1** standards (also known as EC 93): Directives 91/441/EEC (passenger cars only) or 93/59/EEC (passenger cars and light trucks)
- **Euro 2** standards (EC 96): Directives 94/12/EC or 96/69/EC
- **Euro 3** standards (required from 01/2000) and Euro 4 standards (required from 01/2005): Directive 98/69/EC, further amendments in 2002/80/EC
- **Euro 5a** standards (required from 09/2009),
- **Euro 5b** standards (required from 09/2011)
- **Euro 6** standards (required from 09/2014): Commission Regulation (EC) No 692/2008 of 18 July 2008 implementing and amending Regulation (EC) No 715/2007 of the European Parliament and of the Council on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6)

Euro 5a stage introduce a **Particle Number** limit of 6×10^{11} km for passenger cars and light duty vehicles (M, N_1, N_2). The particle number limit must be met in addition to the PM mass emission limits listed in the table on the left.