ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL MULTIDISCIPLINARY ENGINEERING

GRADUATE PROGRAM IN RAILWAY ENGINEERING

The Impact of Electric Train Transportation on CO_2 Emission Reduction: The Case of Addis Ababa-Djibouti Electric Railway Line

A Thesis Submitted To

The School of Graduate Studies of Addis Ababa University in partial fulfillment of the requirements for the Degree of Masters of Science in Mechanical Engineering

(Railway Mechanical Engineering Stream)

BY - SOLOMON FEKADE

JUNE, 2017

ADIS ABEBA

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SCHOOL OF GRADUATE STUDIES

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APPROVED BY BOARD OF EXAMINERS

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SIGNED DECLARATION

This thesis is my original work and all sources of materials used for the thesis have been duly acknowledged.

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SOLOMON FEKADE

Addis Ababa University

June, 2017

The Thesis has been submitted for examination with my approval as an advisor

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Demisse Alemu (PHD)

ACKNOWLEDGMENT

In the name of the Father, the Son and the Holy Spirit, One God, Amen.

God I forward First and for most, I would like to forward magnificence respect to the Almighty GOD for his giving me strength, patience, invaluable cares and support in my life, and frontward too.

My Mom Konjit Nigussie Adela I wish you to rest your soul in heaven. You lost your whole life for me.I will never forget you mom…Never!!!

Dear father Fekade I thank you for your advises, guidance and support.

My brother Tewodros Setargew (Teddy) you are always in my heart. Just silent! You showed me and I have seen that you can give your one life form me so many times, I do too. I have no words.

I want to extend my regards to my advisor Dr. Ing Demisse Alemu, for his invaluable comments and corrections.

I would like to forward my thanks Adis Abeba University Scholars, stuffs and community. I want also to thank the Ethiopian Railway Corporation/ERC, for its full program sponsorship and financial support.

Finally, I want to acknowledge those people who directly and indirectly participated in the process and finalization of this Thesis work.

Thank you!

Solomon Fekade

Acknowledgment

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Title- The Impact of Electric Train Transportation on CO_2 Emission Reduction: The Case of Addis Ababa-Djibouti Electric Railway Line

Abstract:

On this research paper the (CO_2) emission reduction from the operation of Addis Ababa-Djibouti electric railway line project of replaced truck trailer is studied, discussed and quantified. Emission reduction mechanism is applicable by one of globally accepted environmentally friendly, zero emission development option of the electric train railway project. Due to the application of this life saving project it is expected that a great reduction in motorized vehicles from road transport in the ratio of 1 electric train = 50 long trucks that consumes different fuel types which helps to emit carbon dioxide (CO_2) and other toxic gases. The mode shift effect procedure and method applied to estimate the energy and (CO_2) emission avoided by the implementation of this project. The procedure developed is determined 7.707 M ton of CO2e will be saved emissions in the project year of 18 years from (2017-2035) which is applied to Addis Ababa-Djibouti electric railway and the saved energy is *1.10E+11 KWH* (384 million GJ energy, with much 95% of this energy is corresponding to non-renewable energy. Each fright (container, and bulk products) kilometer will result in avoid emissions(gCO_2)and avoided non-renewable energy consumption of Ethiopia (specifically on the constructed railway line of The Addis Ababa-Djibouti corridor which is the major import and export corridor of the Country handling more than 90% of the foreign trade.

In addition, on the project year Ethiopian truck trailer will consume a total of *2,613,308,212 liter* diesel fuel with its direct tail emission of ***6.3190 MT CO_2e*** if vhicle were used. The life cycle analysis GHG gases amount total of ***2.5 MT of CO_2e*** from fuel extraction, refining plant, transportation and leakage are found by using GREET life cycle modeling software. Moreover the emission from service of 30 year or (6,000,000 km travelled) life cycle of fright vehicles of trucks are analyses based on the existing collected data. A total of ***0.00614599 M ton of CO_2e*** from service are carried out. The Microsoft Excel software the GREET life cycle modeling software package is greatly used in the analysis of different data.

Finally a Microsoft Excel software program(GHG emission calculator) are prepared that will be used for anyone to find out the average fuel consumption, LCA emission from vehicles service, emission from electricity generation and CO_2e emitted gas with its percentage of CO_2, N_20 CH_4 and SF_6 by using an input of ton and kilometer variables.

Index Terms: *CO_2e emissions, environment, transportation, railway, energy, electricity, emission reduction, mode shift effect*

Acronyms, abbreviations and general expressions:

AAIT Addis Ababa Institute of Technology

AAU Addis Ababa University

BC Black Carbon

CDM Clean Development Mechanism

CH_4 Methane

CO_2e Carbon Dioxide Equivalent

CSA Central Statistical Agency

D rail/road Demand of Rail/Road

E.C Ethiopian Calendar

E15 15% Ethanol Content of Transport Gasoline

ECRGE Ethiopia’s Climate-Resilient Green Economy Initiative

EMME/2 Transport Modelling Programs, INRO of Canada- 1987

EPSE Ethiopian Petroleum Supply Enterprise

ERA Ethiopian Roads Authority

ERC Ethiopian Railways Corporation

ETB Ethiopian Birr

GDP Gross Domestic Product

GHG Greenhouse Gases (Mainly CO2, N2O, and Methane)

GTP Growth and Transformation Plan

HSR High Speed Rail

ICT Information Communication Technology

IMF International Monetary Fund

IPCC Intergovernmental Panel on Climate Change

Mt Million Metric Tones

MT Metric Tones

MW Mega Watt

N_2O Nitrous Oxide

O-D Origin-Destination

OECD Organization for Economic Co-Operation and Development

P-km Passenger- kilometer

PKM Per passenger kilometer

PM Particulate Matter

POC Primary Organic Carbon

SF_6 Sulfur Hexafluoride

Sq.km/Km2 Square-kilometer

TDM Travel Demand Management

T-km Tone-kilometer

TNA Technology Needs Assessment

UNDP United Nations Development Programme

UNEP United Nations Environmental Programme

UNFCCC United Nations Framework Convention on Climate Change

USD United States Dollars

VKM Value of vehicle kilometers

VOC Volatile organic compound

WB The World Bank

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Chapter 1

1.1. Introduction:

Transport has significant detrimental effects on the built and natural environment, and hence on individuals' lives. It is the only sector in the EU in which greenhouse gas emissions have consistently risen since 1990. It also contributes significantly to global warming and therefore it is obvious that current transport patterns are unsustainable. Without mitigation measures, the transport will be unsustainable in medium to long term. The environmental aspects of transport sustainability are concerning the atmospheric and noise pollution, land take, resource use, the effects of waste disposal on the natural environment and the effects of the above on humans, flora and fauna. These environmental aspects of transport cover its full life-cycle. The largest impacts come from transport use, but also the effects of development and construction of infrastructure and vehicles are considered, as well as the waste from their disposal add to the environmental costs of transport. [28]

The global railway sector is working extremely hard to maintain its environmental advantage by improving its energy efficiency and reducing its CO_2 emissions. For example, 28 European members of UIC have collectively committed to reduce CO_2 emissions per passenger kilometer and ton/kilometer by 50% by 2030, and are well on track to meet this target. [28]

Improving energy efficiency is the most important aspect of the railway's strategies to reduce CO_2e emissions, and of course has significant business benefits by reducing costs. Railway companies use a combination of technical and non-technical means to improve energy efficiency. [25]

Various transportation systems could have several impacts on the environment. Their emissions contribute to air pollution and climate change; their noise causes nuisance and health risks. The systems might also have serious impact on the landscape and ecosystems of an area. In this regard, the ERC's ultimate goal to shift the base of freight and passenger transport from road to rail is centered on principles of environmental, social, and economic sustainability. To achieve the former, and also contribute to the efforts to curbing global climate change, the trains will run on 100 per cent renewable hydroelectric power which creates conducive environment for agrarian-rain-feed communities of Ethiopia.

Figure 1: Ethiopia Djibouti railway locomotive, cars (coaches) and station.

The milestones of the electric traction railway project are geographical necessities, need for alternative means of transport, rapid growth in the demand of transportation service, operating costs, the need to combining road and rail system, saving in travel time, employment generation, and other social benefits. [16]

This electric train will highly reduce the CO_2e gas emitted to the environment by the motorized vehicles. In the last decays Ethiopia used road transport system to collect containers and imported products from Djibouti port. Ethiopia paid a lot of million dollars every year for rental each container being stayed in Djibouti.

Since Ethiopia is becoming a member of the United Nations and agreed and accepted the United Nations Framework Convention on Climate Change and Ethiopia has bring a remarkable contribution in climate friendly projects, we have to get our advantages of climate finance on supporting based on the agreed and signed procedure.

Regarding the above bases this paper will have good importance in preparation of project design documents.

1.2. Statement of the problem

Even though motor vehicles are useful and versatile with a wide range of applications and transportation the outcome of fuel that consumes has problematic for environment. The main problem is the emitted toxic gases are the cause for health problem, change the eco-system and global warming. Hence climate change is serious global concern the Ethiopia Djibouti railway line has great contribution for CO_2e emission reduction on the region. And it is expected that during mode shift of transportation from road to rail, high CO_2e emission reduction will be exhibit but estimation in operation will not be easy since there is gap in getting important data and reliability to quantify how much ton is reduced at the same time the energy will be saved. So the main problem to solve on this project is finding out the CO_2 reduction and energy saved from transform of road to rail transport system.

1.3. Objectives

1.3.1. General Objective

I. The first objective of this research paper is to present reliable estimates and acceptable results, quantify CO_2 emission reduction in Mt CO_2 and energy saved due to the transport mode shift of motorized cars from road transport to Addis Ababa-Djibouti Electric Railway transport.

II. The second objective is to examine and draw lesson from Addis Ababa-Djibouti Electric Railway line.

Generally, this research will put supportive research document for the contribution of environment friendly projects in Ethiopia.

1.3.2. Specific Objective

- ✓ Quantify the project year usages of electric power (energy) KWH and compare with the diesel fuel energy (J)
- ✓ Calculate diesel fuel consumption (litter) of the project year and its direct tail emission (M ton of CO_2e) (if we were used truck trailers)
- ✓ Study and calculate Life cycle emission of the diesel fuel used (kg of CO_2e)
- ✓ Study and calculate Life cycle emission of the services of vehicles used to transport the proposed tonnage (kg of CO_2e)

1.4. Limitation of the study

The study is limited by lack of updated data in Ethiopia about (traffic rail road), petroleum supply, and vehicles fuel combustion performance. It is difficult to get recorded data. Different data is collected from separate departments. If these effects were considered in addition to mode shift, certainly the net avoided emissions would increase.

1.5. Delimitation of the study

This research project was intended to find out the CO_2e emission reduction CO_2e gases from motorized vehicles due to the introduction of electric train and the electric power emission the power used for drive the locomotive but from the Project emission (railway and train construction): Upstream, Operational, Downstream and Leakage emissions are not included in this research project.

1.6. Significance of the research

The aim of this paper is to study a procedure for calculating energy use and emissions avoided by use of electric railway transportation system on Ethio-Djibouti line, the reduced amount of CO_2 emissions to the environment, which were released by motor vehicles (car, lorry and long truck), reduced by using with other means of transportation, on regional level, emphasizing its unexploited sources and advantages over other systems

The advantages of this work will be:

- ✓ It is a basic requirements paper for graduation fulfillment.
- ✓ It helps to put the percentage avoided of CO_2e gas emitted to the environment. This also helps the give a well-studied research document for further references of similar task needed in Ethiopia or other projects in the region. And helps to initiate other country to actively practice on such environment friendly zero emission projects.
- ✓ At the same time helps to quantify energy saved and show the economic advantage of this railway project too.

Chapter 2

2.1. Literature review

Sustainable development was defined in the Brundtland Report (WCDE. Report, November 2015) as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". This leads to the need for transport systems to be developed in sustainable ways. However, one of the effects of transport systems has been the continuous growth of greenhouse gas (GHG) emissions, among which carbon dioxide (Ethiopia will more than double from 150 Mt CO_2e to 400 Mt CO_2e in 2030.) is the main one. GHG released into the atmosphere by nature and by human action absorbs part of the infrared radiation reflected by the earth, which makes it difficult for it to escape into space and increases the planet's warming. The amount of these gases, especially CO_2, resulting from human activity has dramatically grown, leading to an annual increase of average global temperature of 0.850C in the period from 1880 to 2012. The 30 years between 1983 and2012 were warmer than any previous 30-year period in the last 1400 years. In a worst-case scenario, without efforts to reduce the GHG emissions by nations, it is predicted that the average temperature may increase up to 4.80C in the next century. [27] The emissions of CO_2 by transport systems accounts for about 23% of total global emissions coming from fossil fuel consumption, with road transport being responsible for most of these emissions (OECD. Reducing Transport Greenhouse Gas Emissions–Trends & Data. Organization for Economic Co-Operation and Development, November 2015). It is estimated that, until 2050, fossil energy used in transport systems will double (based on data from2009), which would increase even more the emission of GHG unless mitigation actions are implemented (IEA. Transport, energy and Ethiopia will more than double from 150 Mt CO_2e to 400 Mt CO_2e in 2030. [25]

- ✓ Carlos Eduardo Sanches de Andrade * and Márcio de Almeida D'Agosto [4] has wrote and published an article on 5 February 2016 in Federal University of Rio de Janeiro, Cidade Universitária, Centro de Tecnologia, in the title of *The Role of Rail Transit Systems in Reducing Energy and Carbon Dioxide Emissions: The Case of The City of Rio de Janeiro.*
- ✓ The article presents and applies a procedure for calculating energy use and emissions avoided by one of the city Line 4 by attracting users from other transport modes in the period from 2016 to 2040. The procedure uses a detailed demand forecast for this period and considers the

local transport profile and the different fuels used to determine the CO2 and energy consumptions.

- ✓ Maruti Suzuki India Ltd. has undertaken a project activity involving Modal Shift from Roadways to Railways for Finished Goods transport i.e. car transport from their Manesar Plant to Mundra. In the absence of project activity cars would have been transported by road, using trailers, which is more GHG intensive mode of transportation as compared to railways.
- ✓ Based on the United Nations Framework Convention on Climate Change (UNFCCC) of the Clean Development Mechanism (CDM) methodology **AM0090 CDM Methodology Booklet** November 2016 (up to EB 91) *Modal shift in transportation of cargo from road transportation to water or rail transportation* was used for rising climate finance.
- ✓ The developed UNFCCC, CDM methodology is internationally accepted document recommended to bring accurate result if all required data's are available.

The full sustainability of a transport system, in the sense of zero emissions and impacts, is currently not a realistically achievable goal. However, the international community agrees that efforts must be made to reduce carbon emissions. Due to this comprehension of the problem, many countries and cities around the world have established emission reduction goals. In preparation for the adoption of the 2015 International Agreement at Paris climate conference in December 2015, several governments were to submit an "intended nationally determined contribution" (INDC). [23]

Table 2.1: Shows the GHG reduction goals of some nations that submitted an INDC

Country	Intended Nationally Determined Contribution
EU	40% below the 1990 level by 2030
USA	26%–28% below the 2005 level by 2025
Japan	26% below the 2013 level by 2030
China	60%–65% below the 2005 level by 2030
Australia	26%–28% below the 2005 level by 2030
India	33%–35% below the 2005 level by 2030
Brazil	37% below the 2005 level by 2025
Russian Federation	25% to 30% below the 1990 level by 2030

Canada	30%below the 2005 level by 2030
Indonesia	26%below the BAU emissions level by 2020

Table 1. Intended Nationally Determined Contribution to the Paris Agreement. Source: [24]

This paper is try's to present and apply a procedure to estimate the energy and CO_2 emissions avoided due to the implementation of freight rail systems, using the mode shift effect. This procedure is different from others in several aspects: (a) it considers the electric rail system individually, not the public and fright transportation system as whole, enabling it to be compared with the other private or public transportation systems, such as cars and buses; (b) it uses the real transport profile of the studied region Addis-Djibouti, according to its vehicle fleet; and (c) it considers the vehicles and their fuels, removing from the emission calculations the amount of renewable fuels, used exclusively or in blends with fossil fuels—a reality which has been stimulated in Ethiopian and Djibouti by government policies. The procedure was applied to the Ethio-Djibouti Line, which is the 756 km long fully electrified railway.

Like much of Africa, Ethiopia has become warmer over the past century and human induced climate change will bring further warming over the next century at unprecedented rates. Climate models suggest that Ethiopia will see further warming in all seasons of between 0.7°C and 2.3°C by the 2020's and of between 1.4°C and 2.9°C by the 2050s. It is likely that this warming will be associated with heat waves and higher evapo transpiration. (Ethiopia's vision for a climate resilient green economy)

The Ethiopia green growth path envisages to limit the national green gas emission level to 150 Mt CO_2e in 2030 instead of 400 Mt CO_2e under BAU Scenario.

Ethiopia's total emissions are around 150 Mt CO_2e contributing less than 0.3% of global emissions. Of the 150 Mt CO_2e in 2010, more than 85% of GHG emissions came from the agricultural and forestry sectors. They are followed by power, transport, industry and buildings, which contributed 3% each. Road transports constitute 3% of GHG emission and are projected to grow from around 5 Mt CO_2e in 2010 to 40 Mt CO_2e in 2030. [20]

If current practices prevail, GHG emissions in Ethiopia will more than double from 150 Mt CO2e to 400 Mt CO_2e in 2030. But with the implementation of Green economy, the Country will curb the emission by 250 Mt CO_2e in 2030 and remain 150 Mt CO_2e. The largest initiatives with the greatest abatement potential are the construction of an electric rail network (9 Mt CO_2e) followed by the introduction of fuel efficiency standards for all vehicles (3 Mt CO_2e). This assumes the construction of more than 5,000 km of rail tracks and new fuel efficiency standards for 30% of passenger vehicles and 10% of freight vehicles by 2030. Emissions from fuel: – Diesel: 2.67 kg CO_2e /liter – Gasoline: 2.42 kg CO_2e /liter. [20]

Various studies have endeavored to estimate the potential for a shift from road or air transport to rail. These vary widely in methodology, assumptions and results. This analysis covers freight transport.

There are various ways to estimate the potential GHG reduction potential of a shift from road or air to rail transport, each of which has its limitations and problems. Several approaches have therefore been used in parallel and the respective results integrated in order to obtain relatively reliable estimates.

The following approaches were adopted:

- Assessment of estimates from existing studies on overall modal shift potential.
- Estimation of potential modal shift per transport market segment, based on extrapolation of illustrative case studies.
- Estimation of potential modal shift per transport market segment, based on infrastructure capacity analysis.

Greenhouse gas reduction potential modal shift

The average GHG reduction potential of freight transport modal shift is higher than that of passenger transport, since the difference in emissions per unit of volume are higher for freight. For freight transport, estimates that assume single measures like a significant improvement of the quality of supply (ZEW) or EU-wide internalization of external costs (CE, 2008b) result in a projected GHG reduction of 27-33 Mtonne CO_2eq. (10-12%) and 5-6 Mtonne CO_2eq. (2%), respectively. A significant shift to rail transport (Vassallo and Fagan) would result in a reduction of GHG emissions by 45-55 Mtonne CO_2eq. This corresponds with 17-20% of the emissions from the market in which rail and road transport compete.

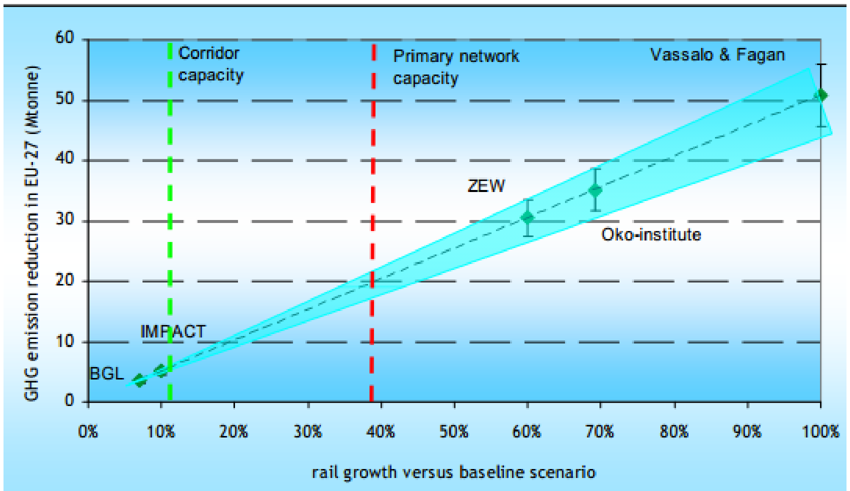


Figure 2.1: Summarizes the GHG reduction potential of a modal shift to rail freight

The green and red dashed lines represent the additional capacity compared with the 2020 baseline scenario under the TEN-T investment scenario. They show that around 5-20 Mtonne of CO_2eq. (2 to 7% in freight transport) could be reduced by fully utilizing the corridors and the primary network respectively in 2020.

The potential for reducing the GHG emissions of passenger transport is harder to estimate unequivocally. The study by Öko-Institute (EEA, 2008) calculates scope for some 70 Mtonne CO_2eq. reduction. If the required policy instruments and measures can be implemented, this would lead to a 9% emissions reduction in the defined passenger transport market in 2030.

There are different methodology's used to approach the emission and energy calculation here bellow is an over view of the methods of International Energy Agency used

Figure 2.2: Industries CO_2e emission

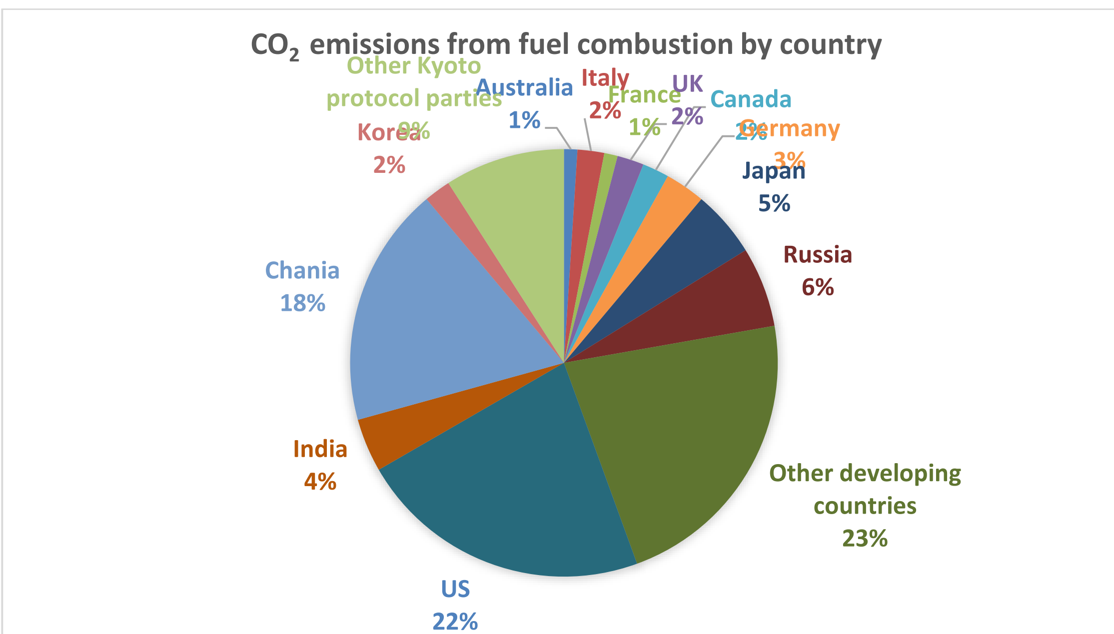


Figure 2.3: CO_2 emissions from fuel combustion by country

The IEA uses the simplest (Tier 1) methodology to estimate CO_2 emissions from fuel combustion based on the 2006 GLs. The computation follows the concept of conservation of carbon, from the fuel com-busted into CO_2. While for the complete methodology the reader should refer to the full IPCC documents, a basic description follows.

Generally, the Tier 1 estimation of CO_2 emissions from fuel combustion for a given fuel can be summarized as follows:

CO_2 Emissions from fuel combustion: key

CO_2 Emissions from fuel combustion

CO_2= Fuel consumption * Emission factor

Where:

Fuel consumption= amount of fuel combusted;

Emission factor = default emission factor

Emissions are then summed across all fuels and all sectors of consumption to obtain national totals.

Changes under the 2006 IPCC Guidelines

IEA Estimates: Changes Under the 2006 IPCC Guidelines

The 2006 IPCC Guidelines methodology: key concepts

Tier 1. Methodology to estimate CO_2 emissions from fuel combustion based on the 2006 GLs, for a given fuel can be summarized as follows.

CO_2 Emissions from fuel combustion

CO_2 = AD * NCV * CC * COF

Where:

- ✓ CO_2 = CO_2 emissions from fuel combustion;
- ✓ AD = Activity data;

- ✓ NCV= Net calorific value;
- ✓ CC= Carbon content;
- ✓ COF= Carbon oxidation factor.

Net calorific values

Net calorific values (NCVs) are used to convert the activity data for all the different fuels from "physical" units (e.g.tonnes) to "energy" units (e.g. Joules).

Calculating and reporting the GHG emissions from freight transport operations:

The following example illustrates various ways of approaching the emissions calculation, reasons for choosing them and the resulting level of accuracy. In practice of course, we would only make use of one of these methods. [21]

Method 1: XYZ have fuel use data

Example

The total fuel used by all the vehicles is 150,000 liters. The Ethiopia emission factor for diesel is 2.67 kgCO_2eq/letter, so:

Total emissions = 150,000 x 2.67

= 400,500 kgCO_2eq

Method 2: XYZ uses fuel spend to calculate fuel use

Unfortunately, XYZ does not collect fuel usage data. Its total fuel spend is $150,300 for the year. Although this actually cost an average of $1.002/ltr it does not have actual price data. Using this data gives an emissions figure of:

Fuel use = Fuel spend ÷ fuel price

= 150,300 ÷ 1.026

= 146,491 litters

Therefore:

Total emissions = 146,491 x 2.67

= 391,131 kgCO_2eq

Method 3: XYZ calculates fuel use from mileage and efficiency as the year's accounts have not yet been completed, XYZ is unable to access this fuel spend data. It knows that its total mileage is 234,267, and it estimates that its trucks get 7.8 mpg (or 1.75 liters per 100km). It therefore calculates its emissions as:

Fuel use = distance ÷ fuel efficiency

= 234,267 ÷ 1.716

= 136,519 liters

Therefore:

Total emissions = 136,519 x 2.67

= 364,506 kgCO_2eq

Method 4: XYZ only have distance data

Unfortunately, the estimate of fuel efficiency is called into question by the new fleet manager due to discrepancies in some of the figures. We decide to calculate emissions on the basis of the distance travelled (we converts this from miles to 377,015 km). We do not have reliable data on the average % loading of the XYZ fleet, so we use the emission factor based on average loading and fuel efficiency for all UK articulated HGVs (for example 0.94353 at the time we check).

Total emissions = distance x emission factor

= 377,015 x 0.94353*

= 355,725 kgCO_2eq

Note how each of the methods above introduces additional estimates and assumptions. With each of these additional assumptions, the accuracy of the result decreases. In this case the final estimate of emissions is around 11% less than the estimate based on direct fuel figures, but in reality the discrepancy could potentially be much greater. [21]

On the above four methodological approach of Calculating and reporting the GHG emissions from Ethio - Djibouti freight transport of replaced truck trailer by the railway operations, we will depend on the data we have to select the method to choose and its accuracy will also relay on it too.

Chapter 3

3.1. Modes of freight transportation

There are five major modern modes of transportation namely: railways, roads, maritime, aviation and pipelines each with its own inherent economic, engineering and service characteristics. Each mode is both competitive and complementary for the other which, if combined optimally, provides maximum contribution to the country’s development. An optimal, cost effective, environmentally friendly transport system could, therefore be planned, developed and operated by properly taking into account the interaction between traffic (demand) and transport (supply) and its intermodal mix based on the inherent advantages and resource costs of different modes of transport.

The six transport mode performance characteristics living in any transportation selection decision are1. Speed 2. Completeness 3. Dependability 4. Capability 5. Frequency 6. Cost

3.2. Road freight transportation

On long hauls, road freight carriers are able to transport certain primary products of an organic nature such as timber, fish, and agricultural products (for example, live-stock, fresh and frozen meats, fruit, vegetables and dairy products); some semi-finished goods; and most finished goods.

Road freight transport is more flexible and versatile than other modes because of vast networks of roads. It can therefore offer point-to-point service between almost any origin and destination.

It is this flexibility and versatility that has enabled road freight transport to become dominant in most countries but it has a great impact on pollution. Mainly CO_2 realized from the vehicles are the dominant draw back from the road transport system world widely.

3.3. The Ethiopia Djibouti railway line

The Djibouti-Ethiopia Railway (Chemin de Fer Djibouti-Ethiopien, or CDE) Project is 784 km railway running from Djibouti to Addis Ababa via Dire Dawa. This line is the only railway line connecting directly in between land locked Ethiopia with Red Sea. Djibouti Port has become a major cargo entry point for Ethiopia as it stopped using other port nearby port since 1998.

This metric-gauge line is 784 km long of which 685 km are located within Ethiopia and approximately 99 km are in Djibouti. This line covers 30 % of population as well as cultivated land of Ethiopia and 70 percent population of Djibouti. Further the industrial centers of Ethiopia located in Dire Dawa, Awash, Metehara, Modjo, Debre Zeit, Akaki, and Addis Ababa falls along this line. This is envisaged as a major export and import connection linking Ethiopia and rest of the World through Djibouti Port in the Red Sea's international shipping routes and has the potential of becoming a regional transport hub in east African hinterland. The railway line has rail roots of the plateau in the middle of Ethiopia, the railway line with a length of 317.774km starts from Sebeta to the southwest of Addis Ababa in the west and runs east wards via Akaki, Gelan, Dukem, Bishoftu, Mojo, Adama, Welenchiti, Metehara, Awash, and Asebot to Mieso. [16]

From Miseso (excluded) ~ Nagad (front-port station of Djibouti) and Djibouti port area

Main lines -Mieso (excluded) ~ Dawanle (located in Ethiopia and on Ethiopia-Djibouti border), about 343km long; Dawanle (excluded) ~ Nagad (front-port station of Djibouti), about 82km long. The total length of the above lines is 425km. [16]

Port distances-Nagad (front-port station of Djibouti) ~ existing port (Djibouti), about 8km long; Nagad (front-port station of Djibouti) ~ new port (Doraleh), about 5.8km long. The total length of the above lines is 13.8km

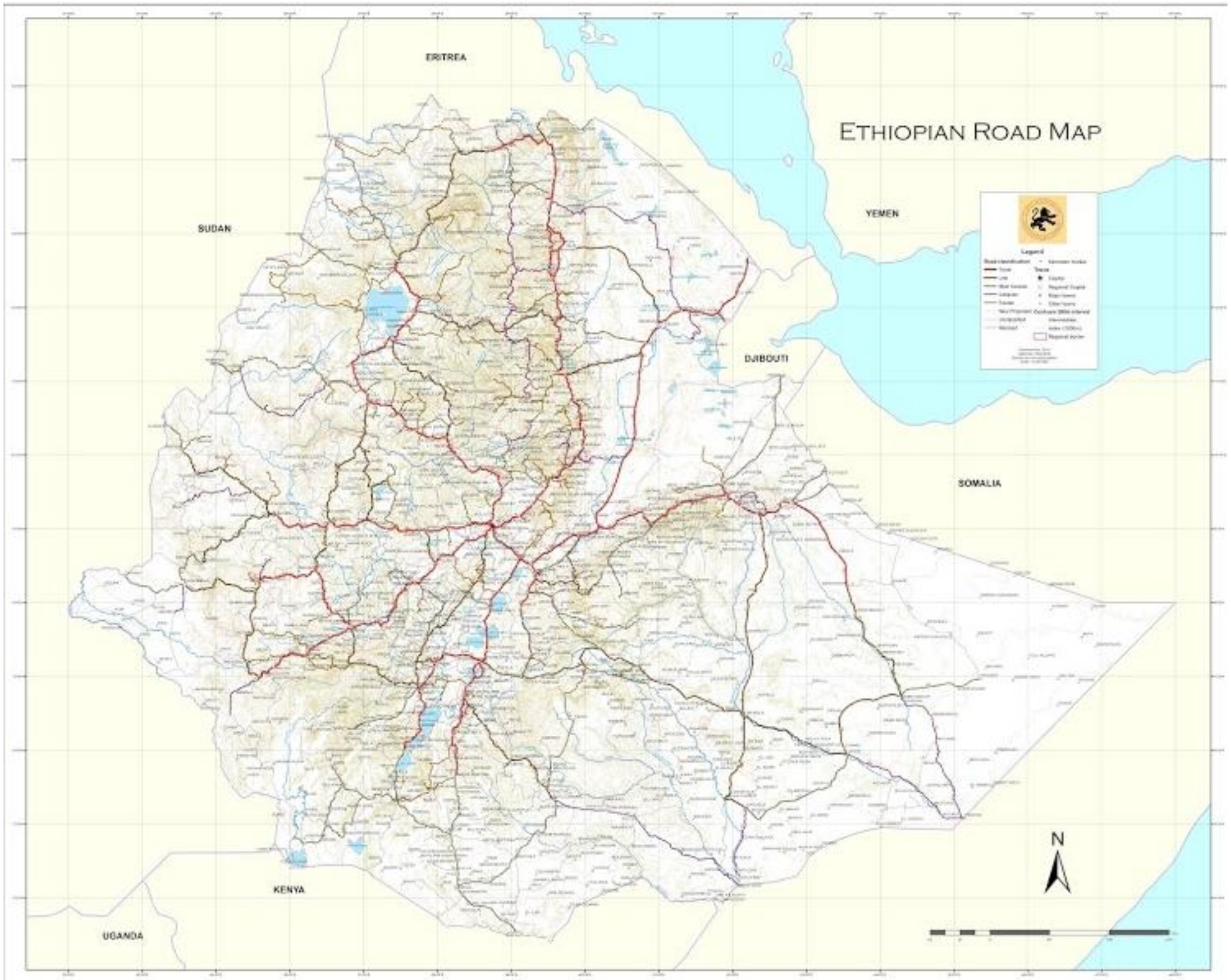


Figure 3.1: Ethiopian road map

3.4. Future annual traffic capacity

1. Sebeta-Adama Section: 2500×10^4t freight traffic capacity, with 25 pairs of passenger train.

2. Adama-Mieso Section: 2000×10^4 t freight traffic capacity, with 10 pairs of passenger train.

3.5. Geological location of the railway line and its significance in national economy and railway network

Located in Ethiopia, this Project is the axis of economy and traffic corridor of the central area, western area and east area of Ethiopia, connecting Addis Ababa, capital of Ethiopia, Dire Dawa, the second largest city, and Adama, the third largest city, along which cities and towns are well developed, so its regional economical and geological advantages are visible.

3.5.1 Its significance and role in national economy:

Ethiopia is located in East Africa, and characterized by lack of resources, weak agricultural and industrial foundation, and slow economic development. It depends on internal aid for a long time, and materials necessary for economic development and people's lives are mainly imported. Djibouti Port is the main collecting & distributing center for goods import and export of Ethiopia, and after this railway line is completed, it will provide a convenient and fast transport mode for goods import and export and thus play an important role in supporting and facilitating the economic development of Ethiopia.

3.5.2. Its significance and role in railway network:

This railway to be built will connect the railway trunk line from Djibouti to Addis Ababa, which is the main transport corridor for both passenger and freight traffic, and for transport of imported goods from Djibouti Port to the inland. Construction of this railway line will play an active demonstrative and guiding role in building east-west trunk line of East Africa railway network as well as Djibouti and Ethiopian national railway network, and facilitating construction of Ethiopian railway network.

3.6. Result of conversion design of freight traffic volume

1/ Traffic volume of station

The designed freight traffic volume of each station on basis of Draft Final Report of Railway Study and according to distribution of cities and towns along the railway line as well as the relevant plans of Ethiopia is shown in the table attached hereto.

2/ Freight flow density

The designed annual freight flow density of each section is shown in the table below.

Unit: 10^4 t

Table 3.1: Freight Volume Density of Section

Section	*Short term*		*Long term*	
	Up	Down	Up	Down
Sebeta(Addis)~ Bishoftu	583	73	1380	253
Bishoftu ~Mojo	614	82	1418	262
Mojo~Adama	686	92	1570	278
Adama~Metehara	780	108	1693	296
Metehara~Mieso	806	111	1732	301

Note: The short term is by 2025 and the long term is by 2035.

Project years

- Initial stage: 2020;
- Short term: 2025
- Long term: 2035

Table 3.2: Freight Traffic Volume in Typical Year

Section	Distance (km)	**Annual Traffic Volume at Each Section**							
		2020		2025		2035		Maximum Design Freight Traffic Density	
		Up line	Down line	Up line	Down line	Up line	Dow n line	Up line	Down line
Indode ~ Adama	112.3	530	190	780	290	1610	420	1600	500
Adama ~ Awash	131	439	136	697	211	1503	314	1700	500
Awash ~ Dire Dawa	210.5	456	144	775	238	1653	351	1850	550
Dire Dawa ~ Djibouti	287.7	479	148	800	242	1700	358	1900	550

The traffic volume design of this railway line shows that the up direction of freight traffic (i.e. Djibouti Port ~ Addis Ababa) is loaded car direction, which is suitable for the situation of resources and current transport of Ethiopia.[16]

The Methara~Mieso section has the largest freight traffic volume, with 806×10^4t short-term and 1732 $\times10^4$t long-term freight flow density in the section (the freight flow fluctuation factor is 1.3).

Table 3.3: Sectional freight traffic density of the project unit: 10,000 tons

Sections	Direction	2020	2025	2035
Indode~Adama	Up line	410	629	1408
	Downline	142	220	322
Adama~Awash	Up line	439	697	1503
	Downline	136	211	314
Awash Dire Dawa	Up line	456	775	1653
	Downline	144	238	351
Dire Dawa~Djibouti	Up line	479	800	1700
	Downline	148	242	358

The comparative analysis shows that the primary and recent estimated results in the *Revised Feasibility Study Report of ERC* are relatively close to the estimates in the evaluation for Dire Dawa-Djibouti section, which makes the long-term estimated results become relatively more optimistic. According to the estimated results of traffic volume in the *Revised Feasibility Study Report of ERC*, the market share of railway in the long run is nearly close to 2/3. Taking into consideration that ERC and design institute may have a relatively reliable, adequate and accurate understanding to the site condition and the first-hand data, the estimated results in Table 4 are approved in the evaluation. Meanwhile, according to the latest data provided by ERC, and taking into consideration the practical conditions of the relatively dense cities and towns, the relatively developed industry and the relatively strong demands on short and medium-distance passenger and freight transportation along the line of

(III) Mass freight traffic volume

Unit: 10^4 t

Table 3.4: Traffic Volume of Mass Goods

Description	Origin	Destination	Via	Short term	Long term
Petroleum	Djibouti Port	Akaki	Adama	180	250
Foodstuff	Djibouti Port	Akaki	Adama	40	75
Chemical fertilizer	Djibouti Port	Akaki	Adama	30	50
Container	Djibouti Port	Akaki	Adama	100	200

3.7. Freight traffic volume

Table 3.5: Summary of Freight Flow Density and Passenger Train Pairs

Section	Freight Flow Density (10^4 t)				Passenger Trains (Pair)	
	Short term		Long term			
	Up	Down	Up	Down	Short term	Long term
Sebeta(Addis)~Bishoftu	583	73	1380	253	9	16
Bishoftu ~Mojo	614	82	1418	262	9	16
Mojo~Adama	686	92	1570	278	9	16
Adama~Methara	780	108	1693	296	5	8
Methara~Mieso	806	111	1732	301	5	8

Note: The Djibouti ~Addis Ababa is the up direction.

3.8 Carrying capacity and traffic capacity

3.8.1 Locomotive configuration

According to locomotive routing designed for the line and in combination of running data, passenger locomotive employs SS9 electric locomotives (equip them at locomotive repair base of Addis, 6 for initial term, 10 for short term and 16 for long term); freight locomotive employs HXD3B electric locomotive (set at Akaki turnaround depot for stationed locomotive, 14 for initial term, 20 for short term and 36 for long term).

3.8.2. Allocation of rolling stock

Based on the demand on passenger and freight transport.

Table 3.6: The allocation of passenger and freight trains is shown as below after study

	Unit	Initial stage	Short term	Long term
Passenger train	Nr.	41	68	108
Freight train	Nr.	819	1170	2360

Remarks: Only usage amount in initial stage is considered for procurement of rolling stocks; transport demand shall be considered for procurement of rolling stocks in short term and long term.

3.8.3. Design carrying capacity

On the basis of track plan and profile design and selected train locomotive and traction mass, the design carrying capacity of each section in the study years is given in the following Table.

Table 3.7: Year Section Design carrying capacity

Year	Section	Design carrying capacity
Short term	Sebeta(Addis)~Bishoftu	165
	Bishoftu ~Mojo	165
	Mojo~Adama	165
	Adama~Methara	43
	Methara~Mieso	43
Long term	Sebeta(Addis)~Bishoftu	165
	Bishoftu ~Mojo	165
	Mojo~Adama	165
	Adama~Methara	43
	Methara~Mieso	43

3.8.4. Required carrying capacity in the study year

According to the forecast traffic volume, the required carrying capacity in the study year is shown

Table 3.8: Required Carrying Capacity (Unit: pairs/day Table)

Section	Passenger train	Through and district trains	Pick-up and drop train	Subtotal	Required carrying capacity
Short term					
Sebeta(Addis)~Bishoftu	9	8	2	19	39
Bishoftu ~Mojo	9	8	2	19	39
Mojo~Adama	9	9	2	20	40
Adama~Methara	5	10	2	17	24
Long Term					
Sebeta(Addis)~Bishoftu	16	17	2	35	68
Bishoftu ~Mojo	16	17	2	35	68
Mojo~Adama	16	19	2	37	70
Adama~Methara	8	21	2	31	42
Methara~Mieso	8	21	2	31	42

Double locomotive traction is adopted for passenger and freight trains. For short term, traction quality is 3500t and number of cars in a train is 44, while for long term, traction quality is 4000t and number of cars in a train is 50.

Table 3.9: Passenger train pairs and route （unit: pair/day）

S/N	Origin - destination		Type of train	Passenger train pairs （pair）	
				Year 2025	Year 2035
1	Addis	Adama	Express	2	4
2			Fast	2	4
3	Addis	Dire Dawa	Express	2	3
4			Fast	2	2

5	Addis	Djibouti	Express	1	1
6			Fast	1	2
Section total		Addis Ababa - Adama		9	16
		Including express		5	8
		Adama - Dire Dawa		5	8
		Including express		3	4
		Dire Dawa - Djibouti		2	3
		Including express		1	1

3.8.5. Design capacity and phased capacity expansion measures

According to calculations of the above required carrying capacity of passenger and freight trains and the design carrying capacity, adaptation of the design carrying capacity and the required carrying capacity is given in the following Table.

Table 3.10: Adaptation of Design Carrying Capacity and Required Carrying Capacity

Unit: pairs/day Table

Year	Section	Design carrying capacity	Required carrying capacity	Adaptation
Short term	Sebeta(Addis)~Bishoftu	165	39	126
	Bishoftu ~Mojo	165	39	126
	Mojo~Adama	165	40	125
	Adama~Methara	43	24	19
	Methara~Mieso	43	24	19
Long term	Sebeta(Addis)~Bishoftu	165	68	97
	Bishoftu ~Mojo	165	68	97
	Mojo~Adama	165	70	95
	Adama~Methara	43	42	1

It can be seen from the above Table that the design carrying capacity can meet the required carrying capacity of each study year; there is a large margin in the design carrying capacity of double-track areas compared with the required carrying capacity, which is favorable for future operation of more passenger trains between two cities.

If the traffic volume continues to increase in the future after the long term, the capacity expansion measure of additional second line may be taken for Adama~ Mieso to further increase the carrying capacity of the line.

3.9. Required power and power consumption

The required power and power consumption in the railway line are shown below:

Table 3.11: Required power and power consumption

Location of the traction substation	*Annual power consumption required （10^4kWh*		*Annual power required （10^4kW）*			
			Average of the year		*Max load of the year*	
	Short term	Long term	Short term	Long term	Short term	Long term
Sebeta	1715	3196	0.196	0.366	0.343	0.639
Akaki	3347	6238	0.382	0.712	0.669	1.248
Bishoftu	2607	4851	0.298	0.554	0.521	0.97
Mojo	2915	5439	0.333	0.621	0.583	1.088
Wachulalu	2278	4232	0.26	0.483	0.456	0.846
Cheleleka	2873	5352	0.328	0.611	0.575	1.07
Haro	2562	4766	0.292	0.544	0.512	0.953
Ajo tere	2412	4471	0.275	0.51	0.482	0.894
Awashisht	2948	5490	0.337	0.627	0.59	1.098
Adele	3084	5742	0.352	0.655	0.617	1.148
Mieso	1817	3381	0.207	0.386	0.363	0.676

3.10. Ethiopia - Djibouti corridor road transport track trailer

3.10.1. Imported track of the last 19 years

3.10.1.1. Baseline data: Raw Data at Ethiopian Revenues and Customs Authority (ERCA)

Table 3.12: Ethiopian Revenues and Customs Authority (ERCA) data codes

87042200	Goods vehicles, with diesel or semi-diesel engines, GVW 5-20tonnes
87042300	Goods vehicles, with diesel or semi-diesel engines, GVW >20tonnes

Table 3.13: Imported track of the last 19 years (goods vehicles, with diesel or semi-diesel engines, GVW >20tonnes)

Year G.C	Year Ethiopian calendar	Goods vehicles, with diesel or semi-diesel engines, GVW > 20tonnes HS code- 87042300
2016 Oct	2009 Oct.	11
2015	2008	56
2014	2007	13
2013	2006	28
2012	2005	20
2011	2004	34
2010	2003	45
2009	2002	47
2008	2001	10
2007	2000	223
2006	1999	697
2005	1998	109
2004	1997	383
2003	1996	376
2002	1995	201
2001	1994	229
2000 GC	1993 EC	144
1999	1992	305
1998	1991	251
1997	1990	90
	Total	3272

In this raw data to analyze the regression analysis of the variable y. to reduce error separating the data in to two categories.

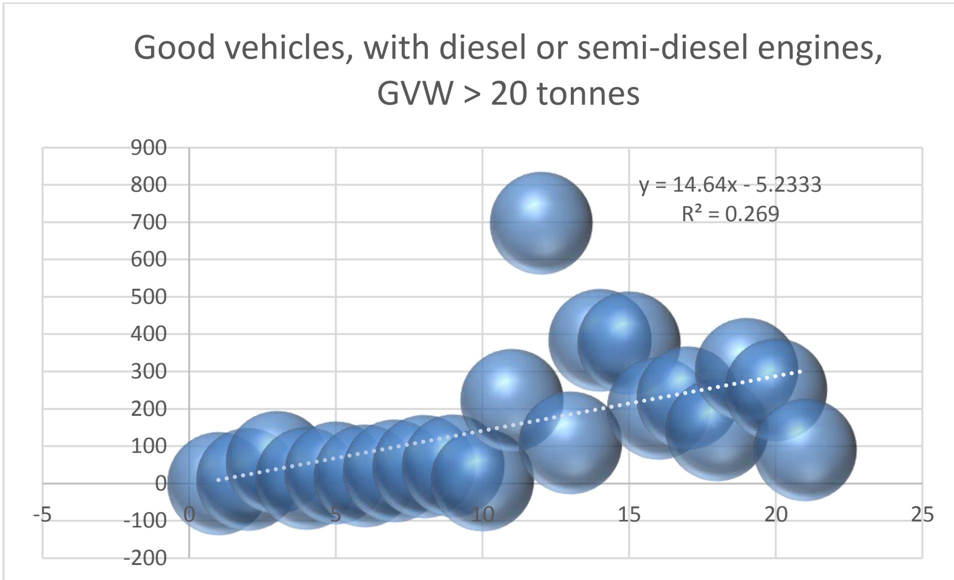


Figure 3.2: Goods vehicles, with diesel or semi-diesel engines, GVW > 20tonnes

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.429829583
R Square	0.18475347
Adjusted R Square	0.133800562
Standard Error	167.307022
Observations	18

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	101496.7	101496.7	3.625965	0.075026
Residual	16	447866.2	27991.64		
Total	17	549362.9			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	29103.71345	15190.53	1.915912	0.073421	-3098.77	61306.1961	-3098.7692	61306.1961
2008	-14.47368421	7.60094	-1.9042	0.075026	-30.587	1.63958781	-30.5869562	1.639587812

Figure 3.3: Regression result of Goods vehicles, with diesel or semi-diesel engines, GVW > 20tonne

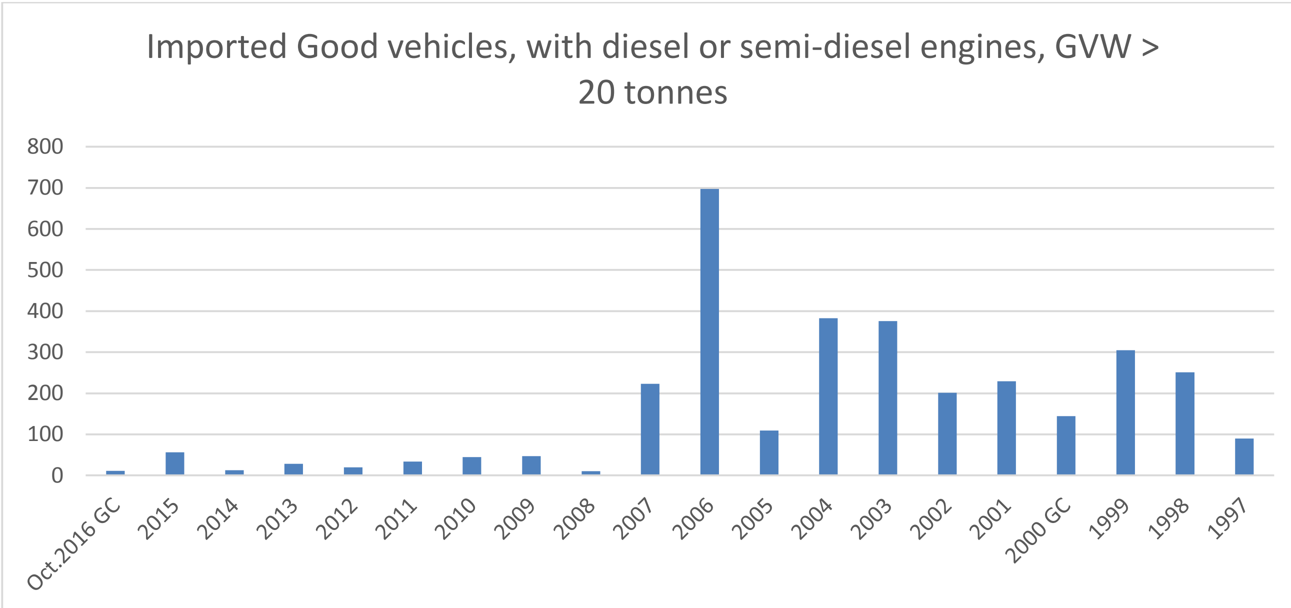


Figure 3.4: Chart result of Goods vehicles, with diesel or semi-diesel engines, GVW > 20tonnes

Table 3.14: Numbers of tracks in the country

	Border crossing operators vehicle number								
Level	Carrying capacity	Year	Associations		Company		Private transport		Car sum
			Number	Car no	No	No	No	Car No	
1ha	30-40	0-10	18	3,666	11	2,113	,,,	,,,	5,779
1le	20-29.9	>> >>	1	127	,,,	,,,	,,,	,,,	127
2 ha	30-40	10-20	13	1,421	,,,	,,,	,,,	,,,	1421
2 le	20-29.9	>> >>	7	985	,,,	,,,	,,,	,,,	985
3ha	30-40	Above 20	9	450	,,,	,,,	,,,	,,,	450
3le	20-29.9		17	1,153	,,,	,,,	,,,	,,,	1,153
4	20-40		,,,,	,,,,	,,,	,,,	15	595	593
Total			65	7,702	11	2,113	15	595	10,510

Data from transport office

A transport operator’s model from Ethiopian shipping and logistic enterprise.

Baseline: Ethiopian Shipping and Logistic Transport Service Enterprise Kality branch Department Heavy Duty Fright Transport Vehicle Data

Figure 3.5: Ethiopian shipping and logistic transport service enterprise Kality branch department heavy duty fright transport vehicle

The total number of trucks, model, type of trucks, fuel consumption, engine data and other important data's. This are important to calculate the emission from the replaced trucks.

Figure 3.6: Ethiopian shipping and logistic transport service enterprise Kality branch department heavy duty fright transport vehicle maintenance workshop

Table 3.15: Ethiopian shipping and logistic transport service enterprise Kality branch department heavy duty fright transport vehicle data

Type of track	IVECO	SINO TRUCK	SCANIA	RENAULT	MACK	
Model	Iveco 260E37 Eurotrakker	ZZ4257S3241V	9BSP6X4 0003589036	KERAX Dxi 1.3	Mack	
Manufactured year	1999	2008		2008	1995	
Engine output	272 hp	371 hp	360 hp	380 hp	190 hp	
In kw	199.41 KW	Maximum output: 371 hp (272 Kw) at 2200 rpm	263KW	278KW	141.68 KW	
In watt		272,000w				
Carrying capacity in ton	20-37 ton	Load Capacity: 20-40t	20-37 ton	20-51 ton	28 ton	
Carrying capacity in kg	37,000 kg	41,000-50,000 kg	37,000 kg	51,000 kg	21,000 kg	
Fuel type		Diesel				
Fuel consumption For Nazret-Djibouti	*50%L.F*	*50%L.F*	*50%L.F*	*50%L.F*	*50%L.F*	
	875	760	800	800		Assigned
	586	540 li loaded	536	536		Loaded
	289	220li loaded	264	264		Empty
	100%L.F	*100%L.F*	*100%L.F*	*100%L.F*	*100%L.F*	*Load Factor*
	1013	903 li	983	983		Assigned
	679	646 lit loaded	659	659		Loaded
	334	262 li empty	234	234		Empty
Fuel consumption For Adis Abeba-Djibouti. 756 * 2 =1512 km	*50%L.F*	*50%L.F*	*50%L.F*	*50%L.F*	*50%L.F*	*Load Factor*
	974	850 lit	890	890		Assigned

rich and back	653	604lit loaded	596	596		Loaded
	321	246lit empty	294	294		Empty
	100%L.F	*100%L.F*	*100%L.F*	*100%L.F*	*100%L. F*	
	1132	1010 li	1090	1090		Assigned
	758	717 li loaded	730	730	532	Loaded
	374	293 li empty	360	360	266	Empty
Vehicle Weight	GVW 28,000 kg	GVW in kg 33000	GVW>2 8,000 kg	GVW in kg 33000		
Fuel consumption (l/100 km)	50 liter	35 liter	48 liter	48 liter	35.18 liter	
Specific fuel consumption:		195 g/kWh				
Emission Standard:		Euro 2				

Figure 3.7: Ethiopian shipping and logistic transport service enterprise Kality branch department heavy duty car carrier

Oil consumption of the trucks

Table 3.16: Shows different type of oil, lubricants and batteries and its changing interval

Parts	TYPE	Changed	Amount (in liter)					
			Sino	Mack	Renault	Iveco	Scania	
Engine oil Emission factor -	TOTAL ***15W 40***	Every 15,000km	25 lit	33 lit	37 lit	29 lit	35 lit	
Gear box Oil	TOTAL transmission oil ***TM80W90***	Every 60,000 km	13 lit	13 lit	13 lit	13 lit	13 lit	
Differential oil	TOTAL Transmission Oil ***TM85W140***	Every 60,000km	26 lit	26 lit	35 lit	26 lit	26 lit	
Hydraulic parts oil	***10ATF*** OR AZOLLA ZS688	Fill when it get reduced	2 lit	2 lit	2 lit	2 lit	2 lit	

Brake fluid(oil)	DOT3/DOT4	Fill when it get reduced	2 lit	2 lit	2 lit	2 lit	2 lit	
Joints (Lubricating grease)	Mult IS EP2 or EP3 multi grade	Every 5,000 km	For all 2 kg 					
Battry(2)	98+-0.5% H_2SO_4	Every 10,000km	48 lit for all 					

Figure 3.8: Shows different type of oil, lubricants and batteries

3.11. Average daily road traffic data from Addis Abeba to Meiso truck and truck trailer

3.11.1. Trucks and truck trailer

Table 3.17: Fright Trucks (GVW <= 20 ton) Average daily traffic Adiis Ababa to Meiso

Section	2007EC	2008EC	2009EC	2010EC	2011EC	2012EC	2013EC	2014 EC	2015 EC
A.A-Akaki	4512	5801	6807	7465	11461	9206	9,337	6,254	2,983
Akaki-D/z	4792	5862	6779	7441	11225	8944	9,951	5,732	4,227
D/z- Naz	4119	3465	5193	6049	7849	6819	7,464	5,939	4,899
Naz-Awa	749	803	1066	1050	1175	1636	1,958	2,368	2,460
Awa-Mieso	325	339	633	383	402	239	379	365	372

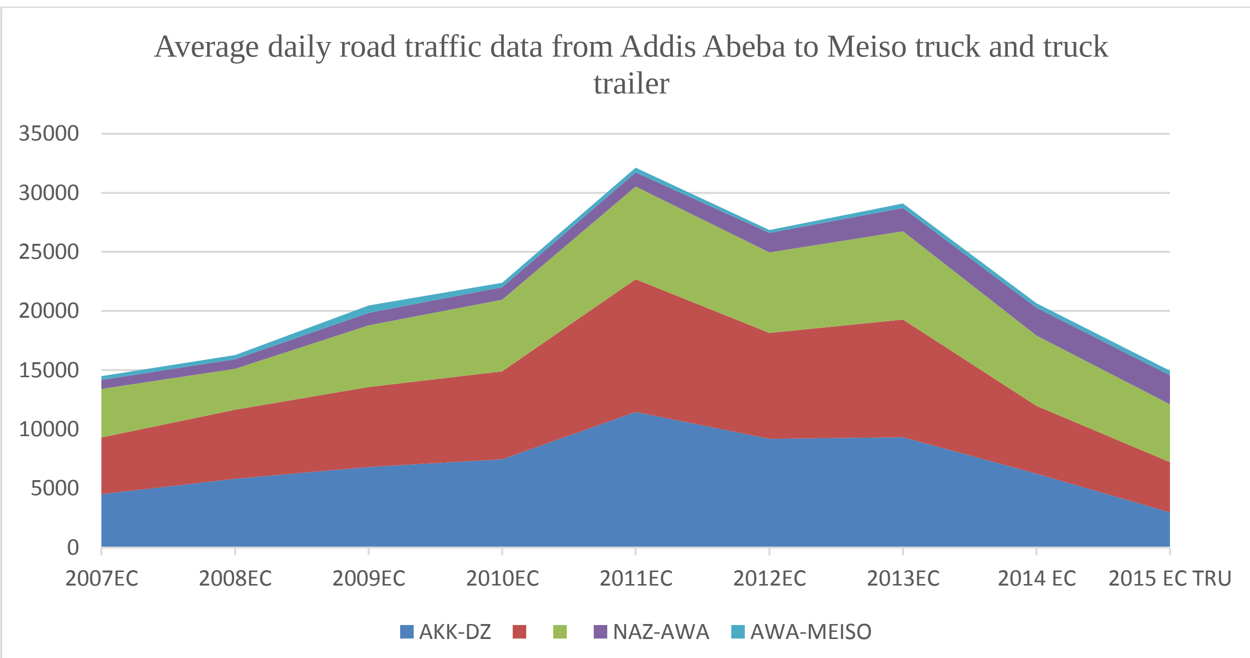


Figure 3.9 Chart shows average daily road traffic data from Addis Abeba to Meiso truck and truck trailer

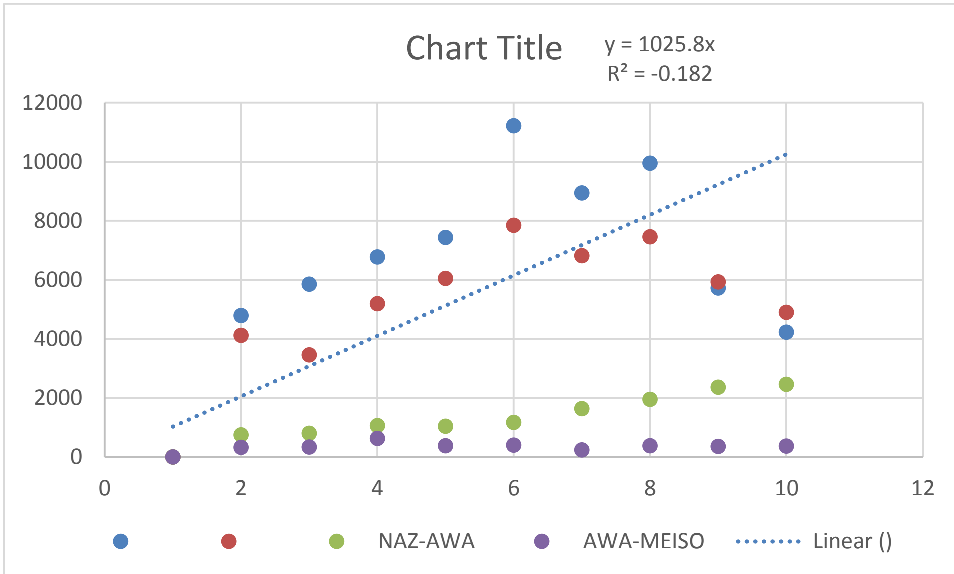


Figure 3.10: Scatter diagram shows average daily road traffic data from Addis Abeba to Meiso truck and truck trailer

Table 3.18: Fright Truck Trailers (GVW > 20 ton) Average daily traffic Addis Ababa to Meiso

Section	2007EC	2008EC	2009EC	2010EC	2011EC	2012EC	2013EC	2014 EC	2015 EC
A.A-Akaki	2361	2259	2451	2564	4141	3624	3,773	2,315	1,069
Akaki-D/z	2583	2298	2486	2642	4042	3559	4,015	2,461	1,256
D/z-Naz	1738	1818	2146	2372	3365	3093	3,256	2,573	2,430
Naz-Awa	1000	1007	1584	1248	1319	1620	1,354	1,484	1,781
Awa-Mieso	222	76	387	95	112	140	155	112	89

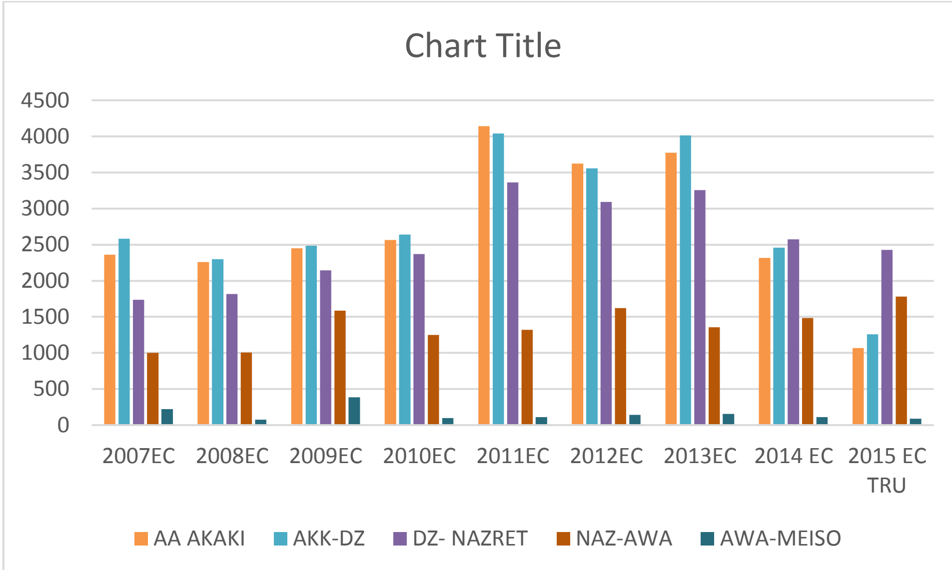


Figure 3.11: Bar chart shows average daily road traffic data from Addis Abeba to Meiso truck and truck trailer

3.12. Emissions

3.12.1. CO_2 equivalents

Figure 3.12: CO_2 Emission from industries

3.12.2. Difference between CO_2 and CO_2e

Carbon dioxide, or CO_2, is a natural, colorless and odorless greenhouse gas that is emitted when fossil fuels (i.e. natural gas, oil, coal etc.) are burnt.

It is the most prevalent greenhouse gas after water vapor and has therefore become the proxy by which we measure greenhouse gas emissions.

However, carbon dioxide is only one of many greenhouse gases that are emitted when humans undertake certain activities. Other greenhouse gases are methane, nitrous oxide and ozone – all of which occur naturally in our atmosphere.

To take into account the emission of other greenhouse gases when calculating the level of greenhouse gas emissions, scientists have devised an equivalent measure – CO_2e (which literally means carbon dioxide equivalent).

CO_2e allows other greenhouse gas emissions to be expressed in terms of CO_2 based on their relative global warming potential (GWP).

CO_2 has a GWP of 1, methane has a GWP of approximately 25 (on a 100-year time horizon). In other words, for every 1 ton of methane (CH_4) emitted, an equivalent of 25 tons of CO_2 would be emitted.

Each greenhouse gas (GHG) has a different global warming potential (GWP) and persists for a different length of time in the atmosphere.

The three main greenhouse gases (along with water vapor) and their 100-year global warming potential (GWP) compared to carbon dioxide are:

1 x – carbon dioxide (CO_2)

25 x – methane (CH_4) – I.e. Releasing 1 kg of CH_4 into the atmosphere is about equivalent to releasing 25 kg of CO_2

298 x – nitrous oxide (N_2O) – I.e. Releasing 1 kg of N_2O into the atmosphere is about equivalent to releasing 298 kg of CO_2.

Water vapor is not considered to be a cause of man-made global warming because it does not persist in the atmosphere for more than a few days.

There are other greenhouse gases which have far greater global warming potential (GWP) but are much less prevalent. These are Sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs).

There are a wide variety of uses for SF6, HFCs, and PFCs but they have been most commonly used as refrigerants and for fire suppression. Many of these compounds also have a depleting effect on ozone in the upper atmosphere.

3.14. Global Warming Potential (GWP)

The following table shows the 100-year global warming potential for greenhouse gases reported by the United Nations Framework Convention on Climate Change (UNFCCC).

How to read this table?

The column on the right shows how much that chemical would warm the earth over a 100-year period as compared to carbon dioxide.

For example, Sulphur hexafluoride is used to fill tennis balls. The table shows that a release on 1 kg of this gas is equivalent to 22,800 kg or 22.8 tons of CO_2. Therefore, releasing one kilogram of Sulphur hexafluoride is about equivalent to driving 5 cars for a year!

Table 3.12: Global Warming Potential (GWP)

Greenhouse Gas	Formula	100-year GWP (AR4)
Carbon dioxide	CO_2	1
Methane	CH_4	25
Nitrous oxide	N_2O	298
Sulphur hexafluoride	SF_6	22,800
Hydrofluorocarbon 23	CHF_3	14,800
Hydrofluorocarbon-32	CH_2F_2	675
Perfluoromethane	CF_4	7,390
Perfluoroethane	C_2F_6	12,200
Perfluoropropane	C_3F_8	8,830
Perfluorobutane	C_4F_{10}	8,860
Perfluorocyclobutane	c-C_4F_8	10,300
Perfluoropentane	C_5F_{12}	13,300
Perfluorohexane	C_6F_{14}	9,300

Chapter 4

4.1. Research Methodology

4.1.1. Research design

This research work is quantitative studies type used a logical and data-led approach to achieve objectives, which is based on previously performed, feasibility studied data's, surveys and research journals, all the parameters that will be used in this research design work is from rail and road transport standard specification.

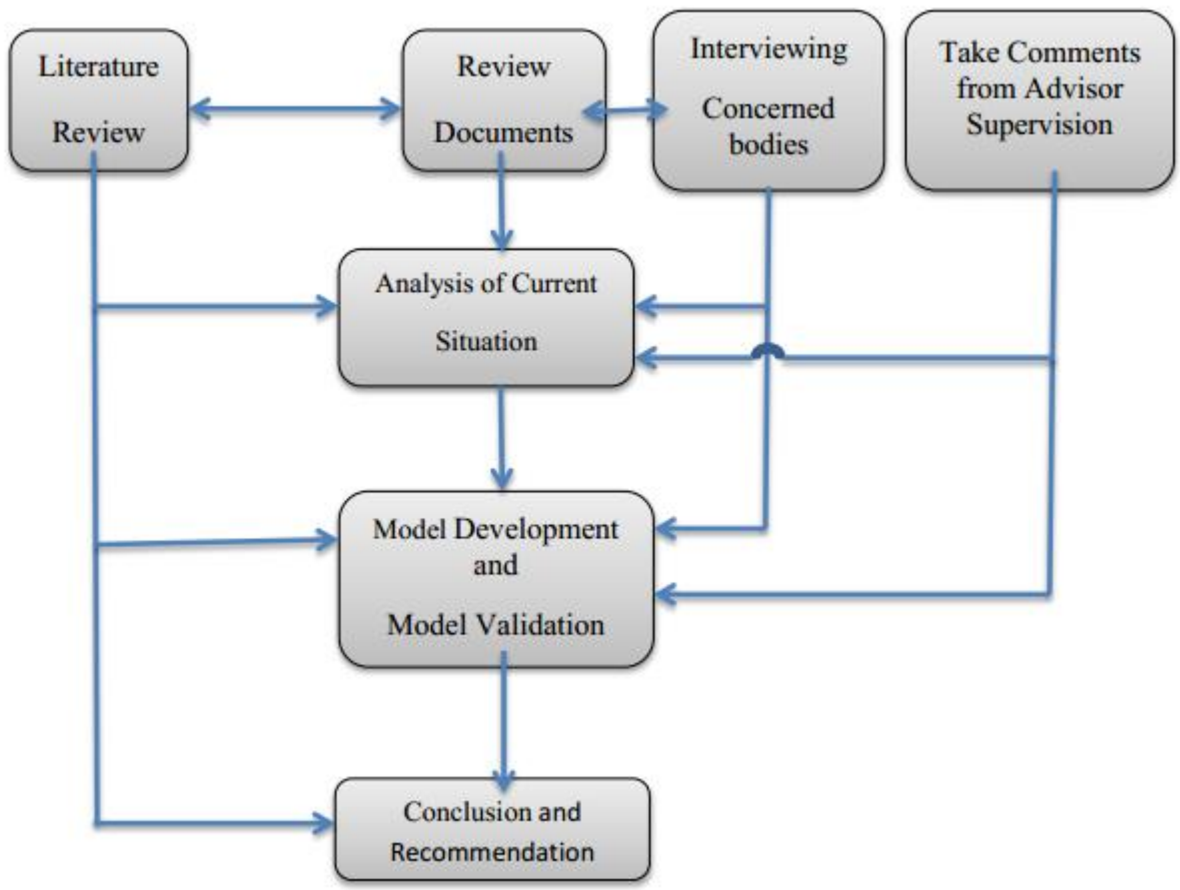


Figure 4.1: Research design

4.1.2. Research area

This research shall address the impact of electric train transportation on emission reduction in the case of Addis Ababa-Djibouti Electric Railway line.

The scope of this work is analyzing different parameter from transport related to CO_2 reduction and energy projects, modal shift effect analyses, data, methods, procedures and evaluation techniques will use to analysis the Addis Ababa-Djibouti railway line projects. Even though Ethiopia has now working on renewable energy choice like hydroelectric power project, wind power projects, planned 5000 km electric rail way lines and other projects, this paper tries to use for finding out CO_2e emission reduction contribution from transport of Addis Ababa-Djibouti Electric Railway line. And this have a great impact for keeping global environment safe.

4.1.3. Data collection

The basic data used in the research is Secondary data of prominent and big data sources of the nation and international organizations like: Central Statistical Agency (CSA), Ethiopian Custom and Revenue Authority, Ethiopian Roads Authority (ERA) Ethio-Djibouti Railway, Ethiopian Railway Corporation (ERC) (specification data, Climate and finance Strategic Document. and operational data results.), Ethiopian Petroleum Supply Enterprise (EPSE), World Bank and Others. Tertiary data is used from WT-Consultant, and CREGC and CREEC. Primary data collection was not considered since it would require a large volume of data involving huge amount of finance, time and expertise. In addition, from internet, electric train and road transport CO2 emission reduction related scientific journals, articles. Different electric train and road transport CO2 emission reduction related books

4.1.4. Descriptions of model and issues of reliability and validity

This paper is tries to present and apply a procedure to estimate the energy and CO_2 emissions avoided due to the implementation of freight rail systems, using the mode shift effect. This procedure is different from others in several aspects: (a) it considers the electric rail system individually, not the public and fright transportation system as whole, enabling it to be compared with the other private or public transportation systems, such as fright transporter; (b) it uses the real transport profile of the studied region, according to its vehicle fleet; and (c) it considers the vehicles and their fuels, removing from the emission calculations the amount of renewable fuels, used exclusively or in blends with fossil fuels consumption is collected from an existing transporter data and the track trailer vehicle drivers.—a reality which has been stimulated in Ethiopian and Djibouti by government policies. The procedure was applied to the Ethio-Djibouti Line, which is the 756 km long fully electrified railway.

4.1.5. Method of analysis

4.1.5.1. Input data

On this research work the input data is the data which is previously analyzed, interpret and mathematically modeled of collected data used to give the required output parameters.

4.2 Modeling

The model considers the following elements:

(a) Debit: The emission produced by the generation of electricity (≈0% it is hydroelectric power generation) used by the freight rail system. This energy will be counted as saved energy in KWh There are two alternatives: considering the value of all the electricity consumed in the operation of the system or only the electric traction energy, responsible for the movement of the trains. Electric traction energy usually ranges from 65% to 75% of total electric energy.

(b) Credit: The emission avoided by the system, which can be divided into the following.

(1) Mode shift, which represents the gains achieved by the fact that users of track trailer fright transport causing higher emissions shift their transport mode of choice and use the railway system, leading to fewer trips with these higher-emission vehicles.

But in fright transport this Land use and Congestion relief counted as zero. It is valuable in case of passenger transport on the city.

(2) Congestion relief (≈0%), which represents the gains obtained by less traffic congestion due to the smaller number of vehicles on the streets, leading to better fuel performance by the vehicles still in traffic.

(3) Land use (≈0%), which represents the gains obtained by a higher population density. In this situation, people need shorter trips and use fewer cars. The use of bicycles and walking is increased since they can complement rail trips. But in fright transport this land use counted as zero. It is valuable in case of passenger transport on the city.

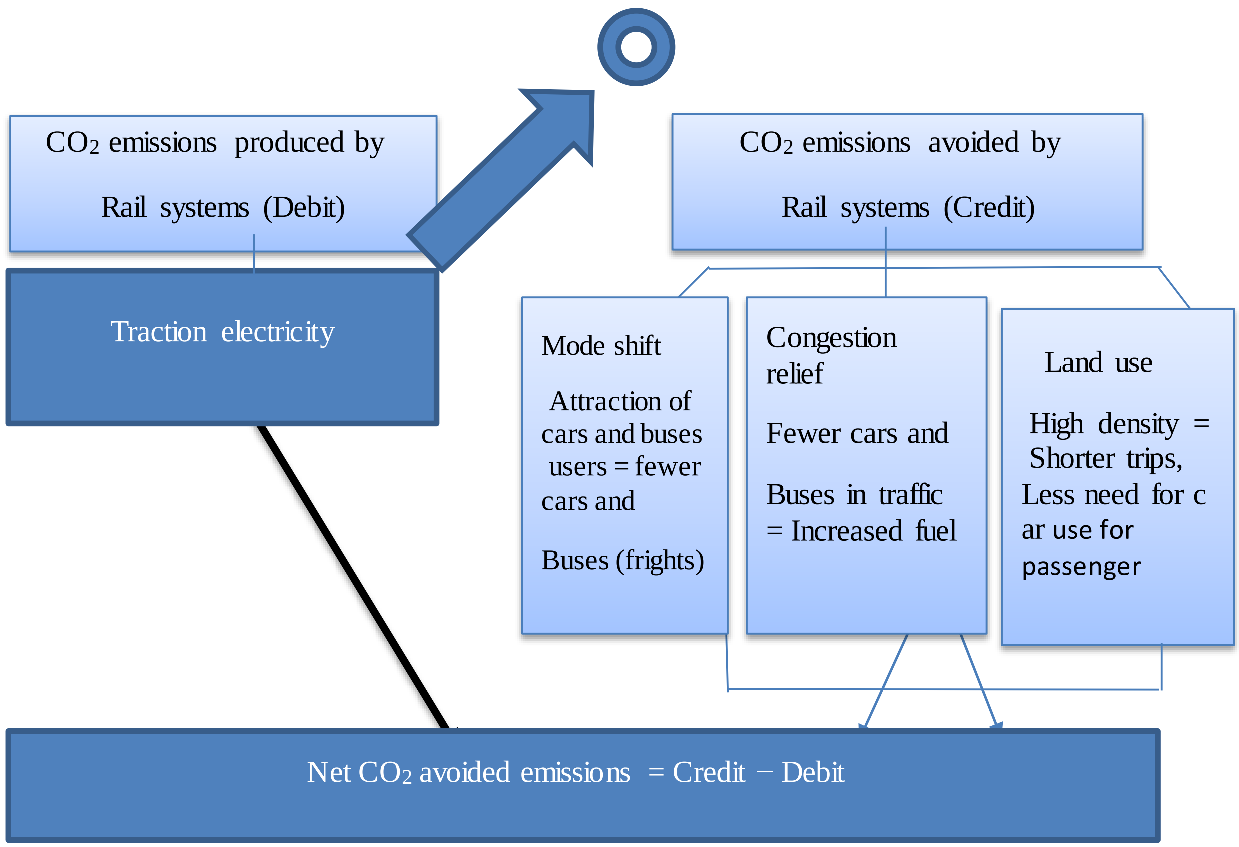


Figure 4.2: Impacts of a freight rail system on CO_2 emissions [4]

Baseline: Raw Data from ERC

It's new "clean, safe and affordable" transport policy which favors the development of such railway project.

The Addis-Djibouti railway will enable Ethiopia easy access to the port of Djibouti providing both passenger and freight service transporting 3,500 tons of goods at a time.

There is already more than adequate traffic of over 9Mn MT a year and growing fast

The railway will have 17 major stations and passes through major cities including Bishoftu, Adama, Metehara and Dire Dawa.

Addis-Djibouti electrified railway, a priority project within the GTP, is expected to reduce the travel time from Addis Ababa to Djibouti by half to less than ten hours with a designated speed of 80 km/hour.

Freight trains shall adopt electric-power dual-locomotive traction, with a traction mass of 3500t.

1/ Type of traction

The installed power capacity will be increased to 2.54 million kW in 2012 and to 7.75million kW in 2015.

2/ Type of locomotive

Based on the feasibility study of Ethiopia/Sebeta-Djibouti/Nagad Railway DC locomotives (SS9, SS4) or AC locomotives (HXD3C, HXD3B) will be used for the line.SS9 is suggested to be used as passenger locomotive and SS4 is used for freight locomotive. [16]

3/ Transportation price rate

Due to the lacking of market investigation for freight price of Ethiopian roads and railways, the evaluation follows the condition of Ethiopian Railway cooperation and the local fact, the financial evaluation is calculated at basic freight price of 0.046 USD/ton-km and basic passenger price of 0.023 USD /ton-km.

Distance from Addis Ababa to Djibouti

Distance between Addis Ababa and Djibouti is **559 kilometers** (347) miles (on airplane)

Driving distance from Addis Ababa to Djibouti is **770.4 kilometers** (479) miles (on road)

Distance between Addis Ababa to Djibouti is **756 kilometers** (470) miles (rail way line)

4/ The Ethiopian fright track trailers are many of them are used vehicles from other country. Because their manufacturing age is old. Many of them greater than 15 years. Their engine efficiency and emission factor also increased.

4.3. Required power and power consumption

The required power and power consumption in the railway line are shown below:

Table 4.1: Required power and power consumption. [16]

Location of traction substation	Annual power consumption (10^4kWh)		
	Initial stage	Short term	Long term
Sebeta	1018	1653	3053
Indodo	2188	3556	6565
Bishoftu	1577	2563	4732
Mojo	2595	2592	4785
Meroe	1639	2576	4683
Senga beret	2396	3765	6846
Metra	1506	2366	4302
Awash	1290	2211	3869
Sirbakunkur	1805	3095	3522
Ak313	-	-	3788
Mieiso	2101	3603	4410

The raw data used above found from final evaluation report of the feasibility study of the ERC which the document prepared and evaluated by China International Engineering Consulting Corporation, September 2012. [16]

Double locomotive traction is adopted for passenger and freight trains. For short term, traction quality is 3500t and number of cars in a train is 44, while for long term, traction quality is 4000t and number of cars in a train is 50.

Ethio -Djibouti Line, which is the 756 km long fully electrified railway.

1 kWh = 1 E3 watt-hour = 1.34 horsepower-hour = 3413 Btu = 2.655 E6 foot pounds = 3.60 E6 Joules = 8.60 E5 calories (gram-calories)

Gasoline: 1 gal gasoline (mid-grade) = 125,000 Btu

Unit’s volume 1 gallon =3.7854 litter

Distance 1mile =1.609km

Table 4.2: Road daily traffic roots of 2015 GC Ethiopian Djibouti data from Ethiopian road Authority.[17]

NO	Route name		Length	Cars buses		Truck	Trailler total	
1	Addis ababa	Akaki	24	897	1,718	2,983	1,069	6,667
2	Akaki	D/zeit	32	1,904	2,404	4,227	1,256	9,791
3	D/zeit	Nazreth	51	2,134	3,355	4,899	2,430	12,818
4	Nazreth	Awash	125	904	1,299	2,460	1,781	6,444
5	Awash st.	Mieso	74	185	254	372	89	900
6	Mieso	Asebetef	24	163	223	297	80	763
7	Asebeteferi	Kobo	111	161	299	401	121	982
8	Kobo	Kulubi	27	118	323	330	107	878
9	Kulubi	Dengego	31	206	601	1,040	302	2,149
10	Dengego	Diredew	20	223	612	1,061	286	2,182
11	Deri dawa	Dewele	224	114	84	372	107	677
		Total km	743					

4.4. Software

Micro-Soft Excel and the GREET LIFE CYCLE MODEL computer program was used for the calibration computation and development of the life cycle emission model from the replaced motor vehicle truck and emission calculation.

4.5. Analysis

The study contains variables which assumed to have a determining role in transport system i.e the ton km and in the study calibration and developments. This incorporated variable of: transport in respect of import export and local trade; loads in terms of annual freight volumes; time in terms of travel.

4.5.1. Sectional freight traffic density of the project unit: 10,000 tons

Table 4.3: Sectional Freight Traffic Density of the Project Unit: 10,000 tons

Sections	km	Direction	2020	2025	2035
Indode~Adama	96	Upline	410	629	1408
		Downline	142	220	322
Adama~Awash	130	Upline	439	697	1503
		Downline	136	211	314
Awash~Dire Dawa	232	Upline	456	775	1653
		Downline	144	238	351
Dire Dawa~Djibouti	318.46	Upline	479	800	1700
		Downline	148	242	358

Data from: ERC final evaluation report of the feasibility study Document prepared and evaluated by *China International Engineering Consulting Corporation, September 2012. [5]*

4.5.2. Ton kilometer

1. Estimate the transport performance of Addis Djibouti in TON KM. This is related to the railway line capacity of attracting users. The greater the number of users, the greater will be the amount of TON KM. Each user will travel from an origin (a rail station) to a destination (another rail station). For a given origin–destination (O–D) pair, TON KM will be obtained by multiplying the number of users traveling by the distance between this O–D pair. Thus, for a given time period, total TON KM can be expressed by the summation of TON KM of all O–D pairs:

$$\text{Ton KM} = \sum_{\substack{i=1 \\ j=1}}^{n} (Pij * dij) \qquad \text{.....} (1)$$

Where P_{ij} is the number of ton traveling from an origin i to a destination j and d_{ij} is the distance between origin i and destination j

4.5.3. Calculate energy and CO2 emission debit. This is a function of train scheduling and load.

The train load affects the train weight. In a given time period, the greater the train load or the number of train departures, the greater will be the amount of electricity consumed. A train usually consists of a number of individual parts (cars). Each car has a consumption value for electricity depending on its fright load. Consideration is only given to the traction electricity with transmission and losses. The emission factor is given by the Ethiopian government, since the electricity network is nationally integrated. In this way, for a given time period, energy can be estimated by:

$$En = c \times Ec \qquad (2)$$

Where En is the Energy consumption; c is the number of car-km and Ec is the Energy consumption per car-km.

The number of car-km can be expressed as:

$$c = d \times l \times n \qquad (3)$$

Where c is the number of car-km; d is the number of train departures; l is the distance traveled per departure and n is the number of cars per train. CO2 emissions can be expressed by:

Here for calculating energy there are two alternatives: considering the value of all the electricity consumed in the operation of the system or only the electric traction energy, responsible for the movement of the trains. Electric traction energy usually ranges from 65% to 75% of total electric energy.

To take more reliable and accurate estimation, in this paper used by considering the value of all the electricity consumed in the operation of the system. Take the power consumption plan of the project year from the feasibility study. It is needed to compare electric energy consumption with the fuel energy.

$$Em = En \times Ef \qquad (4)$$

Where Em is the CO2 emissions; En is the Energy consumption as per Equation and Ef is the CO2emission factor per unit of energy.

Example -Sebeta Mieso (short term) (electric power in kWh) = $\sum_{sebta}^{Mieso} 1018 + 2188 + 1577 \ldots + 1001 + 2101$

$= 19116 \times 10^4$ kWh

[1J= 3600000*KWH]

Table 4.4: Sebeta Meiso annual power consumption (kWh)

	Electric power consumption			
	KWHE4	KWH	to J	Energy (J)
Short term annual total	**19116**	191160000	3600000	6.881760E+14
Mid-term annual total	48550	485500000	3600000	1.747800E+15
Long term annual total	50555	505550000	3600000	1.819980E+15

Table 4.5: Sebeta - Meiso annual power consumption (kWh)

Location of traction	Annual power consumption (10^4kWh)		
substation	Initial stage	Short term	Long term
Sebeta	1018	1653	3053
Indodo	2188	3556	6565
Bishoftu	1577	2563	4732
Mojo	2595	2592	4785
Meroe	1639	2576	4683
Senga beret	2396	3765	6846
Metra	1506	2366	4302
Awash	1290	2211	3869
Sirbakunkur	1805	3095	3522
Ak313	1001	20570	3788
Mieiso	2101	3603	4410
TOTAL From Sebta to Mieso	19116	48550	50555

Note: the annual average load utilization hour is calculated as 8760h.

[1KWH =0.000000278*Joule]

[1 kWh = 1 E3 watt-hour = 1.34 horsepower-hour = 3413 Btu = = 3.60 E6 Joules = 8.60 E5 calories (gram-calories)]

Table 4.6: Annual and total project year (2017-2035) power consumptions from electricity

Annual Electric power consumption						
	KWHE4	KWH	Energy (J)	PROJECT YEAR	Total kwh	Total (Joule)
Short term annual total	19116	191160000	6.881760E+14	2017-2020	7.646400E+08	2.752704E+15
Midterm annual total	48550	485500000	1.747800E+15	2021-2025	1.942000E+09	8.739000E+15
Long term annual total	50555	505550000	1.819980E+15	2026-2035	2.022200E+09	1.819980E+16
Total					4.7288400E+09	2.969150E+16

Route Section 1 Indode ~ Adama*)* Distance (96km)

Annual dispatched fright in ton

Annual Dispatched fright ton (unit: 10^4 TON) = 522

(Up line + down line) ton = 5,220,000 (Annual Dispatched tons)

Ton KM = (5,220,000 ton * 96km)

= 501,120,000-ton km

4.5.4. Fuel per ton km

Equation 2- Fuel consumptions per ton km

Table 4.7: Different truck types fuel consumption per ton km

Truck trailer type	***Average load (ton) (T)***	***Distance 754 × 2(km) (D)***	***Fuel consumption (litter) Data from*** the Ethiopian shipping and logistic service fuel consumption data.) *(Mb)*
IVECO	40	1508	730
SCANIA	40	1508	714
SINO TRUCK	40	1508	730
RENAULT	40	1508	758
			Average 733.75 lit

Fuel consumption of the track trailer (GVW>20ton)

To get the estimated fuel consumption of track trailers, in this paper diesel fuel consumption of data sheet of transporter (the Ethiopian shipping and logistic service fuel consumption data.) is used.

D = Distance of the baseline trip route (km) and reverse trip

Average Fuel consumption per km (loading 40 ton): $\frac{Mb}{D}$

$$= \frac{fuel\ used}{distance\ travilled} \quad \text{.......... (5)}$$

$$= \frac{733.75\ litter}{1508\ km}$$

Average Fuel consumption per km (loading 40 ton is) = $0.4865671\ lit/km$

Fuel consumption per truck (loading 40 ton is $0.4865671\ lit/km$)

$$\boldsymbol{Fuel\ consumption\ per\ one\ ton\ of\ fright} = \frac{0.4865671\ lit/km}{40\ ton} \quad \text{.......... (6)}$$

$$= \frac{\cong 0.5\ lit/km}{40\ ton} = 0.0125 \frac{lit}{ton\ km}$$

Example - Indode~Adama

Ton km = 393600000

Fuel per ton km $= 0.0125 \frac{lit}{ton\ km}$

$$\boldsymbol{Total\ fuel\ (Q_f) = 393600000\ \text{tonkm} \times 0.0125 \frac{lit}{ton\ km}} \quad \text{.......... (7)}$$

$$Q_f = 4920000\ liters$$

$$En = Q_f \times E_d$$

Where Q_f is the quantity of fuel, as in Equation (6), and E_d is the energy density per unit of fuel.

The corresponding CO2 emission is:

$$\boldsymbol{E_n = Q_f \times E_f} \quad \text{.......... (8)}$$

Where Q_f is the quantity of fuel, as in Equation (8), and E_f is the CO_2 emission factor per unit of fuel

4.5.3.1. Short term (2020) annual ton km and Fuel Ethiopia – Djibouti

Table 4.8: Short term (2020) annual ton km and fuel Ethiopia – Djibouti

Sections	km	Direction	Ton 2020	Ton km	Fuel(liter)
Indode~Adama	96	Up line	4100000	393600000	4920000
		Downline	1420000	136320000	1704000
Adama~Awash	130	Up line	4390000	570700000	7133750
		Downline	1360000	176800000	2210000
Awash ~Dire Dawa	232	Up line	4560000	1.058E+09	13224000
		Downline	1440000	334080000	4176000
Dire Dawa~Djibouti	318.46	Up line	4790000	1.525E+09	19067793
		Downline	1480000	471320800	5891510

4.6. Emission

Equation to calculate emission from fuel

$$\boldsymbol{Emission(kgCO2e) = fuel\ consumed(liter) \times emission\ factor(\frac{kgCO2e}{liter})} \text{ .... (9)}$$

<u>Example - Indode~Adama</u>

Fuel = $4920000\ liters$

Emission factor = per litter it releases Emissions from fuel: – Diesel: 2.67 kg CO2e/liter – Gasoline: 2.42 kg CO_2e/liter (Federal Democratic Republic of Ethiopia, 2011 CRGE report).

$$\boldsymbol{Emission(kgCO2e) = 4920000\ liter \times 2.67(\frac{kgCO2e}{liter})}$$

$$\boldsymbol{= 13136400\ \text{kgCO2e}}$$

4.6.1. CO2e from all section in the short term (2020)

Table 4.9: Shows annual CO2e from all section in the short term (2020)

Sections	km	Direction	Ton	Ton km	Fuel liter	Emission *2.67*kg CO2e/liter
Indode~Adama	96	Up line	4100000	393600000	4920000	11900315.88
		Downline	1420000	136320000	1704000	4121572.817
Adama~Awash	130	Up line	4390000	570700000	7133750	17254853.33
		Downline	1360000	176800000	2210000	5345467.092
Awash~Dire Dawa	232	Up line	4560000	1.058E+09	13224000	31988145.83
		Downline	1440000	334080000	4176000	10100755.92
Dire Dawa~Djibouti	318.46	Up line	4790000	1.525E+09	19067793	46107677.12
		Downline	1480000	471320800	5891510	14250168.7

	Km	Ton	Ton km	Fuel liter	Emission
Total	776.46	23540000	4.666E+09	58327053	141068956.7

Saved total emission from fuel only is 155,733,231.5 kgCO2e.

155,733,231.5 kgCO2e = 155,733.2315 tonCO2e. = 0.1557332315 Million ton

The emission from hydroelectric power generation subtracted in the life cycle analysis. Hence the value will reduce when we subtract from total emission.

4.6.2. Midterm annual (2025) ton km and fuel and emission Ethiopia – Djibouti

Table 4.10: Midterm (2025) ton km and fuel and emission Ethiopia – Djibouti

Sections	Distance km	**Fright Volume(ton) 2025**	**TON KM 2025**	**LIT/TON KM**	**Fuel in liter 2025**	**Emission Factor**	***Emission 2025 KGCO₂e***
Indode~Adama	96	6290000	603840000	0.0125	7548000	2.67	**18256826**
		2200000	211200000	0.0125	2640000	2.67	**6385535**
Adama~Awash	130	6970000	906100000	0.0125	11326250	2.67	**27395519**
		2110000	274300000	0.0125	3428750	2.67	**8293335**
Awash~Dire dawa	232	7750000	1.798E+09	0.0125	22475000	2.67	**54361707**
		2380000	552160000	0.0125	6902000	2.67	**16694305**
Diredawa ~Djibouti	318.46	8000000	2.548E+09	0.0125	31846000	2.67	**77037614**
		2420000	770673200	0.0125	9633415	2.67	**23300952**
Total		38120000	7.664E+09		95799415		**2.32E+08**

4.6.3. Long term (2035) annual ton km and fuel and emission Ethiopia – Djibouti

Table 4.11: Long-term (2035) annual ton km and fuel and emission Ethiopia – Djibouti

Sections		**2035**	**TON KM 2035**	**LIT/ TON KM**	**2035**	**EMISSION FACTOR**	**2035 EMISSION KGCO$_2$e**
	Km						
Indode~Adama	96	14080000	1351680000	0.0125	16896000	2.67	**40867426**
		3220000	309120000	0.0125	3864000	2.67	**9346102**
Adama~Awash	130	15030000	1953900000	0.0125	24423750	2.67	**59075272**
		3140000	408200000	0.0125	5102500	2.67	**12341740**
Awash~Dire Dawa	232	16530000	3834960000	0.0125	47937000	2.67	**1.16E+08**
		3510000	814320000	0.0125	10179000	2.67	**24620593**
Dire Dawa~Djibouti	318.46	17000000	5413820000	0.0125	67672750	2.67	**1.64E+08**
		3580000	1140086800	0.0125	14251085	2.67	**34470003**
Total		76090000	1.5226E+10		1.9E+08		**4.6E+08**

4.6.4. Annual fuel consumption and emission of the three terms (2020), (2025) and (2035)

Table 4.12: Annual fuel consumption and emission of the three terms (2020), (2025) and (2035)

	Km	Ton	Ton km	Fuel liter	Emission
Total of 2020	776.46	23540000	4.67E+09	58327053	**1.41E+08**
Total of 2025	776.46	38120000	7.66E+09	9.6E+07	**2.32E+08**
Total of 2035	776.46	76090000	1.52E+10	1.90E+08	**4.6E+08**
Total of all 2020-2035		137750000	2.756E+10	3.44E+08	**833263987.9**

4.6.5. Total annual emission of the three terms.

Table 4.13: The total annual emission of the three terms.

	km	Ton	Ton km	Fuel liter	Emission KGCO$_2$e
Total of 2017	776.46	23540000	4.67E+09	58327053	**1.41E+08**
Total of 2018	776.46	23540000	4.67E+09	58327053	**1.41E+08**
Total of 2019	776.46	23540000	4.67E+09	58327053	**1.41E+08**
Total of 2020	**776.46**	**23540000**	**4.67E+09**	**58327053**	**1.41E+08**
Total of 20221	776.46	38120000	7.66E+09	9.6E+07	**2.32E+08**
Total of 20222	776.46	38120000	7.66E+09	9.6E+07	**2.32E+08**
Total of 20223	776.46	38120000	7.66E+09	9.6E+07	**2.32E+08**
Total of 20224	776.46	38120000	7.66E+09	9.6E+07	**2.32E+08**
Total of 20225	**776.46**	**38120000**	**7.66E+09**	**9.6E+07**	**2.32E+08**
Total of 2026	776.46	76090000	1.52E+10	1.90E+08	**4.6E+08**
Total of 2027	776.46	76090000	1.52E+10	1.90E+08	**4.6E+08**
Total of 2028	776.46	76090000	1.52E+10	1.90E+08	**4.6E+08**
Total of 2029	776.46	76090000	1.52E+10	1.90E+08	**4.6E+08**
Total of 2030	776.46	76090000	1.52E+10	1.90E+08	**4.6E+08**
Total of 2031	776.46	76090000	1.52E+10	1.90E+08	**4.6E+08**
Total of 2032	776.46	76090000	1.52E+10	1.90E+08	**4.6E+08**
Total of 2033	776.46	76090000	1.52E+10	1.90E+08	**4.6E+08**
Total of 2034	776.46	76090000	1.52E+10	1.90E+08	**4.6E+08**

Total of 2035	**776.46**	**76090000**	**1.52E+10**	**1.90E+08**	**4.6E+08**
					0
Total of all 2020-2035		**1045660000**	**2.09E+11**	**2613308212**	**6.319019356375E+09**

Table 4.14: Total Emission in TON (2020-2035)

Total Emission in TON (2020-2035) = 6.98E+06

= 6.319019356375E+09 KG of CO_2e

= 6319019.356375 TON of CO_2e

= 6.319019356375 Million ton of CO_2e

= 6.319MT CO_2e

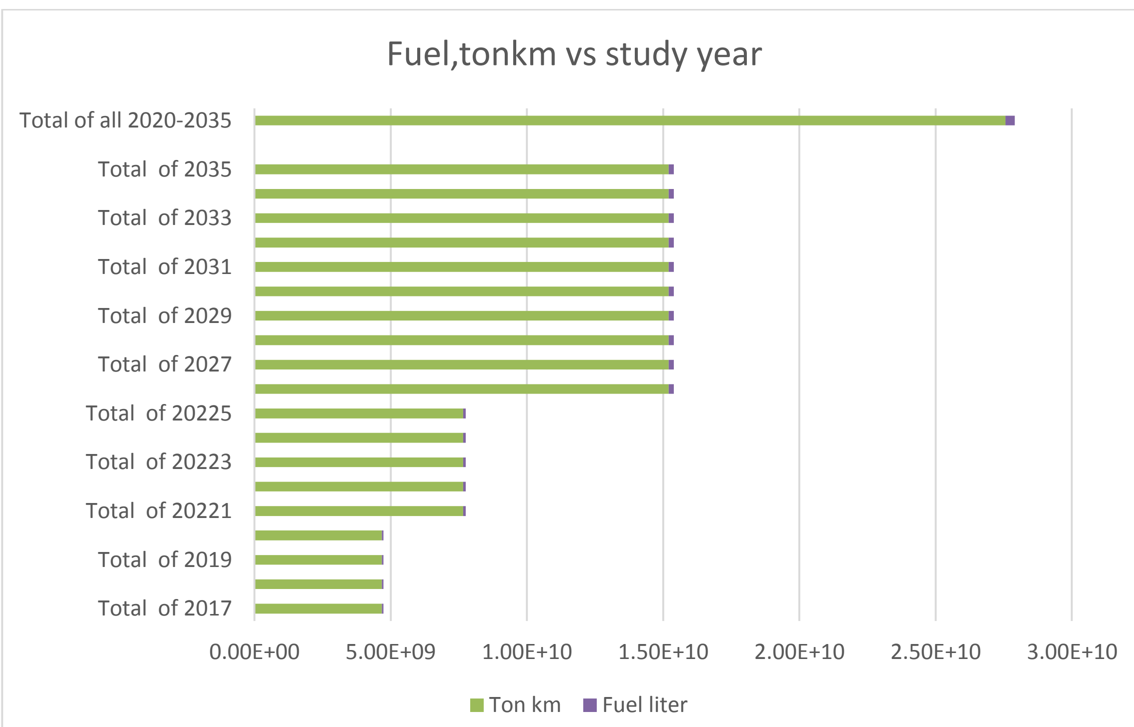


Figure 4.3: Fuel, ton km vs project year

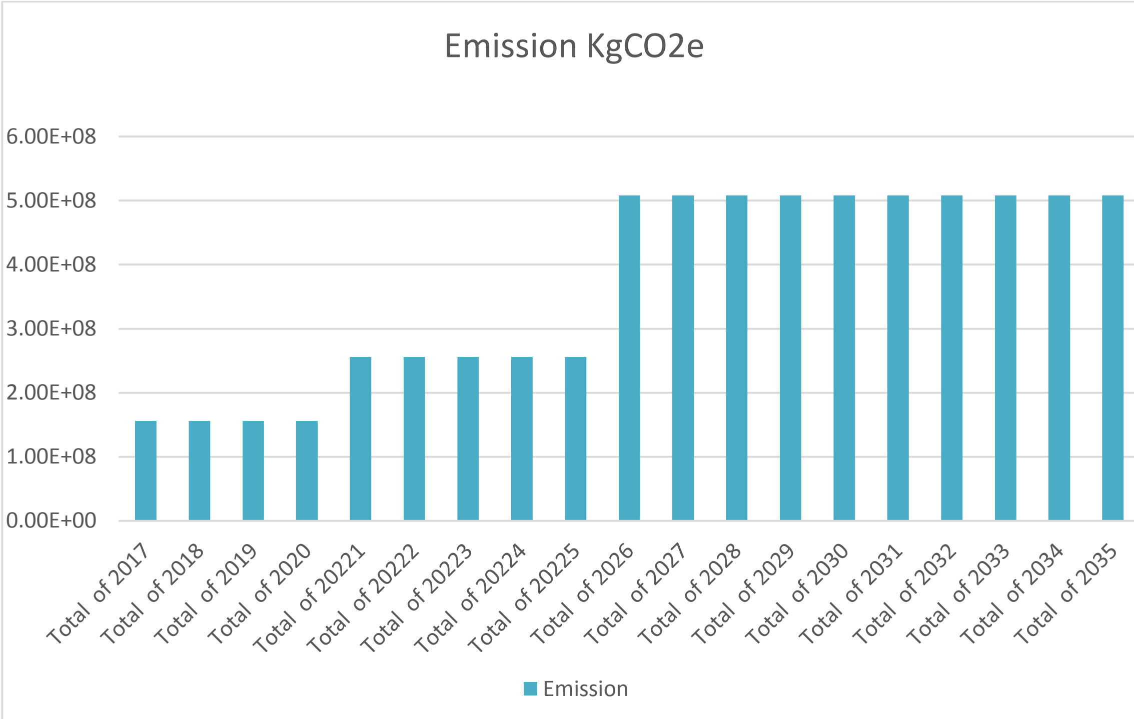


Figure 4.4: Emission vs project year

4.7. Emission from hydroelectric power generation used for the railway operation

Hydroelectric dams produce significant amounts of carbon dioxide and methane, and in some cases produce more of these greenhouse gases than power plants running on fossil fuels. Carbon emissions vary from dam to dam, says Philip Fearnside from Brazil's National Institute for Research in the Amazon in Manaus. "But we do know that there are enough emissions to worry about." [26]

Wildlife Impacts

Dammed reservoirs are used for multiple purposes, such as agricultural irrigation, flood control, and recreation, so not all wildlife impacts associated with dams can be directly attributed to hydroelectric power. However, hydroelectric facilities can still have a major impact on aquatic ecosystems. For example, though there are a variety of methods to minimize the impact (including fish ladders and in-take screens), fish and other organisms can be injured and killed by turbine blades. [27]

The related electric power consumption will also to be: the Ethiopian hydroelectric generated power (KWhr) will be multiplied by the electric specific emission factor of 0.118948451 (KgCO2/KWh) [27]

Hence,

$$Emission(elt) = power\ (kwhr)\ \times electric\ emission\ factor \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (10)$$

$$\text{Emission(elt)} = \mathbf{531580000} \times 0.118948451$$

$\boldsymbol{Emission(elt)}$ = **63230618** (KgCO2/KWh)

Emission from hydroelectric power production

Electric specific emission factor is (KgCO2/KWh)

From the above table we can see that total annual power and energy consumption of electric train during the short term of service time. Energy annual consumption of ETHIOPIA DJIBOUTI is

= 2.86E+08 + 531580000

= 531.58 ton annual CO_2e from Sebeta -Meiso rail root

Table 4.15: Annual Electric power consumption Sebeta –Meiso and emission

Location of traction	Annual power consumption (104kWh)			Annual power consumption in Kwh			Electric specific emission factor 0.118948451 (KgCO2/KWh)		
substation	Initial stage	Short term	Long term	Initial stage	Short term	Long term	Initial term	Short term	Long term
Sebeta	1018	1653	3053	101800000	1.65E+08	3.05E+08	12108952.3	19662179	36314962
Indodo	2188	3556	6565	218800000	3.56E+08	6.57E+08	26025921.1	42298069	78089658
Bishoftu	1577	2563	4732	157700000	2.56E+08	4.73E+08	18758170.7	30486488	56286407
Mojo	2595	2592	4785	259500000	2.59E+08	4.79E+08	30867123	30831438	56916834
Merebe	1639	2576	4683	163900000	2.58E+08	4.68E+08	19495651.1	30641121	55703560
Senga beret	2396	3765	6846	239600000	3.77E+08	6.85E+08	28500048.9	44784092	81432110
Methara	1506	2366	4302	150600000	2.37E+08	4.3E+08	17913636.7	28143204	51171624
Awash	1290	2211	3869	129000000	2.21E+08	3.87E+08	15344350.2	26299503	46021156
Sirba Kunkur	1805	3095	3522	180500000	3.1E+08	3.52E+08	21470195.4	36814546	41893644
Ak313	-	-	3788			3.79E+08	0	0	45057673
Mieiso	2101	3603	4410	210100000	3.6E+08	4.41E+08	24991069.6	42857127	52456267

Table 4.16: Emission from hydroelectric power production

Location of traction	Annual power consumption (10^4kWh)			Annual power consumption (kWh)		
substation	Initial stage	Short term	Long term	Initial	Short	Long
Sebeta	1018	1653	3053	101800000	1.65E+08	3.05E+08
Indodo	2188	3556	6565	218800000	3.56E+08	6.57E+08
Bishoftu	1577	2563	4732	157700000	2.56E+08	4.73E+08
Mojo	2595	2592	4785	259500000	2.59E+08	4.79E+08
Merebe	1639	2576	4683	163900000	2.58E+08	4.68E+08
Senga beret	2396	3765	6846	239600000	3.77E+08	6.85E+08
Methara	1506	2366	4302	150600000	2.37E+08	4.3E+08
Awash	1290	2211	3869	129000000	2.21E+08	3.87E+08
Sirbakunkur	1805	3095	3522	180500000	3.1E+08	3.52E+08
Ak313	-	-	3788			3.79E+08
Mieiso	2101	3603	4410	210100000	3.6E+08	4.41E+08

Table 4.17: Total emission (hydroelectric generation) from Sebeta -Meiso rail root the three project years

Location of traction substation	Emission Electric specific emission factor $= (Kwh) \times 0.118948451\ (KgCO2/KWh)$			Total emission of the there terms.
	Initial term	Short term	Long term	
Sebeta	12108952.3	19662179	36314962	68086093.35
Indodo	26025921.1	42298069	78089658	146413648.3
Bishoftu	18758170.7	30486488	56286407	105531065.7
Mojo	30867123	30831438	56916834	118615395.3
Merebe	19495651.1	30641121	55703560	105840331.7
Senga beret	28500048.9	44784092	81432110	154716250.2
Methara	17913636.7	28143204	51171624	97228463.85
Awash	15344350.2	26299503	46021156	87665008.39
Sirbakunkur	21470195.4	36814546	41893644	100178385.4
Ak313	0	0	45057673	45057673.24
Mieiso	24991069.6	42857127	52456267	120304463.3
Total	215475119	3.33E+08	6.01E+08	1149636779

Table 4.18: Total emission of the project (electric)

Total emission of the project (electric) = 1,149,636,779 Kg of CO_2e
= 1,149,636.779 ton of CO_2e
= 1.149636779 Million ton of CO_2e
= 1.149 MT of CO_2e

4.8. Life Cycle Analysis of fuel and vehicles

For the analysis of life cycle emission calculation it is known that ETHIOIA did not have plants to extract out fuel in the country. The diesel fuel and other fuel oil and lubricants are mainly imported from Areb country and South Sudan. The fuel extracted out from early stage to refinery and transportation up to the fuel tank station will have different level of emission. This emissions includes emission in crude oil extraction, oil petroleum and Naphtha refinery plants, transportation of raw material to the finished fuel to gas station and leakage are accounted among the main emission sources.

In life cycle analysis the ISO 14040:2006 describes the principles and framework for life cycle assessment (LCA).

ISO describes LCA as-' the completion and evaluation of input, output and environmental impacts of a product system through a product life cycle.'

LCA addresses the environmental aspects and potential environmental impacts (e.g. use of resources and the environmental consequences of releases) throughout a product's life cycle from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal) The LCA inventory captures all life-cycle (LC) phases of the vehicle subdivided in three parts:

- UPSTREAM (raw materials extraction and production),
- CORE (components manufacturing and assembly) and
- DOWNSTREAM (vehicle operation and end of life).

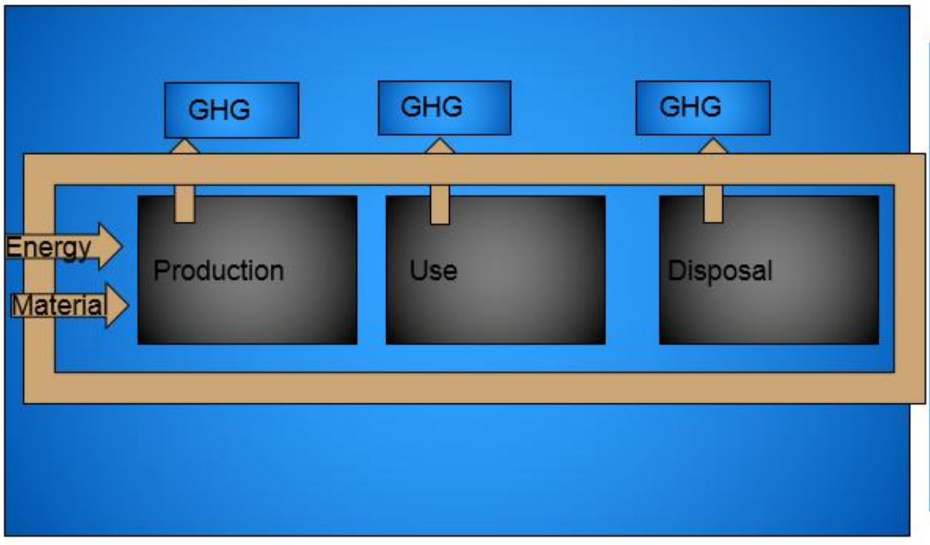


Figure 4.5: Life cycle analysis []

In life cycle model analysis the software is make it simpler to calculate the emission from complex extraction and refinery chemical process. The fuel are different type like petroleum, diesel. It has a transportation emission by giving some important variables e.g. the destination, mode of transport, amount of fuel transported in litter and the distance in km or miles for the analysis.

4.8.1. The life **cycle** *model software*

Figure 4.6: Greet Software

Select out the fuel we want to view the

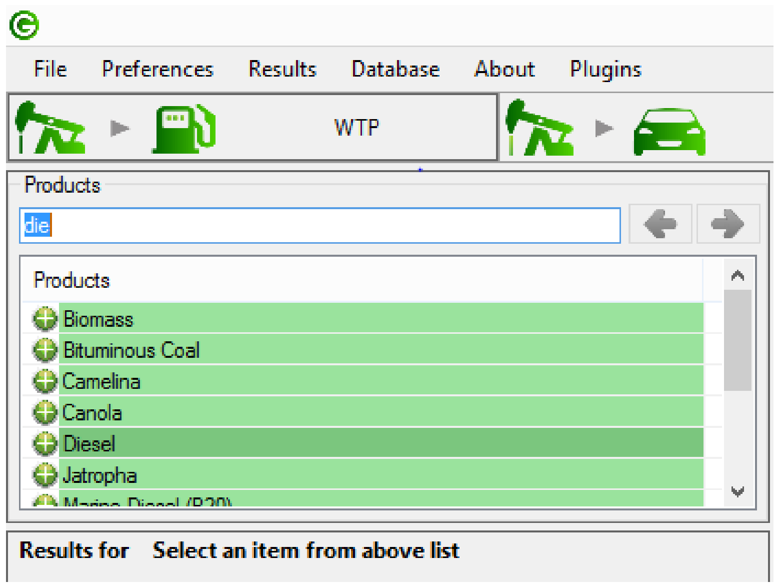


Figure 4.7: Open WTP-→ diesel

Input parameters

Destination – in the analysis of LCA we use the data of US conventional diesel fuel extraction and refinery emission result are studied per 1 litter of diesel fuel extraction from crude oil. We use this value because the technology used in extraction and refining similar with Middle East and Africa refinery with a little decrease in emission.

Table 4.19: Emissions

Emissions		
Well to Use		
Emissions		
CO2 Total	**0.48**	**kg**
CO2	0.48	kg
CO2_Biogenic	-1.93e-4	kg
VOC	0.28	g
CO	0.50	g
NOx	1.12	g
PM10	72.90	mg
PM2.5	59.94	mg
SOx	0.72	g
CH4	5.96	g
N2O	8.85	mg
SO2	14.69	ng
BC	8.92	mg

POC	18.44	mg
Groups		
GHG-100	0.67	kg

Total fuel used in the project year - **2,613,308,212 liter diesel fuel**

Hence from one litter of crude fuel extraction and refinery it has a total of CO2 0.48 kg

The total emission - $2613308212\ litter \times 0.4 kgCO2$

= 1254387941.76 kg CO2

The emission calculated bellow

Table 4.20: Total GHG gases from fuel (extraction, refinery and leakages)

Emissions			Total fuel	Total Emission	
CO2 Total	0.48	kg	2613308212	1254387942	kg
CO2	0.48	kg	2613308212	1254387942	kg
CO2_Biogenic	-1.93E-04	kg	2613308212	-504368.48	kg
VOC	0.28	g	2613308212	731726299	g
CO	0.5	g	2613308212	1306654106	g
NOx	1.12	g	2613308212	2926905197	g
PM10	72.9	mg	2613308212	1.9051E+11	mg
PM2.5	59.94	mg	2613308212	1.5664E+11	mg
SOx	0.72	g	2613308212	1881581913	g
CH4	5.96	g	2613308212	1.5575E+10	g
N2O	8.85	mg	2613308212	2.3128E+10	mg
SO2	14.69	ng	2613308212	3.8389E+10	ng
BC	8.92	mg	2613308212	2.3311E+10	mg
POC	18.44	mg	2613308212	4.8189E+10	mg

Table 4.21: Total GHG gases from fuel (extraction, refinery and leakages) in (kg)

Emissions			Total fuel	Total Emission		Total Emission	KG
	Value	Unit			Unit		Unit
CO2	0.48	kg	2.61E+09	1.25E+09	kg	1.25E+09	kg
CO2_Biogenic	-1.93E-04	kg	2.61E+09	-504368	kg	1.25E+09	kg
VOC	0.28	g	2.61E+09	7.32E+08	g	731726.3	kg

CO	0.5	g	2.61E+09	1.31E+09	g	1306654	kg
NOx	1.12	g	2.61E+09	2.93E+09	g	2926905	kg
PM10	72.9	mg	2.61E+09	1.91E+11	mg	190510.2	kg
PM2.5	59.94	mg	2.61E+09	1.57E+11	mg	156641.7	kg
SOx	0.72	g	2.61E+09	1.88E+09	g	1881582	kg
CH4	5.96	g	2.61E+09	1.56E+10	g	15575317	kg
N2O	8.85	mg	2.61E+09	2.31E+10	mg	23127.78	kg
SO2	14.69	ng	2.61E+09	3.84E+10	ng	3.83895	kg
BC	8.92	mg	2.61E+09	2.33E+10	mg	23310.71	kg
POC	18.44	mg	2.61E+09	4.82E+10	mg	48189.4	kg
Total (kg)						2.53E+09	kg
Total (ton)						2531640	TON

The life cycle emission from crude oil extraction and refining 2,531,639,852.kg of CO_2e is found by using GREET life Cycle Model software package.

Table 4.22: Results shows emission from extraction of fuel

Results shows emission from extraction of fuel 2,531,639,852.kg CO_2e
= 2,531,639.852 ton of CO_2e
= 2.531639.852 Million ton of CO_2e
= 2.5 MT of CO_2e

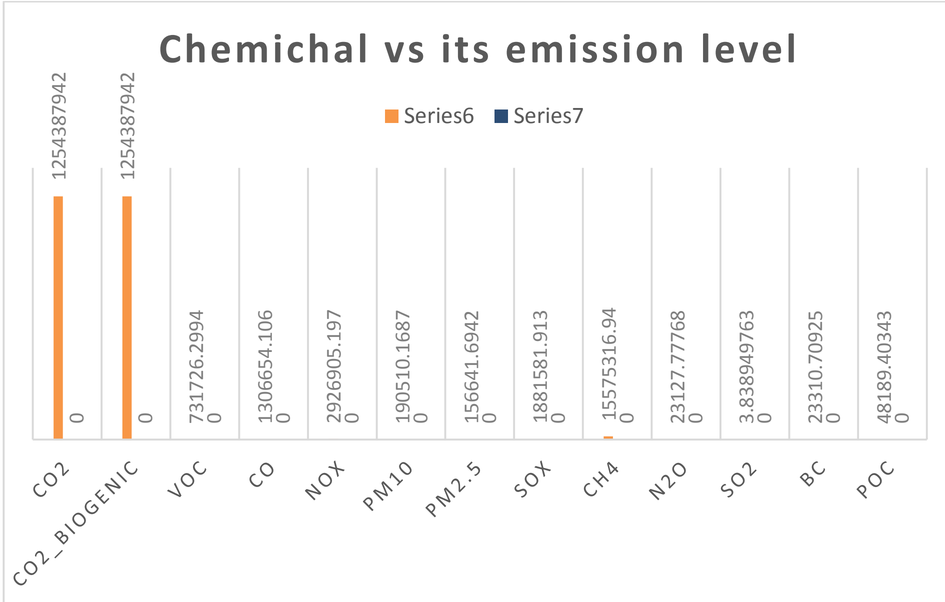


Figure 4.8: Chemicals vs emission level

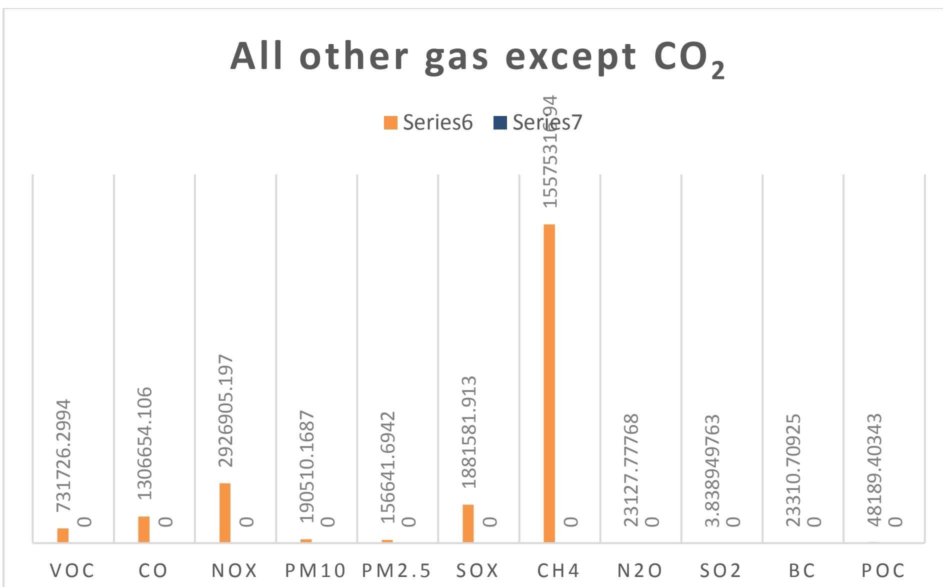


Figure 4.9: All other gases except CO_2

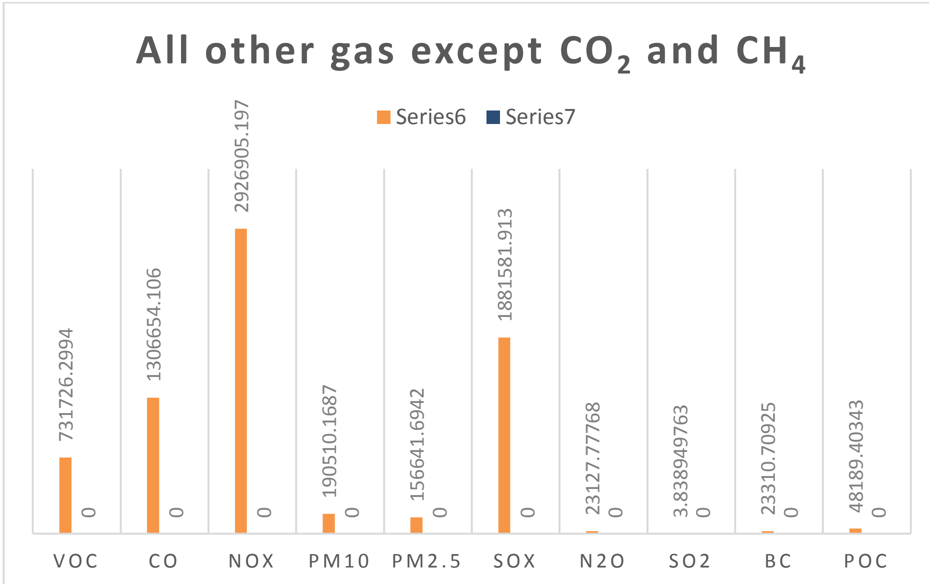


Figure 4.10: All other gases except CO_2 and CH_4

From the above graph we can see that the main pollutant in the first rank is CO_2 and CO_2 biogenic. CH_4, NOX, SOX, CO, VOC are toxic chemicals that harm not only human being but the whole ecosystem. Hence trapping those much of pollutant from exhausting to the environment and eco system will save many lives. This exemplary project will trap the listed amount of gases. So in this project our focus is not the complexity of doing some project but this work will mark out to give emphasis on the significance of climate friendly project for our country and the world. Because it has a great risk. It is a question of survival and life continuity for the coming generation.

The amount of these gases, especially CO_2, resulting from human activity has dramatically grown, leading to an annual increase of average global temperature of 0.850C in the period from 1880 to 2012. The 30 years between 1983 and2012 were warmer than any previous 30-year period in the last 1400 years. In a worst-case scenario, without efforts to reduce the GHG emissions by nations, it is predicted that the average temperature may increase up to 4.80C in the next century (IPCC. Fifth Assessment Report, November 2015). The emissions of CO_2 by transport systems accounts for about 23% of total global emissions coming from fossil fuel consumption, with road transport being responsible for most of these emissions (OECD. Reducing Transport Greenhouse Gas Emissions–Trends & Data. Organization for Economic Co-Operation and Development, November 2015). It is estimated that, until 2050, fossil energy used in transport systems will double (based on data from2009), which would increase even more the emission of GHG unless mitigation actions are implemented (IEA. Transport, energy and Ethiopia will more than double from 150 Mt CO_2e to 400 Mt CO_2e in 2030.. International Energy Agency. Available online, November 2015).

4.8.2. The emission in the transport of diesel fuel by the use of GREET life cycle model software package

The emission created in the transport of 2,613,308,212 liter diesel fuel is due to the transportation and leakage of fuel imported from the Middle East countries like Saudi Arabiya, Yemen or South Sudan.

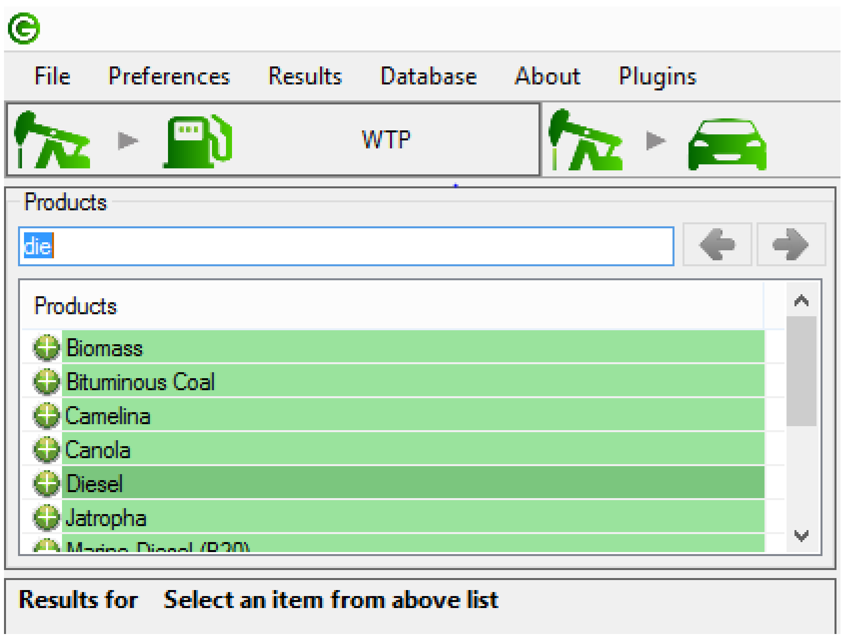


Figure 4.11: Open new pathway

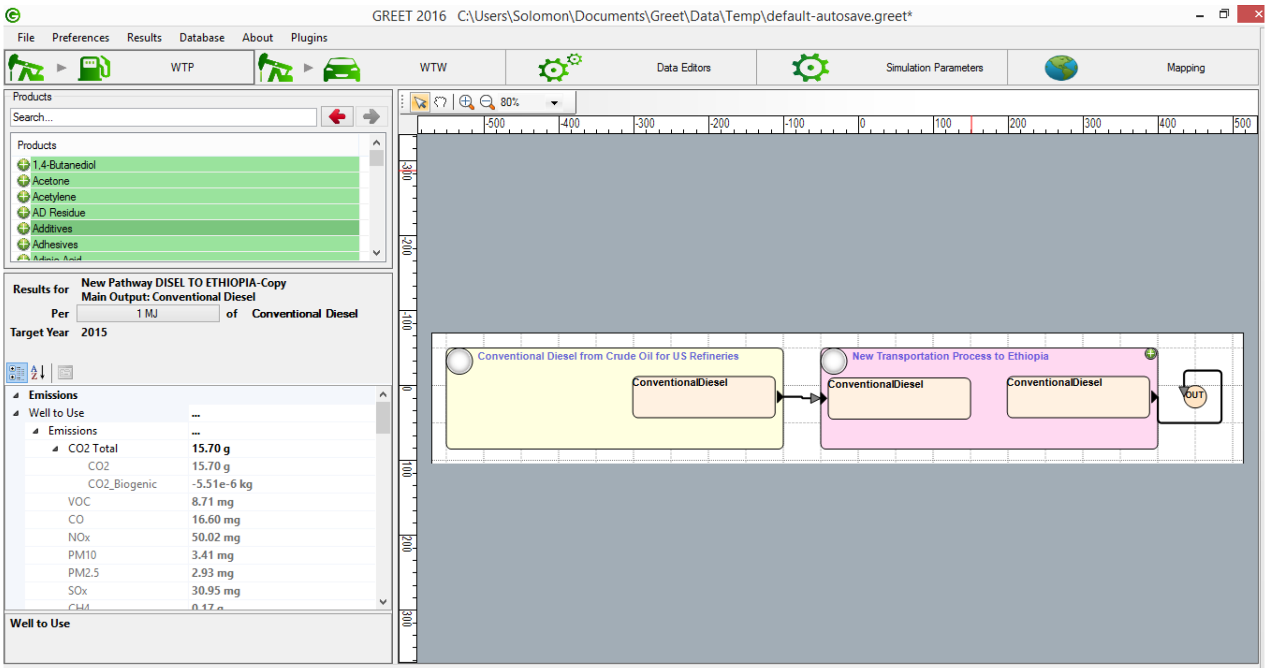


Figure 4.12: New transport process

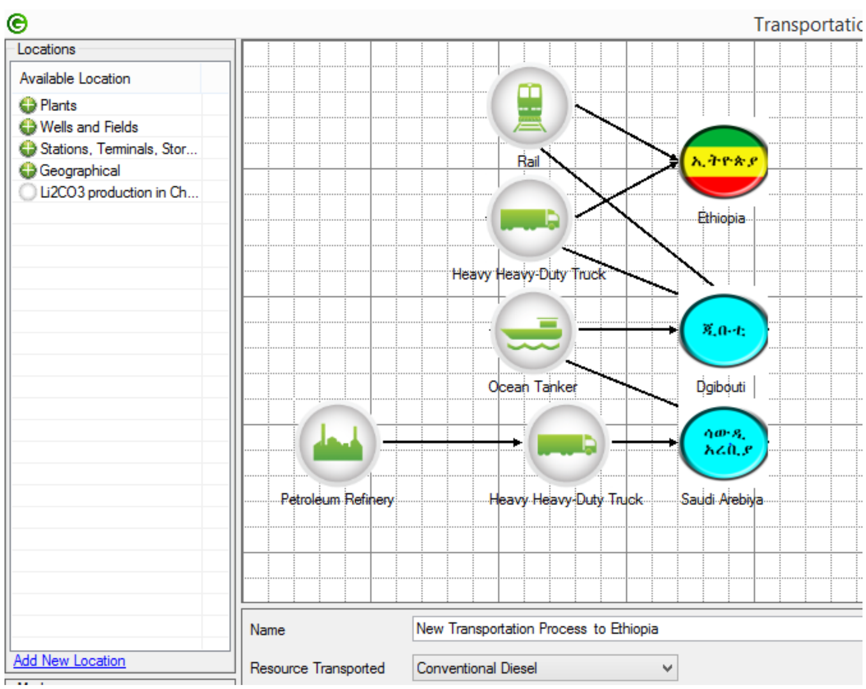


Figure 4.13: Transport process 2

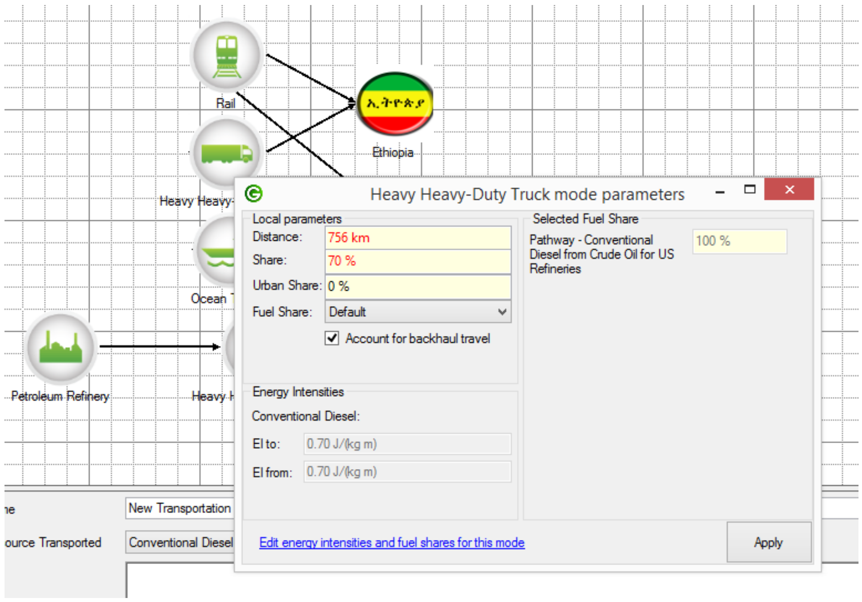


Figure 4.14: Mode parameters

4.8.2.1. Emission result from life cycle assessment model of the Ethiopian vehicles truck trailer (GVW>20 TON) Parameters.

Truck type –IVECO, SCANIYA, RENAULT, SINO TRUCK and MACK

- Fuel used diesel fuel (convectional diesel fuel)
- With free load 48 litter/100km
- Fuel consumption per truck (loading 40 ton is 0.4865671 lit/km)
- Average fuel consumption- 0.0125 litter/ton km
- Emission factor = per litter it releases Emissions from fuel: – Diesel: 2.67 kg CO2e/liter – Gasoline: 2.42 kg CO_2e/liter (Federal Democratic Republic of Ethiopia, 2011 CRGE report).

$$Emission\ per\ km = 2.67kg\boldsymbol{CO}_2\frac{\boldsymbol{e}}{litert} \times 0.4865671\,\frac{lit}{km}$$

$$= \mathbf{1.299}\,\boldsymbol{kgCO_2e/killometer}$$

- Average life time 30 years.
- Average pay load 40 ton
- Total vehicle kilometer travelled 6,000,000 km

- Oil change 30 times, Lubricant change 30 times and lithium battery

Note: Vehicle construction emission from composite, rubber, metals and other material are not included.

Steps

Figure 4.15: 1-Open GREET Life Cycle model software

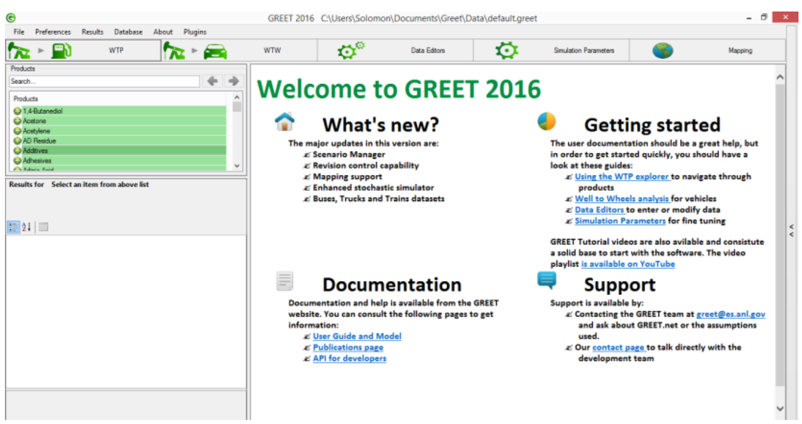


Figure 4.16: Open GREET window

2- Go to data editor. To add a new vehicle

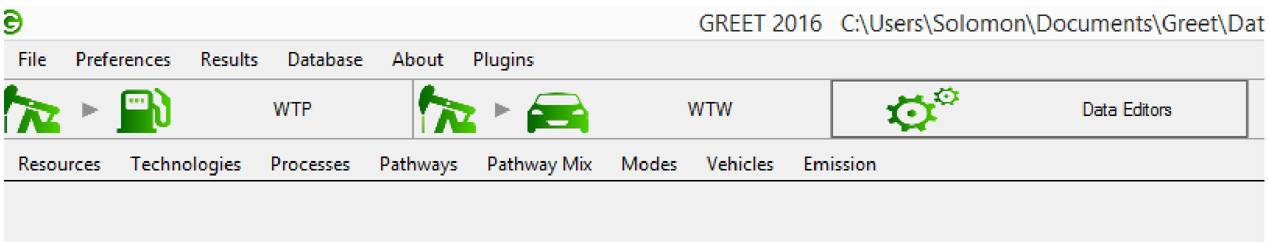


Figure 4.17: Add a new vehicle

3- Vehicle and select add vehicle – the editor opened and we see three panels

- ➢ The center is the vehicle operational mode panel where vehicles modes of operation can be added and energy sources and tell pipe emission can be added and modified.
- ➢ At the right the vehicle attribute panel where we can add a more detail information about the life cycle of the vehicle.
- ➢ And at the left the family menu where the items are dragged to the center and right panels

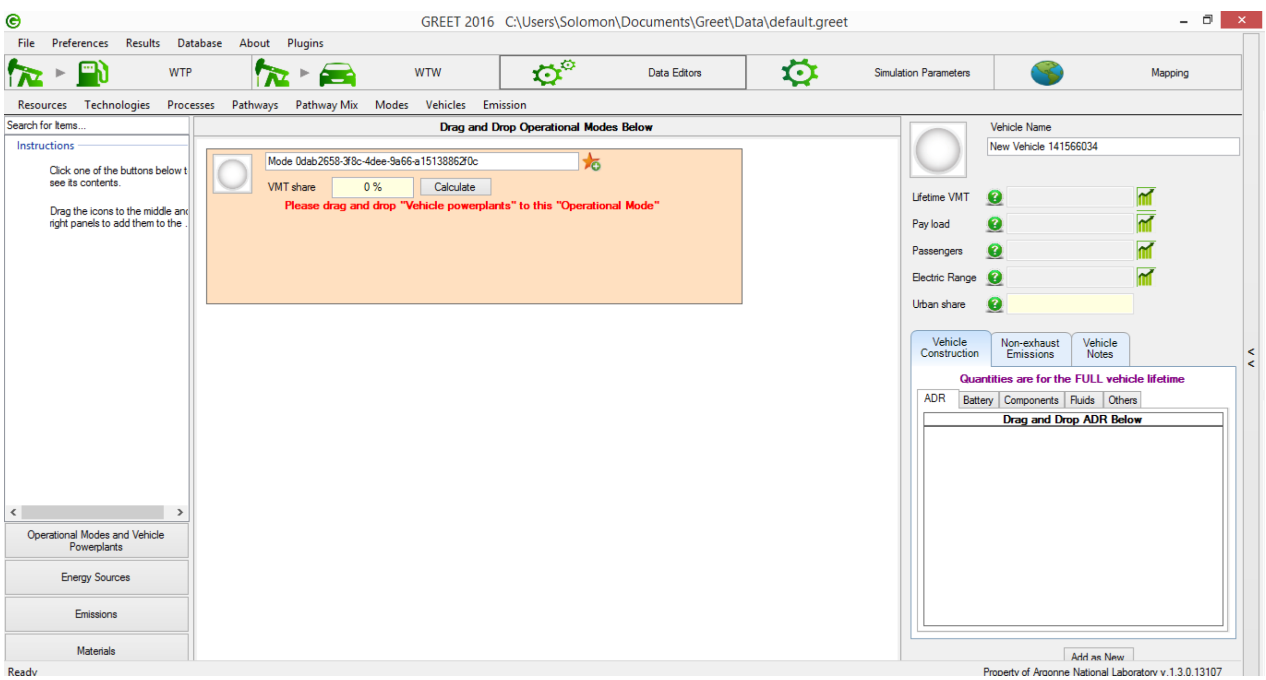


Figure 4.18: Vehicle attribute editor

4- Fill out the vehicle name and vehicle attribute at the right panel

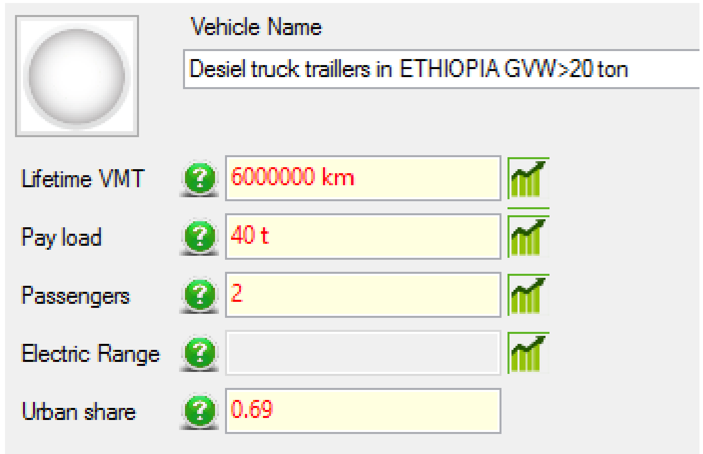


Figure 4.19: Vehicle attribute-name and vehicle mile travel (VMT), pay load

5-Next move to the vehicle operational mode panel typically named as CD, REGULAR or CS.

The three modes are CD, REGULAR or CS

Regular modes used for one single operational mode which covers most conventional vehicles, while Charge depleting (Electric vehicles and Hybrid) and Charge sustaining (Electric vehicles and Hybrid) or CD and CS modes are used for vehicles with electric batteries plug in hybrids which have one or more operational modes

(We write regular because our vehicles are not hybrid or electric capability.

And specify the VMT (vehicle miles travelled) share as 100%

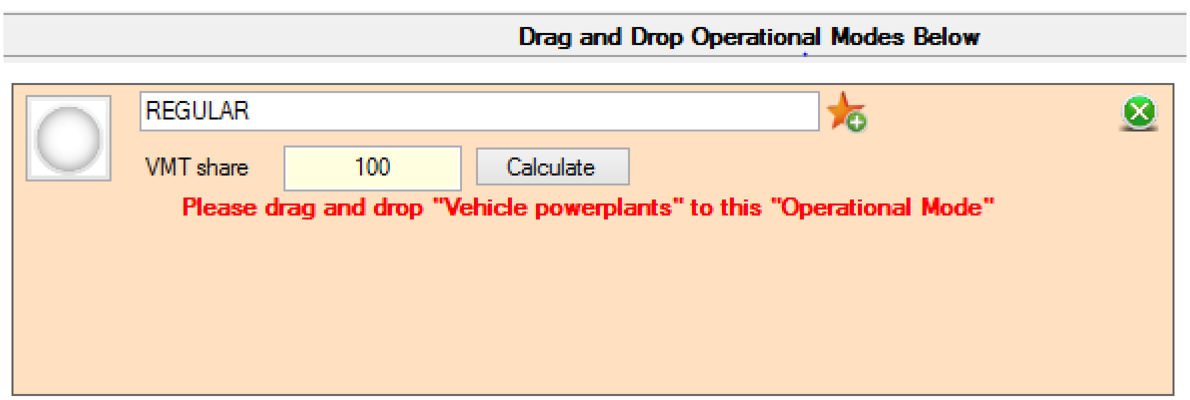


Figure 4.20: Operational modes

6- Now drag in the power plant Internal Combustion engine from left panel

And at list to name one energy source

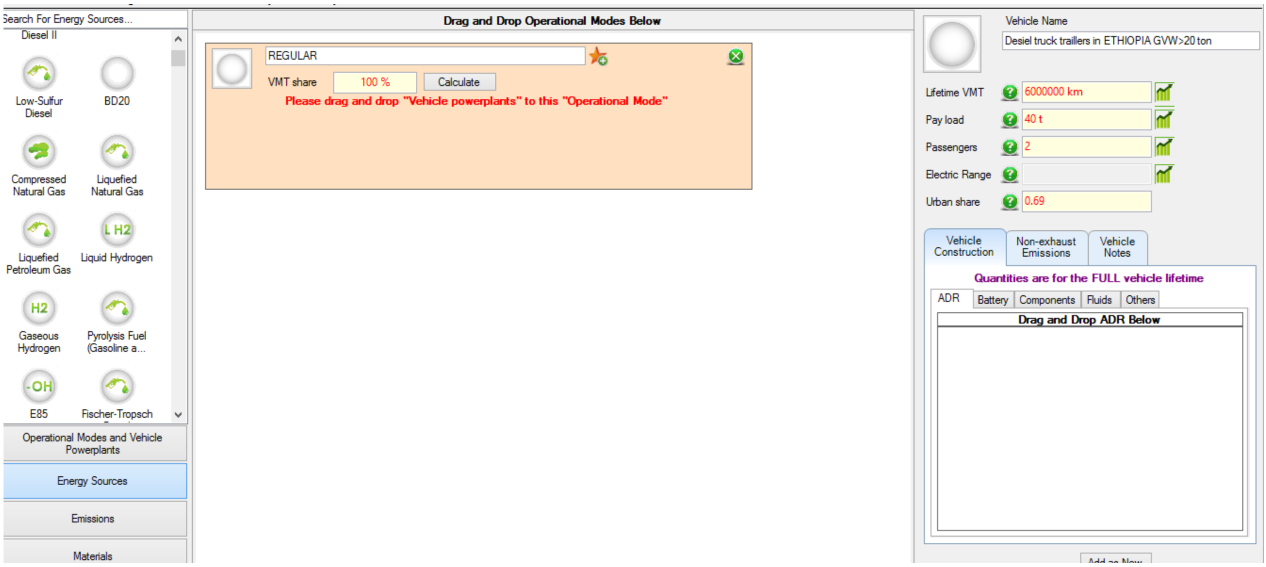


Figure 4.21: Power plant

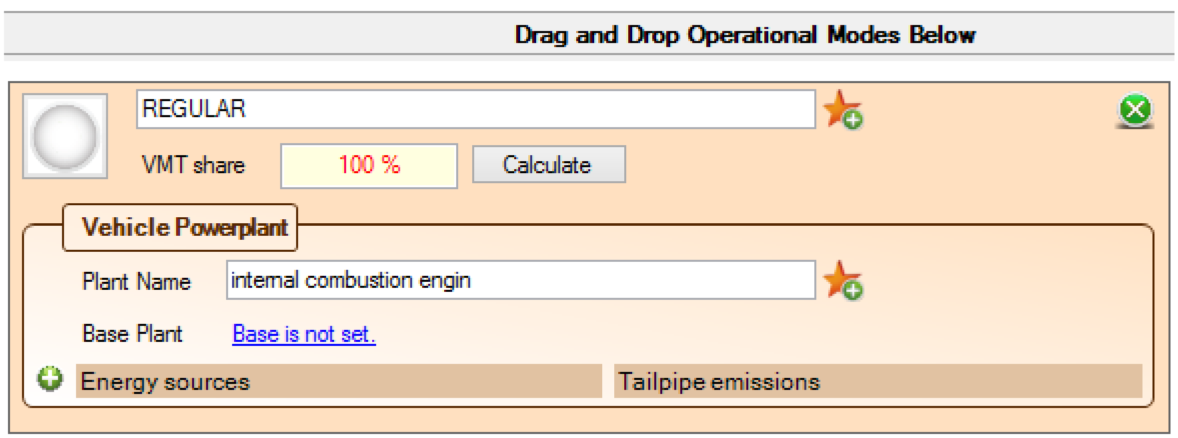


Figure 4.22: Mode type

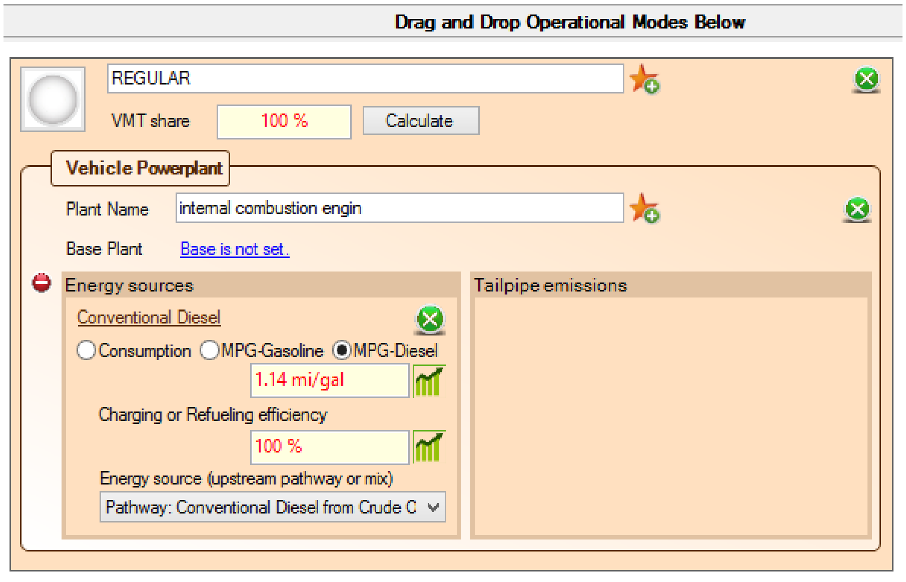


Figure 4.23: Energy sources and its parameters

7- Insert the energy sources and fuel consumption by converting our fuel consumption in to mils/ gallon 1 mils = 1.6 km, 1 gallon= 3.78 litter.

- Fuel consumption per truck (loading 40 ton is 0.4865671 lit/km

(0.486*3.78) gallon /1.6 mile

= 1.839223638 gallon/ 1.6mile

- With free load 48 litter/100km
- 182 gallon/160 mile = **1.1375 miles/gallon**

And the refuel efficiency 100%

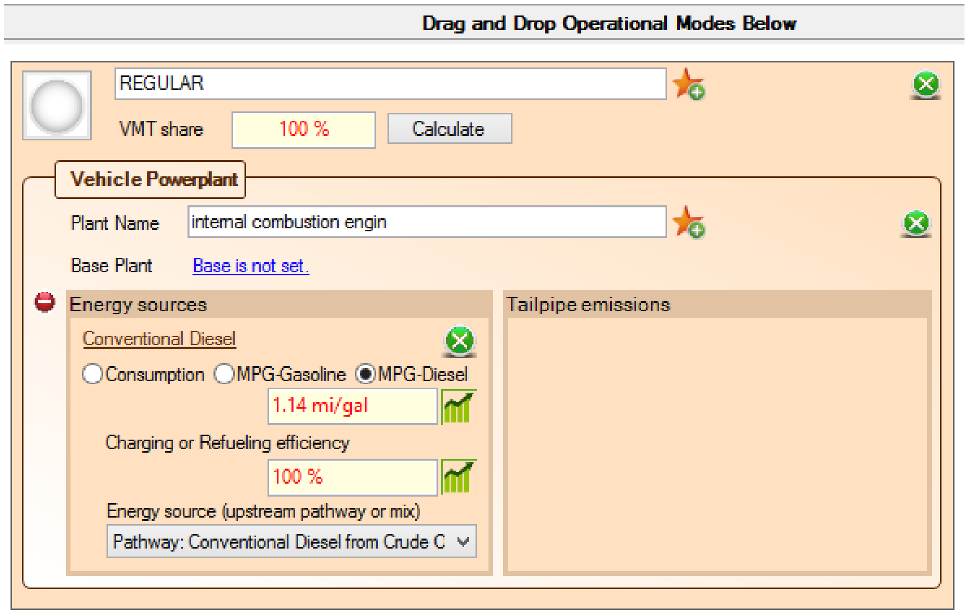


Figure 4.24: Tailpipe emission

8- Now drag in the emissions and put the value, CO2, CH4 AND NO2, VOC, CO, NOX PM10…

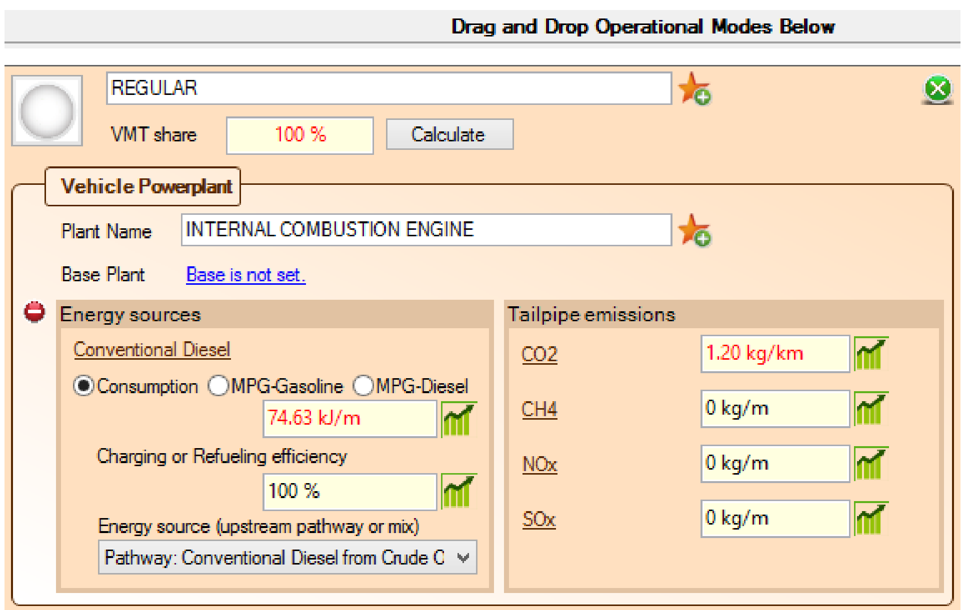


Figure 4.25: CO_2, CH_4, SO_2

9- In vehicle construction tab click on battery and drag over lid acid battery from material menu and fill out the weight, quantity and the replaced time over the life time of the vehicle.

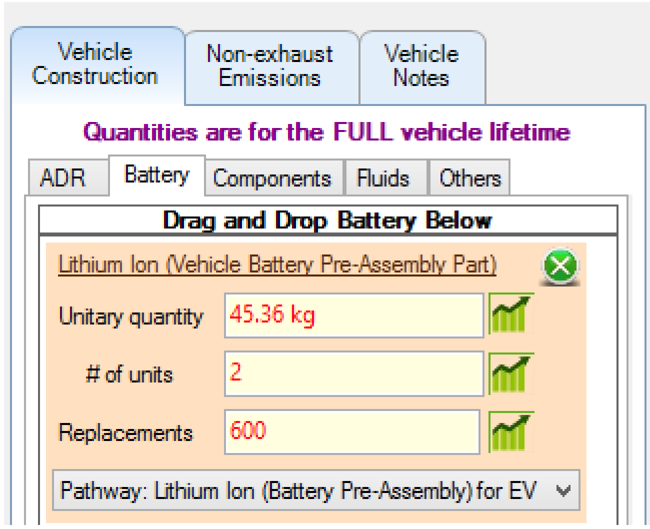


Figure 4.26: Battery replacement interval

10- Click on fluids and drag and drop from material menu fill all the engine oils, braking fluid transmission and steering fluids.

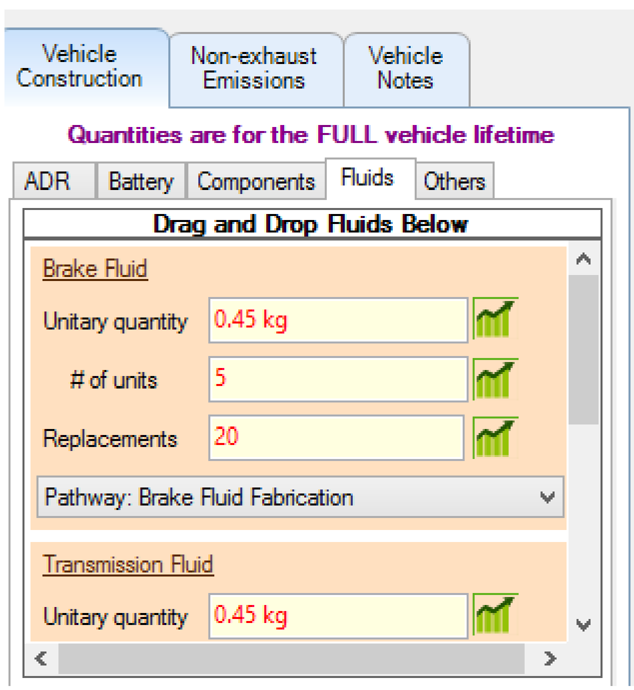


Figure 4.27: Vehicle fluids, oil and lubricant

11- Add non exhaust emissions, add values

12- Finally click on ADD AS NEW.

To view the result for the new vehicle go to WTP pane and click on the menu list the convectional diesel

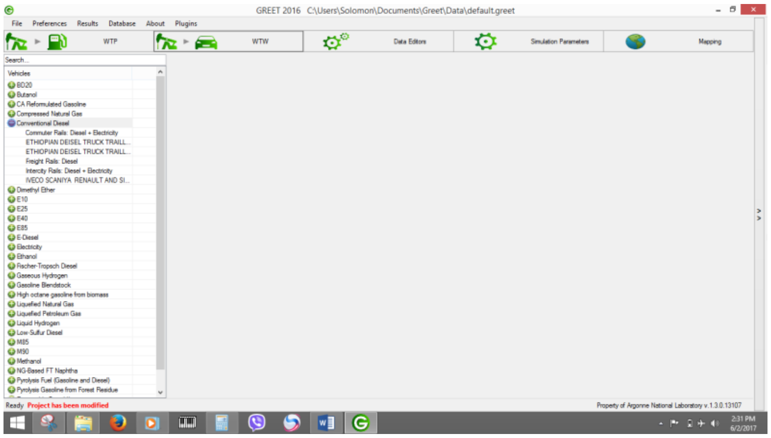
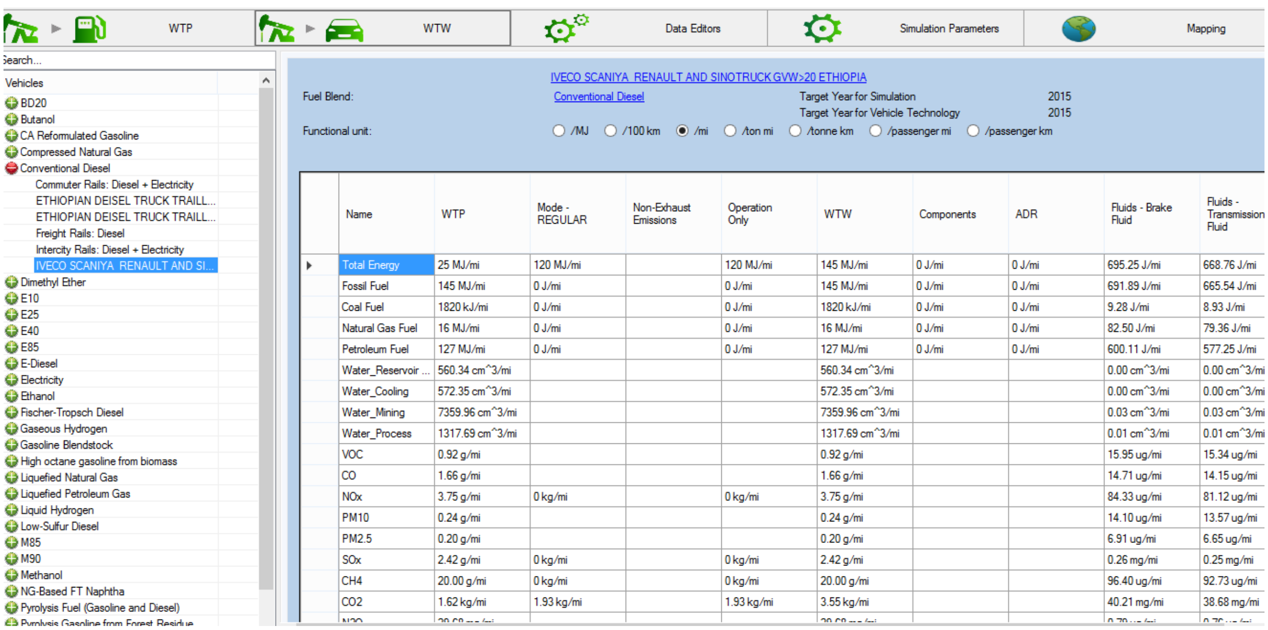


Figure 4.28: WTP window



Name	WTP	Mode - REGULAR	Non-Exhaust Emissions	Operation Only	WTW	Components	ADR	Fluids - Brake Fluid	Fluids - Transmission Fluid
Total Energy	25 MJ/mi	120 MJ/mi		120 MJ/mi	145 MJ/mi	0 J/mi	0 J/mi	695.25 J/mi	668.76 J/mi
Fossil Fuel	145 MJ/mi	0 J/mi		0 J/mi	145 MJ/mi	0 J/mi	0 J/mi	691.89 J/mi	665.54 J/mi
Coal Fuel	1820 kJ/mi	0 J/mi		0 J/mi	1820 kJ/mi	0 J/mi	0 J/mi	9.28 J/mi	8.93 J/mi
Natural Gas Fuel	16 MJ/mi	0 J/mi		0 J/mi	16 MJ/mi	0 J/mi	0 J/mi	82.50 J/mi	79.36 J/mi
Petroleum Fuel	127 MJ/mi	0 J/mi		0 J/mi	127 MJ/mi	0 J/mi	0 J/mi	600.11 J/mi	577.25 J/mi
Water_Reservoir ...	560.34 cm^3/mi				560.34 cm^3/mi			0.00 cm^3/mi	0.00 cm^3/mi
Water_Cooling	572.35 cm^3/mi				572.35 cm^3/mi			0.00 cm^3/mi	0.00 cm^3/mi
Water_Mining	7359.96 cm^3/mi				7359.96 cm^3/mi			0.03 cm^3/mi	0.03 cm^3/mi
Water_Process	1317.69 cm^3/mi				1317.69 cm^3/mi			0.01 cm^3/mi	0.01 cm^3/mi
VOC	0.92 g/mi				0.92 g/mi			15.95 ug/mi	15.34 ug/mi
CO	1.66 g/mi				1.66 g/mi			14.71 ug/mi	14.15 ug/mi
NOx	3.75 g/mi	0 kg/mi		0 kg/mi	3.75 g/mi			84.33 ug/mi	81.12 ug/mi
PM10	0.24 g/mi				0.24 g/mi			14.10 ug/mi	13.57 ug/mi
PM2.5	0.20 g/mi				0.20 g/mi			6.91 ug/mi	6.65 ug/mi
SOx	2.42 g/mi	0 kg/mi		0 kg/mi	2.42 g/mi			0.26 mg/mi	0.25 mg/mi
CH4	20.00 g/mi	0 kg/mi		0 kg/mi	20.00 g/mi			96.40 ug/mi	92.73 ug/mi
CO2	1.62 kg/mi	1.93 kg/mi		1.93 kg/mi	3.55 kg/mi			40.21 mg/mi	38.68 mg/mi

Figure 4.29: Results

Table 4.23: GHG results from vehicles service g/mile, mg/mile and kg/mile…

VOC	0.92 g/mi
CO	1.66 g/mi
NOx	3.75 g/mi
PM10	0.24 g/mi
PM2.5	0.20 g/mi
SOx	2.42 g/mi
CH4	20.00 g/mi
CO2	1.62 kg/mi
N2O	29.68 mg/mi
SO2	49.27 ng/mi
BC	29.93 mg/mi
POC	61.85 mg/mi
CO2_Biogenic	-6.46e-4 kg/mi
GHG-100	2.23 kg/mi

The LCA emission result is a large table display for energy consumption and emission breakdowns on separated list of each showing contribution from different stages of life cycle pathway.

Options are allow to select out the units as we like and if we click at the top left blank box of the table, it will highlight every cell. And we can right click on the box to copy all values to move them in to excel spreadsheet.

The result from a vehicles service emission who is giving service year 30 year(or the project year) if the truck trailer travelled a minimum of 555.5 km a day or [6,000,000 km] travelled will be found by the help of the GREET life cycle software is 6146599 kg of CO_2e

Table 4.24: LCA result vehicle truck trailer GVW>20 ton

LCA result vehicle truck trailer GVW>20 ton	
Service year	30 year
Kilometer travelled	6,000,000 km
Total emission from vehicles oil, battery, lubricants…	***6146599 kg of CO_2e = 6,146.599 ton of CO_2e =0.00614599 M ton of CO_2e***

4.8.3. Excel software package

Excel emission calculator allows anybody to get the emission from road transport. LCA emission also presented with all GHG emission values.

4.8.3.1. Working steps flow charts (to determine fuel consumption and emission from ton km travelled)

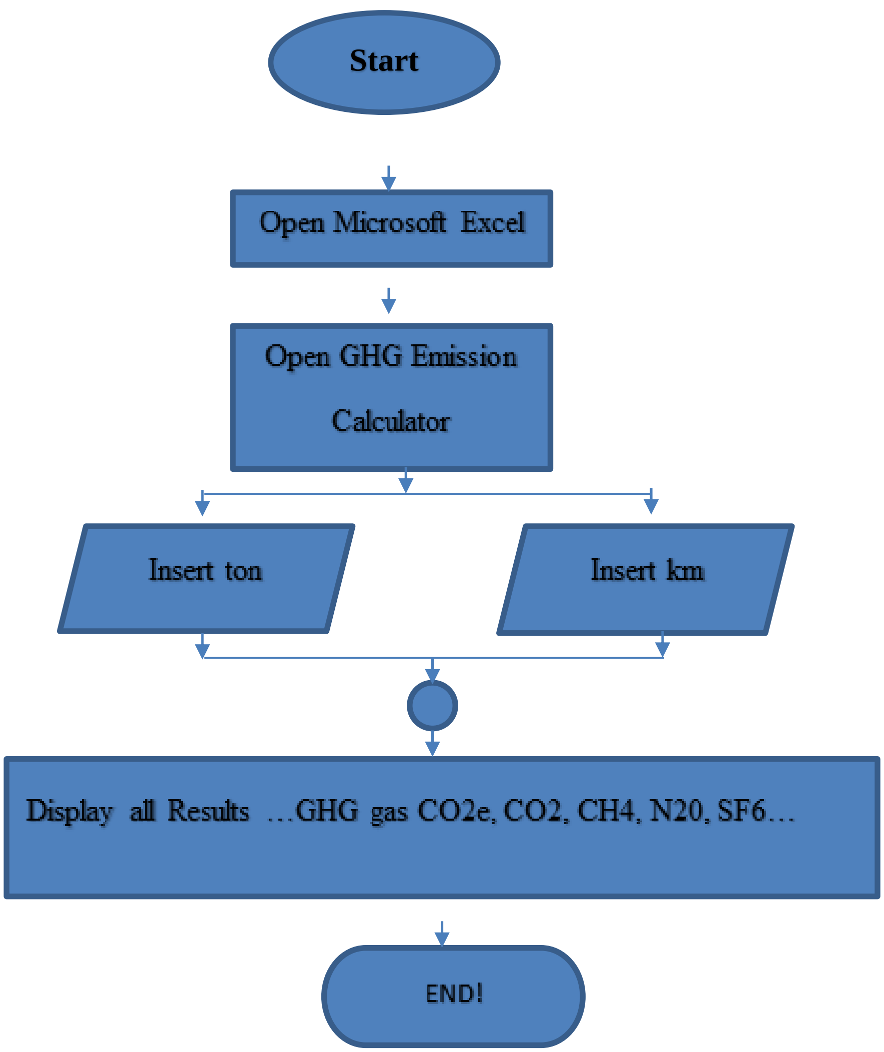


Figure 4.30: Working steps flow charts emission from ton and km

4.8.3.2. Working steps flow charts (to determine vehicle life cycle emission from km/ miles travelled)

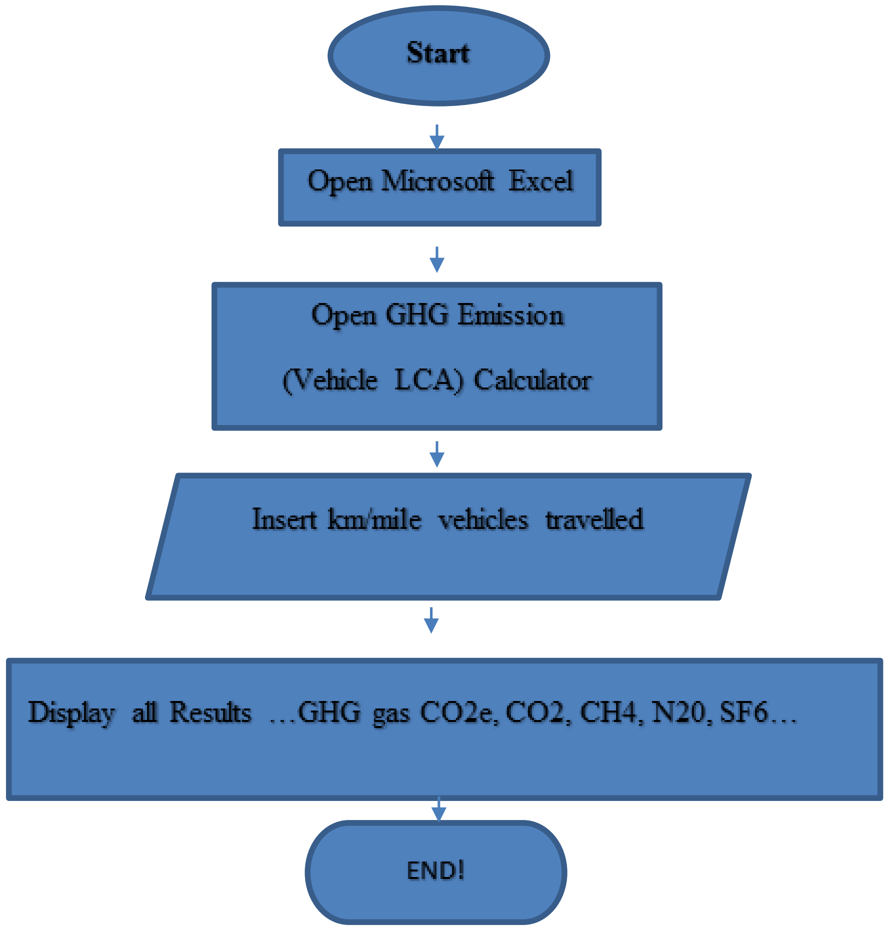


Figure 4.31: Working steps flow charts vehicle LCA emission from km/miles

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
				GREEN HOUSE GAS EMISSION CALLCULATOR (CO2, NO2, CH4, SO2…)															
STEPS 1- INSERT ton(fright), STEP 2-INSERT killometer(COLUMEN B), STEP 3- PRESS ENTER AND SEE THE RESULTS																			
EMISSION FROM ROAD TRANSPORT						EMISSION FROM EXTRACTION OF DIESIL FUEL (kg of gas)													
TON	KM	TONKM	FUEL LIT/T	EMISSION	CO2e	CH4	CO2	CO2BIO	NOX	VOC	SOX	CO	PM10	PM2.5	N20	SO2	BC	POC	ALL C
100	1000	100000	1250	2.67	3337.5	7.45	600	2412.5	1.4	0.35	0.9	0.625	0.091125	0.074925	0.010625	0.0183625	0.01115	0.02305	3023
40	700	28000	350	2.67	934.5	2.086	168	675.5	0.392	0.098	0.252	0.175	0.025515	0.020979	0.002975	0.0051415	0.003122	0.006454	846.5
1	1000	1000	12.5	2.67	33.375	0.0745	6	24.125	0.014	0.0035	0.009	0.00625	0.0009113	0.00074925	0.0001063	0.00018363	0.0001115	0.0002305	30.23
14080000	96	1.35E+09	16896000	2.67	45112320	100700.2	8110080	32609280	18923.52	4730.88	12165.12	8448	1231.7184	1012.74624	143.616	248.20224	150.71232	311.56224	40867
3220000	96	3.09E+08	3864000	2.67	10316880	23029.44	1854720	7457520	4327.68	1081.92	2782.08	1932	281.6856	231.60816	32.844	56.76216	34.46688	71.25216	9346
15030000	130	1.95E+09	24423750	2.67	65211413	145565.6	11723400	47137838	27354.6	6838.65	17585.1	12211.88	1780.4914	1463.95958	207.60188	358.784888	217.85985	450.37395	59075
3140000	130	4.08E+08	5102500	2.67	13623675	30410.9	2449200	9847825	5714.8	1428.7	3673.8	2551.25	371.97225	305.84385	43.37125	74.955725	45.5143	94.0901	12341
16530000	232	3.83E+09	47937000	2.67	1.28E+08	285704.5	23009760	92518410	53689.44	13422.36	34514.64	23968.5	3494.6073	2873.34378	407.4645	704.19453	427.59804	883.95828	1.16E
3510000	232	8.14E+08	10179000	2.67	27177930	60666.84	4885920	19645470	11400.48	2850.12	7328.88	5089.5	742.0491	610.12926	86.5215	149.52951	90.79668	187.70076	24620
		0	0	2.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	2.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	2.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	2.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	2.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	2.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	2.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
		0	0	2.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Figure 4.32: Emission calculator Excel window

STEP-1 INSERT KM OR MILE, STEP-2 PRESS ENTER, STEP-3 VIEW RESULTS															
		EMISSION FROM VEHICLES LIFE CYCLE SERVICE kg/mile												EMISSION FROM	
KM	Miles	CH4	CO2	CO2BIO	NOX	VOC	SOX	CO	PM10	PM2.5	N20	SO2	BC	POC	ALL CO2e
	1	0.02	1.62	-0.00065	0.00375	0.00092	0.00242	0.00166	0.00024	0.0002	0.00002968	4.927E-10	0.00002993	0.00006185	1.648665
	500	10	810	-0.323	1.875	0.46	1.21	0.83	0.12	0.1	0.01484	2.464E-07	0.014965	0.030925	824.3327
6000000	3728227	74564.54	6039728	-2408.43	13980.85	3429.969	9022.31	6188.857	894.7745	745.6454	110.653782	0.0018369	111.585839	230.590849	6146599
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 4.33: Emission results from vehicles life cycle

4.9. Results:

All results are listed below

Table 4.25: All results of emission and energy

Total Emission in MTON from disel fuel combustion (2020-2035) = 6.98E+06

= 6,980,000 TON of CO_2e

= **6.319019356375** Million ton of CO_2e

= 6.319019356375MT CO_2e

Total emission of the project (hydroelectric generation) = 1,149,636,779 Kg of CO_2e

= 1,149,636.779 ton of CO_2e

= 1.149636779 Million ton of CO_2e

= 1.149 MT of CO_2e

Results shows emission from extraction of fuel 2,531,639,852.kg CO_2e

= 2,531,639.852 ton of CO_2e

= 2.531639.852 Million ton of CO_2e

= 2.5 MT of CO_2e

LCA result vehicle truck trailer GVW>20 ton	
Service year	30 year
Kilometer travelled	6,000,000 km
Total emission from vehicles oil, battery, lubricants…	***6146599 kg of CO_2e = 6,146.599 ton of CO_2e = 0.00614599 M ton of CO_2e***

[1KWH =0.000000278*Joule]

[1 kWh = 1 E3 watt-hour = 1.34 horsepower-hour = 3413 Btu = = 3.60 E6 Joules = 8.60 E5 calories (gram-calories)]

Table 4.26: Annual and total project year (2017-2035) power consumptions from electricity

Annual Electric power consumption						
	KWHE4	KWH	Energy (J)	PROJECT YEAR	Total kwh	Total (Joule)
Short term annual total	19116	191160000	6.881760E+14	2017-2020	7.646400E+08	2.752704E+15
Midterm annual total	48550	485500000	1.747800E+15	2021-2025	1.942000E+09	8.739000E+15
Long term annual total	50555	505550000	1.819980E+15	2026-2035	2.022200E+09	1.819980E+16
					4.7288400E+09	**2.969150E+16**

Table 4.27: Total energy from diesel fuel

Energy consumption conversion of diesel fuel to kwh and joule			
Fuel will be use by the vehicles litter	Btu	kWh	Joule
2.61E+09 Lit	**3.92E+14**	**1.15E+11**	**4.13474E+17**

Table 4.28: Ethiopia Djibouti line net energy and avoided emission results of project year (2020-2035)

Avoided (Credit from mode shift)	
Total Energy used	(from fuel) Sebta- Meiso(317km) & Meiso-Djibouti (339km) = 1.15E+11 kWh **= 4.13474E+17 Joule**
Total CO_2 emission	**6.319019356375** Mton of CO_2e + 2.531639.852 M ton of CO_2e from LCA +0.00614599 **= 8.85065835M ton of CO_2e**
Total nonrenewable energy	1.15E+11KWH
Renewable energy	0KWH
Produced (Debit from Rail System)	
Total nonrenewable energy(annual)	0KWH
Total renewable energy	Sebeta - Meiso (from electricity) =4.7288400E+09 kWh = 2.97E+16 Joule
Total CO_2 emission	**1.149 ton of CO_2e Sebta Mieso**

Note: Electric Power consumption is from the Sebeta to Mieso. Mieso – Djibouti data is not available. Hence electric power consumption is not studied.

Net Avoided = (Credit - Debit)	
Total CO2 emission	7.70165 M ton of CO2e
Total energy saved	**= 1.10E+11kWh** **= 3.84E+17 Joule**

Chapter 5

5.1. Conclusion:

Fright rail systems powered by electricity can contribute to the reduction of GHG emissions of the transport system and make it more sustainable. The condition for that result is that the rail system emission per VKM be lower than that of the replaced transport modes. The procedure developed to determine energy and net avoided emissions applied to Ethiopia - Djibouti line will reduce a total ***7.70165 M ton of CO2e*** exhaust gas from fossil fuel which agree 5M ton of CO_2e in 2010 the CRGE report plane of reducing gases. Based on the CRGE study (2010) The Ethiopia green growth path envisages to limit the national green gas emission level to 150 Mt CO_2e in 2030 instead of 400 Mt CO_2e under BAU Scenario. Hence together with the future planed 5,000 km electric railway line supports the green growth plan with a reduction of ***7.70165 M ton of CO2e*** from 756 km of Ethiopia and Djibouti.

Mode shift effect from road to rail expected because rail transport is safe, relabel, cost effective and fast mode of transport. Therefor high emission level of old truck thrillers number on the line will greatly reduce. The Road transports constitute 3% of GHG emission in Ethiopia.

In the project activity it is expected 1,045,660,000 tons of fright will be transported by the Ethiopian railways from Ethiopia to Djibouti and vice versa. If this amount of fright were transported by the motor vehicle track trailer, it consumes 2,613,308,212 litter of fuel with respective emission of ***6.319019356375*** million ton of CO_2e. The emission from fuel combustion is high because, our old truck and trend of operation. Form the survey data shows, the Ethiopian fuel consumption of an old truck is greater than 50 litter/100 km with that of less than 35 lit/100km new trucks. Most of the drivers and owners didn’t use emission control technologies hence the tail pipe emission is very high.

In addition, if we consider the life cycle emission of 2,613,308,212 litter fuel it has 2.5 Million ton of CO_2e will be released in crude oil extraction, refining, transportation and leakage. The total emission from fuel combustion ***6.319019356375*** Million ton of CO_2e plus 2.5 million ton of CO_2e emission from LC process minus emission from electricity 1.149 Million ton of CO_2e will results 7.67001 million ton of CO_2e which is higher emission and higher results studded by Federal

Democratic Republic of Ethiopia, climate resultant green economy, 2011 CRGE report. This report presents the overall road transport emission of the Ethiopia.
This indicates us how much pollute the environment if it were used the old fright truck trailer on the transportation of those fright. As the same time for the past 20 year even though it was the import export tonnage fright is minimum, it had its own contribution on emission.

Even though hydroelectric power generation has relatively very low emission it has its own impact on biodiversity and ecosystem changing ability. It has also a minimum percentage of emission. In the project period of (2020-2035) The Ethiopian railways will use electric power of Addis Abeba to Meiso (317.774 KM) 4.7288400E+09 kWh = 2.97E+16 Joule with the respective emission of 1.149 million ton of CO_2e.

The total saved energy is 1.10E+11kWh = 30.630877 million kW or 3.84E+17 Joule. This value will be decreased if the energy consumption of Meiso-Djibouti is subtracted from the overall energy of fuel which is 1.15E+11 kWh.

5.2. Recommendation

Human beings has gone a long way to build today's world in different jonnies, processes and activities. In this all activities he uses an energy source, among this burning of fossil fuel is the main one. In the last centuries even if he uses burning this fossil fuel, the emitted CO_2 was easily trapped by plants and the ecosystem. Now a day deforestation, the higher level of emitting exhaust gas from large number of motor vehicles and industries are dramatically increased and now became beyond the trap level this gases by the plants and the ecosystem. This causes ice melt, ozone layer deprecation, global warming, desertification, radiation causes for cancer.

Most of fright truck in Ethiopia have not emission standards. The high level of practice this trend will increase the risk of climate change. Hence in this regard the author recommends the concerned body work hard in changing the transportation system in to the railway and low emission road vehicles.

Finally, the author recommends again that the following points to be further studied in the future to benefit the results of this research and compile the study as a concrete work:

The high level GHG emission of city used taxis imported from Europe and Arab country in Ethiopia that makes Africa garbage place for other and policy makers to realize its impact on our society's health and environment.

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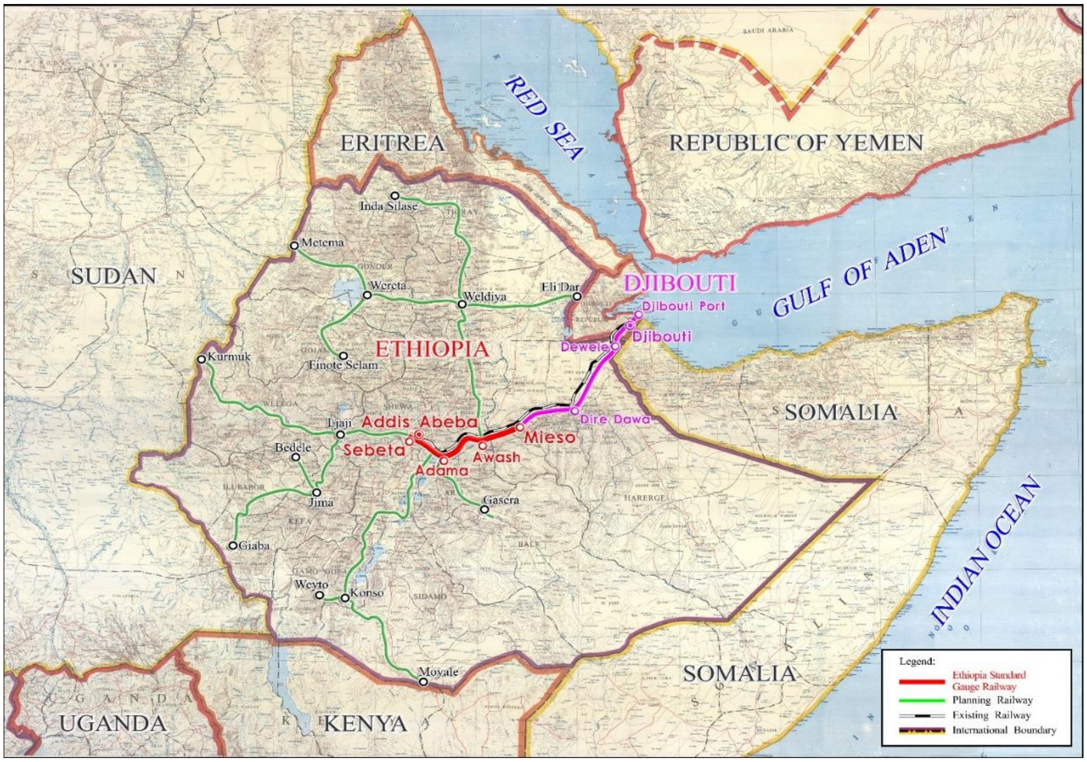
Appendices:

Appendix: A- Ethiopian standard gauge railway location map



Appendix: B- The Ethiopian Road map

Appendix: C- Required power and power consumption

The required power and power consumption in the railway line are shown below:

Location of the traction substation	Annual power consumption required （10^4kWh		Annual power required （10^4kW）			
			Average of the year		Max load of the year	
	Short term	Long term	Short term	Long term	Short term	Long term
Sebeta	1715	3196	0.196	0.366	0.343	0.639
Akaki	3347	6238	0.382	0.712	0.669	1.248
Bishoftu	2607	4851	0.298	0.554	0.521	0.97
Mojo	2915	5439	0.333	0.621	0.583	1.088
Wachulalu	2278	4232	0.26	0.483	0.456	0.846

Cheleleka	2873	5352	0.328	0.611	0.575	1.07
Haro	2562	4766	0.292	0.544	0.512	0.953
Ajo tere	2412	4471	0.275	0.51	0.482	0.894
Awashisht	2948	5490	0.337	0.627	0.59	1.098
Adele	3084	5742	0.352	0.655	0.617	1.148
Mieso	1817	3381	0.207	0.386	0.363	0.676

The raw data used above found from final evaluation report of the feasibility study of the ERC which the document prepared and evaluated by China International Engineering Consulting Corporation, September 2012.

Location of traction substation	Annual power consumption (104kWh)		
	Initial stage	Short term	Long term
Sebeta	1018	1653	3053
Indodo	2188	3556	6565
Bishoftu	1577	2563	4732
Mojo	2595	2592	4785
Merebe	1639	2576	4683
Senga beret	2396	3765	6846
Methara	1506	2366	4302
Awash	1290	2211	3869
Sirbakunkur	1805	3095	3522
Ak313	-	-	3788
Mieiso	2101	3603	4410

Appendix: D- Addis Abeba – Djibouti railway station distance table

Table 4-1-1: Sebeta-Mieso Station Table

No.	Station	Center distance of station	Station interval (km)	Type of station
1	Sebeta	DK1+100	14.421	Overtaking station
2	Labu	DK15+500	16.096	Passenger station
3	Indone	DK31+600	32.500	Depot station
4	Bishoftu	DK68+100	24.481	Intermediate station
5	Mojo	DK92+600	20.369	Intermediate station
6	Adama	DK112+970	11.600	Intermediate station
7	Wachulalu	DK131+600	8.200	Passing station
8	Merebe	DK139+800	8.150	Passing station （reserved for operation）
9	Welenchiti	DK1147+950	8.000	Passing station
10	Chisa	DK155+950	13.450	Passing station
11	Senga Beret	DK169+400	11.300	Passing station （reserved for operation）
12	Oda Deba	DK180+700	12.200	Passing station
13	Haro	DK192+900	13.600	Passing station （reserved for operation）
14	Duftu	DK206+500	12.493	Passing station
15	Metehara	DK219+000	8.000	Intermediate station
16	Ajo Tere	DK237+000	9.000	Passing station （reserved for operation）
17	Awash Park	DK246+000	12.100	Passing station
18	Awash	DK258+100	11.600	Intermediate station
19	Awashisht	DK269+700	10.300	Passing station （reserved for operation）
20	Hardim	DK280+200	11.850	Passing station
21	Sirba Kunkur	DK291+850	10.300	Passing station （reserved for operation）
22	Adele	DK302+150	8.500	Passing station
23	Sebaka	DK311+650	10.850	Passing station （reserved for operation）
24	Asebot	DK321+500	13.100	Passing station
25	Mieso	DK337+500		Intermediate station