ESTIMATING TRANSPORTATION ENERGY DEMAND IN TURKEY VIA GENETIC ALGORITHM, GHG EMISSION FOR ELECTRIC CARS SCENARIO AND ITS CLIMATE CHANGE EFFECT

by

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B.S., Civil Engineering, Boğaziçi University, 2015

Submitted to the Institute for Graduate Studies in
Science and Engineering in partial fulfillment of
the requirements for the degree of
Master of Science

Graduate Program in Civil Engineering

Boğaziçi University

2018

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DATE OF APPROVAL: 31.07.2018

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my thesis supervisor Prof. Bekir Cem Avcı for his help, guidance, friendly encouragement, and especially for his belief.

I would like to thank Assoc. Prof. Ilgın Gökaşar for her support while starting my master program and for the rest of my master program.

I would like to express my special thanks to my colleague Selahattin Akalp and Hasan Börke Birgin for their helps on preparation of my studies.

I would like to express my special thanks to my friends Abdurrahman Ovalı and Mehmet Emre Ek for their helps.

Most of all, I would like to express my special thanks to my family Şerafettin Tiranlar, Berra Tiranlar and Muharrem Can Tiranlar for the endless support and encouragement they have given me throughout my studies.

ABSTRACT

ESTIMATING TRANSPORTATION ENERGY DEMAND IN TURKEY VIA GENETIC ALGORITHM, GHG EMISSION FOR ELECTRIC CARS SCENARIO AND ITS CLIMATE CHANGE EFFECT

The aim of this thesis is to examine changes in transport energy demand, changes in the types of vehicles and the effect of this change on GHG emissions and climate change. According to Turkish Statistical Institute energy demand on highways increases every year. Increase in population, GNP and developments on highways are the main reasons of this situation. Energy demand on highways is calculated with the help of the genetic algorithm in this thesis. The genetic algorithm performs in MATLAB. While calculating the energy demand, parameters of the expected values are collected from national and international reports and some regression models. Estimated energy demand shows that a need for electric vehicles has risen due to their diminishing effect on fuel oil usage. In order to analyze this situation at first number of electric vehicles is forecasted for the year 2050. Then the impact of the electric vehicles is detailed with three different scenarios. Positive effect of electric vehicles is to decrease oil production and consumption. Thus, GHG emissions reduces definitely, but there will be an additional demand on electric generation which will still cause GHG emissions. The amount of additional emissions is operated in three different generation processes. Finally, it is observed that all of the scenarios have a positive impact on mitigating GHG emissions. Also, this impact is evaluated according to emission target of Turkey in Paris Agreement. The electric vehicles help Turkey to achieve the reduction target between 8 to %10 depending on electric generation process.

ÖZET

TÜRKİYE'DE ULAŞTIRMA SEKTÖRÜNÜN ENERJİ TALEBİNİN GENETİK ALGORİTMA YOLUYA TAHMİNİ, ELEKTRİKLİ ARAÇLAR SENARYOSU İÇİN SERA GAZI SALINIMI TAHMİNİ, BUNLARIN İKLİM DEĞİŞİKLİĞİNE ETKİSİ

Bu tezin amacı, ulaştırma sektöründe enerji talebindeki değişiklikleri, araç tiplerindeki değişimleri ve bu değişikliklerin sera gazı salınımı ve iklim değişikliği üzerindeki etkisini incelemektir. Türkiye İstatistik Kurumu'na göre karayolları üzerindeki enerji talebi her yıl artmaktadır. Nüfus ve gayrisafi milli hasıladaki artış ve otoyollardaki gelişmeler bu durumun ana nedenidir. Bu tezde genetik algoritma yardımıyla otoyolda enerji talebi hesaplanmaktadır. Genetik algoritma MATLAB'da kodlanmıştır. Enerji talebini hesaplarken, beklenilen parametreler, ulusal ve uluslararası raporlardan ve bazı regresyon modellerinden toplanmıştır. Karayollarında enerji talebini tahmin ettikten sonra ulaştırma sektöründe yeni durum ele alınmaktadır. Bu yeni durum elektrikli araçlardır. Öncelikle elektrikli araç sayısı tahmin edilmektedir. Daha sonra elektrikli taşıtların etkisi bazı senaryolarla detaylandırılmıştır. Elektrikli taşıtların pozitif etkisi petrol üretimindeki ve tüketimindeki azalmadır. Böylece sera gazı salınımları kesinlikle azalmaktadır. Öte yandan, elektrik üretimine, geçmişten daha fazla sera gazı salınımına neden olacak ek bir talep olacaktır. Ek salınım miktarı üç farklı nesil senaryo ile işlenmektedir. Son olarak, tüm senaryoların sera gazı salınımı üzerinde olumlu bir etkisi olduğu görülmektedir. Ayrıca bu etki, Paris Anlaşması'nda Türkiye'nin salınım hedefine göre değerlendirilmektedir. Elektrikli araçlar, Türkiye'nin elektrik üretim sürecine bağlı olarak %8 ile %10 arasında bir azaltma hedefine ulaşmasına yardımcı olmaktadır.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS . . . iii
ABSTRACT . . . iv
ÖZET . . . v
LIST OF FIGURES . . . viii
LIST OF TABLES . . . xi
LIST OF SYMBOLS . . . xii
LIST OF ACRONYMS/ABBREVIATIONS . . . xiii
1. INTRODUCTION . . . 1
1.1. General . . . 1
1.2. Thesis Outline . . . 3
2. LITERATURE REVIEW . . . 5
2.1. Energy Demand Estimation . . . 5
2.2. GHG Emission From Transportation Activities . . . 20
3. METHODOLOGY . . . 24
3.1. General . . . 24
3.2. Future Energy Demand in Highway Transport Sector . . . 26
3.2.1. Genetic Algorithm . . . 27
3.2.2. Genetic Algorithm Application on The Case of Turkey . . . 29
3.2.3. Turkey's Future GNP Estimation . . . 37
3.2.4. Turkey's Future Population Estimation . . . 38
3.2.5. Turkey's Future Total Vehicle-Km . . . 39
3.2.5.1. Estimation of Cars' Number . . . 40
3.2.5.2. Estimation of Coaches' Number . . . 41
3.2.5.3. Estimation of Trucks' Number . . . 42
3.2.5.4. Estimation of Car Equivalent Number . . . 43
3.2.6. Energy Demand Estimation on Highways For Turkey . . . 45
3.3. Mitigation of Fuel Oil's Negative Effect . . . 45
3.3.1. Fully Electric Vehicles . . . 46
3.3.2. Hybrid Vehicles . . . 48

3.3.3. Comparing Petrol or Diesel Engine Vehicles and Electric Vehicles 50
3.4. Effects of Electric Vehicle on Climate Change 51
3.4.1. GHG Emission Due to Oil Production 52
3.4.2. GHG Emission Due to Oil Consumption 54
3.4.3. GHG Emission Due to the New Electric Demand for Electric Vehicles 55
3.4.3.1. Scenario 1-Business as Usual 55
3.4.3.2. Scenario 2-Environmental Enemy 57
3.4.3.3. Scenario 3-Environment Friendly 58
3.4.4. Paris Agreement Targets of Turkey and Effect of Electric Vehicles on Turkey's Target 59
4. CONCLUSION 61
REFERENCES 63

LIST OF FIGURES

Figure 2.1. Flowchar of DE algorithm. 6

Figure 2.2. Future projections of total energy demand in MTOE according to Scenario 1 8

Figure 2.3. Future projections of total energy demand in MTOE according to Scenario 2 8

Figure 2.4. Future projections of total energy demand in MTOE according to Scenario 3. 9

Figure 2.5. Flowchart of ABC algorithm. 11

Figure 2.6. Performance of TED estimation models for the training set. 12

Figure 2.7. Performance of TED estimation models for the training set. 13

Figure 2.8. Curve fitting for GNP of Turkey. 13

Figure 2.9. Curve fitting for vehicle-km of Turkey. 14

Figure 2.10. The TED estimations of Turkey from 2014 to 2034 based on Scenario 1. 14

Figure 2.11. The TED estimations of Turkey from 2014 to 2034 based on Scenario 2. 15

Figure 2.12. Future estimations of transport energy demand using HASTEDE and MENR. 18

Figure 2.13. Future projections of transport energy demand using GATEDE and MENR. 19

Figure 2.14. World energy consumption by sector. 20

Figure 2.15. CO_2 emissions in transportation sub-sectors in Turkey in MT CO_2 equivalent (1990-2009). 23

Figure 3.1. Flowchart of GA processes. 29

Figure 3.2. General trend of energy demand on highway and related parameters. 30

Figure 3.3. Average error values of generations. 32

Figure 3.4. Average error values of generations and number of successful chromosomes. 32

Figure 3.5. Average error values of generations and best generation. 33

Figure 3.6. Values of weighting factors. 34

Figure 3.7. Energy demand of Turkey. 35

Figure 3.8. Estimation of GNP of Turkey between 2020 and 2050. 38

Figure 3.9. Estimation of population for Turkey between 2020 and 2050. . . . 39

Figure 3.10. Estimation of number of cars for Turkey between 2020 and 2050. . 41

Figure 3.11. Estimation of number of coaches for Turkey between 2020 and 2050. 42

Figure 3.12. Estimation of number of trucks for Turkey between 2020 and 2050. 43

Figure 3.13. The relation between annual vehicle-km and CEA. 44

Figure 3.14. Estimation of total vehicle-km for Turkey between 2020 and 2050. 44

Figure 3.15. Estimation of energy demand on highways for Turkey between 2020 and 2050. 45

Figure 3.16. Estimation of number of fully electric cars for Turkey between 2020 and 2050. 48

Figure 3.17. Estimation of number of hybrid cars for Turkey between 2020 and 2050. 49

Figure 3.18. The additional electric demand due to electric vehicles. 50

Figure 3.19. Energy need on highways from oil according to electric vehicles scenarios. 51

Figure 3.20. GHG emission savings from refineries. 53

Figure 3.21. GHG emission savings from fuel oil. 54

Figure 3.22. GHG emission from electric generation according to Scenario 1. . . 57

Figure 3.23. GHG emission from electric generation according to Scenario 2. . . 58

Figure 3.24. GHG emission from electric generation according to Scenario 3. . . 59

Figure 3.25. GHG emission decrease according to scenarios. 60

LIST OF TABLES

Table 2.1. Future projection of total energy demand in MTOE according to the LEH scenarios. 17

Table 2.2. Carbon dioxide emissions projection by end user in the UK. 21

Table 3.1. Values of weighting factors. 34

Table 3.2. Comparing the observed energy demand and GA values. 36

Table 3.3. Annual average travel distance and transformation to car equivalent. 40

Table 3.4. Cumulative sales figures of fully electric vehicles in Turkey. 47

Table 3.5. Cumulative sales figures of hybrid vehicles in Turkey. 49

Table 3.6. Emission values of GHG per 1 MTOE. 53

Table 3.7. Annual electric generation shares of power plants in Turkey. 56

Table 3.8. Estimated electric generation shares of power plants in Turkey. . . 56

LIST OF SYMBOLS

A	Starting Value of GNP
a	Coefficient of quadratic equation
b	Coefficient of quadratic equation
c	Coefficient of quadratic equation
E	Energy Demand from Genetic Algorithm
E_linear	Energy Demand from Linear Equation
$E_quadratic$	Energy Demand from Quadratic Equation
$F_(est - exp)(\overrightarrow{X})$	Energy Demand from Exponential Equation
$F_(est - linear)(\overrightarrow{X})$	Energy Demand from Linear Equation
$F_(est - quad)(\overrightarrow{X})$	Energy Demand from Quadratic Equation
Y	Years
P	Final Value of GNP
R	Rate of Growth
w_i	Weighting Factors
X_1	GDP (page), GNP (page)
X_2	Population
X_3	Import Values (page), Total Annual Vehicle-km (page)
X_4	Export Values
x	Years
y	Number of Cars (page), Number of Coaches (page), Number of trucks (page), Number of Electric Vehicles (page), Number of Hybrid Vehicles (page)

LIST OF ACRONYMS/ABBREVIATIONS

ABC	Artificial Bee Colony
AVG	Average
CEA	Car Equivalent Approach
DEA	Differential Evolution Algorithm
EIA	Energy Information Administration
GA	Genetic Algorithm
GATEDE	Genetic Algorithm Transport Energy Demand Estimation
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GNP	Gross National Product
HASTEDE	Harmony Search Transport Energy Demand Estimation
HGT	Hybrid Gravitational Search-Teaching-Learning-Based Optimization
HS	Harmony Search
IPCC	Intergovernmental Panel on Climate Change
LEH	Low, Expected and High Scenarios
LPG	Liquefied Petroleum Gas
MENR	Ministry of Energy and Natural Sources
MoEU	Ministry of Environment and Urbanization
MT	Million Tons
MtC	Million Tons Carbon
MTOE	Million Tons Oile Equivalent
NCCAP	National Certification Council for Activity Professionals
PWC	PricewaterhouseCoopers
TED	Turkey Energy Demand
TLBO	Teaching-Learning-Based Optimization
WECTNC	World Energy Council Turkish National Committee

1. INTRODUCTION

1.1. General

Energy is defined as the ability to do work. Namely in order to do work, energy is needed definitely. In the past mankind required energy only for the purpose of survival. However, in developing world the need for energy increases as the industry and machines have been coming into people lives. Increased effect of industry and machines the demand for energy rises proportionally.

Nevertheless, people have to be careful about energy consumption because the sources of energy are limited. Increasing population and machines push people to consume more and more energy in every aspect of life. Together with the people, countries have to find sustainable solutions.

Accurate estimation techniques have to be used to obtain the consumption tendency of energy while searching sustainable solutions since the scope of the solutions might change according to this tendency. In other words, effective and efficient solutions can be found with the help of algorithm methods. Thus the considered solution would be admissible and adapted easily.

From another point of view energy and GHG emissions are linked together, because in generation process of energy greenhouse gasses are emitted directly to the environment. Therefore, increase in energy demand will affect the environment negatively. By the means of energy demand estimation this negative effect can be forecasted smoothly.

In the past studies, energy demand of Turkey is estimated frequently. Some of these studies try to determine energy demand in general although others focus on energy demand in specific sectors. In every study, it is clearly seen that the energy demand in Turkey will have a growing trend. For generation process, renewable energy

sources are the most effective solution. Hence the negative impacts on environment will decrease certainly.

In addition to renewable energy sources, there is another suggestion for reducing GHG's on transport sector which is the electric vehicles. Transport sector is one of the main causes in the increase of energy demand. Energy source of transport sector is generally fuel oil that is harmful for the environment. Nonetheless electric vehicles are totally environmentally friendly.

Thus, electric vehicles are becoming popular all around the world. The studies about the transport sector mainly propose electrical vehicles as a good solution to decrease adverse influence of fuel oil.

This study includes the energy demand on highway in Turkey and the effect of electric vehicles on environment. In this study, it is suggested that energy demand on highway depends on three main variables that are the GDP, the population as well as the total vehicle-km. Then energy demand formula is derived thanks to the genetic algorithm. The genetic algorithm is performed in MATLAB. While estimating energy demand expected GDP, population and total vehicle-km are collected from governmental reports and some regression models.

Afterwards evolution of the electric vehicles and their impacts are studied separately. Number of electric vehicles is estimated via regression models. Furthermore, electric vehicles are separated into two types which are fully electric vehicles and hybrid vehicles. These two types are analyzed individually.

After forecasting the number of electric vehicles, their impacts on environment is evaluated with different scenarios. Although electric vehicles affect environment positively, they will create new demand for electricity. Electric vehicles will decrease the usage of fuel oil precisely; however, there will be a new demand on electricity. The balance between these two situations is very important because it will show the effectiveness of electric vehicles on environment.

In this study, there are three different scenarios about generating the additional electric demand. Turkey produce electric energy via power plants. These power plants use coal, natural gas, liquid gas, hydro, and renewable sources. Therefore, generation of additional electric energy might be procured in different ways. The first scenario approaches this situation from business-as-usual perspective. Namely the additional electric demand will be supplied from the sources according to their shares. The second scenario uses coal power plants in order to generate the additional electric demand. Therefore, this scenario is the worst-case scenario for the environment. The final scenario is totally environmentally friendly case because the additional electric energy will be supplied from renewable sources. Therefore, GHG emissions in generating process decrease to the minimum value.

In all of the scenarios GHG emissions from transport sector reduce demonstrably. Nonetheless the third scenario has the most effective influence on the environment. After many years the third scenario becomes more powerful than other scenarios. Hence Turkey might construct a sustainable development in transport sector thanks to electric vehicles and renewable sources.

Recently awareness of the people toward the environment has risen as the destructive natural disasters start to happen more than before. The main reason for the disasters is predicted as global warming due to damaging activities on the environment. In order to overcome these negative situation countries have been making agreements such as Rio Summit, Kyoto Protocol and Paris Agreement. Finally, all countries including Turkey have some GHG emissions targets. This study helps to show the positive impact of electric vehicles and renewable sources on Turkey's target.

1.2. Thesis Outline

This thesis approaches Turkey's energy demand on highways, its adaptation to electric vehicles and the impact of electric vehicles on environment in 4 chapters. In Chapter 1 there is an introduction for Turkey's energy and electric vehicles. Additionally, predicted impacts of electric vehicles are detailed in Chapter 1. Detailed literature

review is introduced in Chapter 2. Detailed literature review consists of energy estimation algorithms, share of transport sector in energy demand and the relation between transport sector and climate change. In Chapter 3 methods which are used for estimating the energy demand and the impact on environment are mentioned comprehensively. Lastly concluding comments and suggestions for future works are presented in Chapter 4.

2. LITERATURE REVIEW

2.1. Energy Demand Estimation

Energy demand is one of the key pieces in every country. Almost every device need energy to work. Owing to increasing number of people and technological developments, demands for energy will rise at every turn. Scientists, planners, local authorities, and business owners are driven to make realistic future estimations for the energy demand given that the energy issue has a tremendous impact on daily life.

On the other hands, it is very challenging to make a prediction about energy demand since there is not any "de facto" formula to calculate it. Therefore, numerous algorithm types have been used to forecast the energy demand. In these algorithms energy demand is dependent on many other variables like GDP or population. Naturally, they need expected future data from these variables. While estimating the data people usually use survey and planning reports of governments or institutes.

"Differential Evolution Algorithm (DEA) was designed to be a stochastic direct search method" (Storn and Pierce, 1995). This method was developed by Price and Storn in 1995, and aims to optimize a case in an iterative fashion. While optimizing the problem in many areas like engineering or statistics, the global optimum is searched. However, objective functions sometimes tend to be non-differentiable, non-continuous or have many local points instead of global ones. The solutions in the DEA are subjected to recombination, selection as well as evaluation. The DEA can offer one of the most effective ways to reach approximate solutions for such a problem which is difficult and infeasible to solve analytically.

According to Ozsaglam and Cunkas (2008), processes of the DEA can be described as the following flowchart:

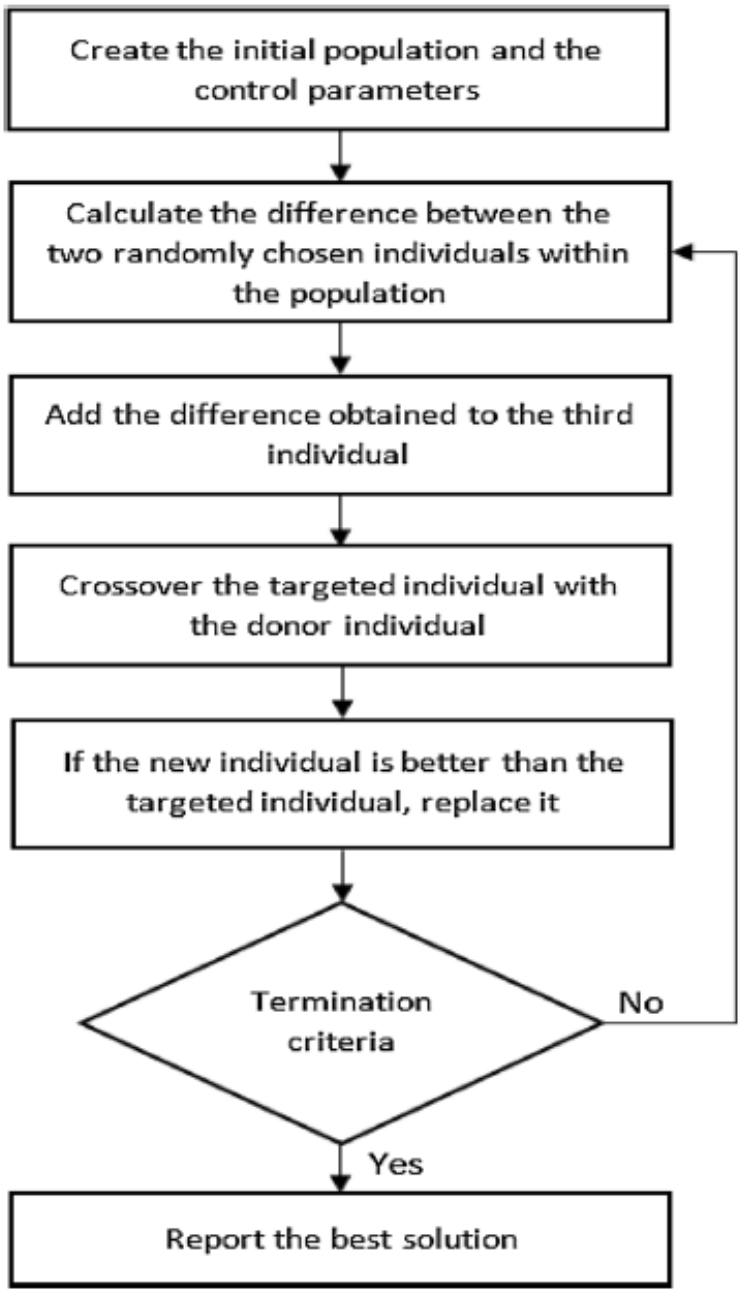

Figure 2.1. Flowchar of DE algorithm (Beskirli *et al.*, 2017).

In the above flowchart, a certain population should be created randomly as the first step. After that, the trial vector is produced by three candidates for each candidate solution and at each iteration. Then the vector components will also be swapped randomly. Finally, new individual will be replaced if it optimizes better than the previous one.

Beskirli *et al.* (2017) utilize the aforementioned algorithm while estimating Turkey's energy demand. Four economic-based criteria are taken into consideration while calculating energy demand. These criteria are the GDP, the population, the import and the export from 1979 to 2011.

These criteria constitute two types of equations. One of them is linear equation and the other one is quadratic equation. The equations are of the form as illustrated in Equation 2.1 and Equation 2.1.

$$E_{linear} = w_1 + w_2X_1 + w_3X_2 + w_4X_3 + w_5X_4 \tag{2.1}$$

$$\begin{aligned} E_{quadratic} = {} & w_1 + w_2X_1 + w_3X_2 + w_4X_3 + w_5X_4 + w_6X_1X_2 \\ & + w_7X_1X_3 + w_8X_1X_4 + w_9X_2X_3 + w_{10}X_2X_4 \\ & + w_{11}X_3X_4 + w_{12}{X_1}^2 + w_{13}{X_2}^2 + w_{14}{X_3}^2 + w_{15}{X_4}^2 \end{aligned} \tag{2.2}$$

By utilizing the GDP, the population, the import and the export data sets the DEA retrieves proper weighing factors, w_i for both equation types. After finding them it is important to having future data in order to calculate energy demand. For the future data Beskirli *et al.* (2017) create three different scenarios with different growth rate.

In the first scenario, growth rates of the GDP, the population, the import and the export are %4, %0.5, %2.5, and %3 respectively. In the second scenario, these four parameters change to %5, %0.6, %3.5, and %3.5, respectively. Finally, the GDP rises to %6 and the population increases to %0.75. The import and the export rates turn out to be %4 and %5.5.

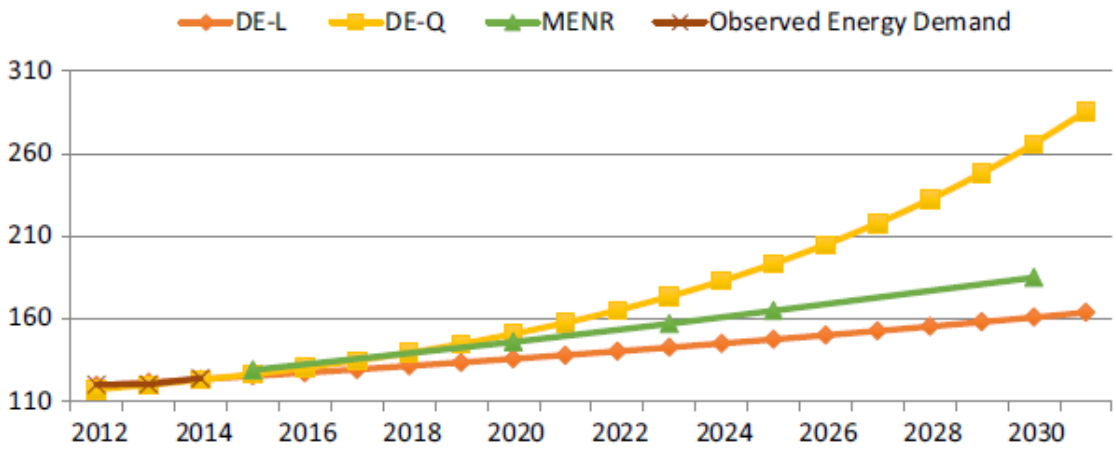

Figure 2.2. Future projections of total energy demand in MTOE according to Scenario 1. (Beskirli *et al.*, 2017).

In the Figure 2.2, it is clearly seen that the linear form is less than the MENR projections, although the quadratic form is higher than the MENR projections. The linear and the quadratic forms are very close to observed energy demand at the beginning; however, the gap between the linear and the quadratic forms and the MENR projections increase in every year when the future estimation is of concern.

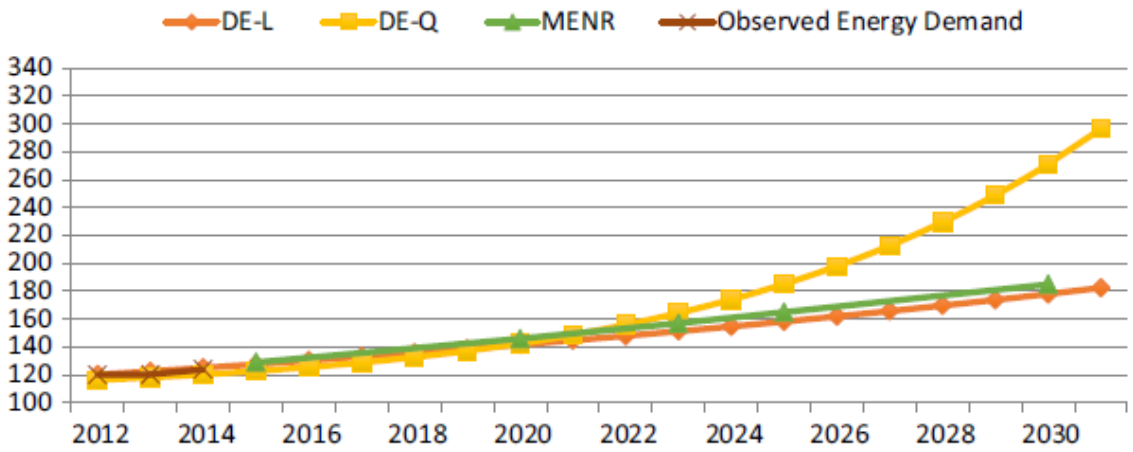

Figure 2.3. Future projections of total energy demand in MTOE according to Scenario 2. (Beskirli *et al.*, 2017).

Figure 2.3 indicates that the linear form and the MENR projections are very close to each other. The quadratic form starts to move away from both of the other approaches after 2020. Note that the observed energy demand agrees considerably well with the linear and the quadratic forms at the very beginning.

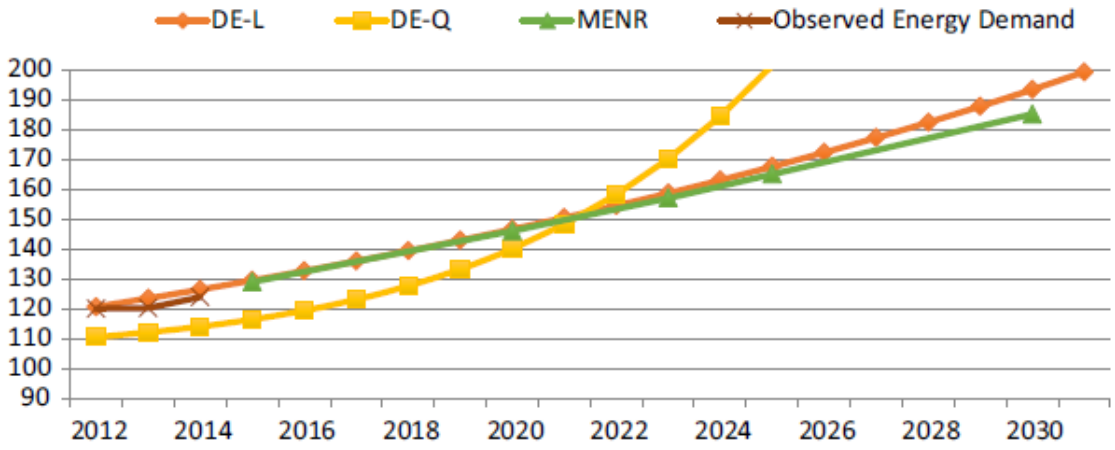

Figure 2.4. Future projections of total energy demand in MTOE according to Scenario 3 (Beskirli *et al.*, 2017).

Figure 2.4 implies that the linear form and the MENR projections exhibit somewhat similar trends again. On the other hand, the quadratic form tends to produce higher estimations after 2023 while the situation is other way around before the year of 2023.

Finally, Beskirli *et al.* (2017) claim that the quadratic form provides better estimates when compared to the linear form if the deviation ratios of both forms are considered.

The DEA is one of the efficient ways to generate a future estimation for the energy demand. However, there are some disadvantages of the DEA. One of the disadvantages is about the global solution. Same parameters may not guarantee the global solution. Thus, the solution could overlap with one of the local solutions.

Moreover, Beskirli *et al.* (2017) intends to find the energy demand without considering sub-sectors, such as transportation, industry, households, etc. Additionally, in every scenario the variables are determined with constant rate. For future estimations, it can be acceptable to have an average rate. But, calculating the energy demand annually may not be a robust approach since the rate of change differs almost for every year, and results can be adversely affected.

Sonmez *et al.* (2017) evaluate the concept of the energy demand in another algorithm which is called the artificial bee colony algorithm (ABC). The ABC is firstly defined by Dervis Karaboga in 2005. The motivation of the algorithm is directly inspired from bee colonies and their behaviors. The ABC is an optimization algorithm and the method is called as population-based search. In this method, the positions of the food, in other words individuals, describe all of the possible solutions. The artificial bees modify the positions of the food, and their main purpose is to find food sources with of the most nectar. The highest nectar will be the final solution.

The procedure of the ABC algorithm starts with creating food sources randomly. With reference to these sources number of the bees is determined, and the limiting values are specified properly. Then the bees start to work on these food sources. In other words, the solutions are obtained via the aim function. If a certain solution is better than the previous one, this solution is stored instead of the previous solution. The limit values can be changed with respect to food sources. After that, the bees are assigned a new task. They reset the limit values based on the previous experiences and try to find a new solution. The new and the former solutions are compared again, and the better one is selected. In this way, the algorithm enables to eliminate the local values. Lastly, the algorithm stops when the ultimate criterion is reached.

Karaboga and Akay (2009) suggest that the ABC algorithm is more flexible and doable in comparison with the other available ones. This algorithm is designed very similar to food search behavior of bees. Thereby, it is based on swarm intelligence. Although ABC algorithm is firstly designed for numerical problems, within upcoming period it is used in real design problems. Finally, this algorithm is relatively less control

parameters which means user friendly because user is less interested in these parameter during process.

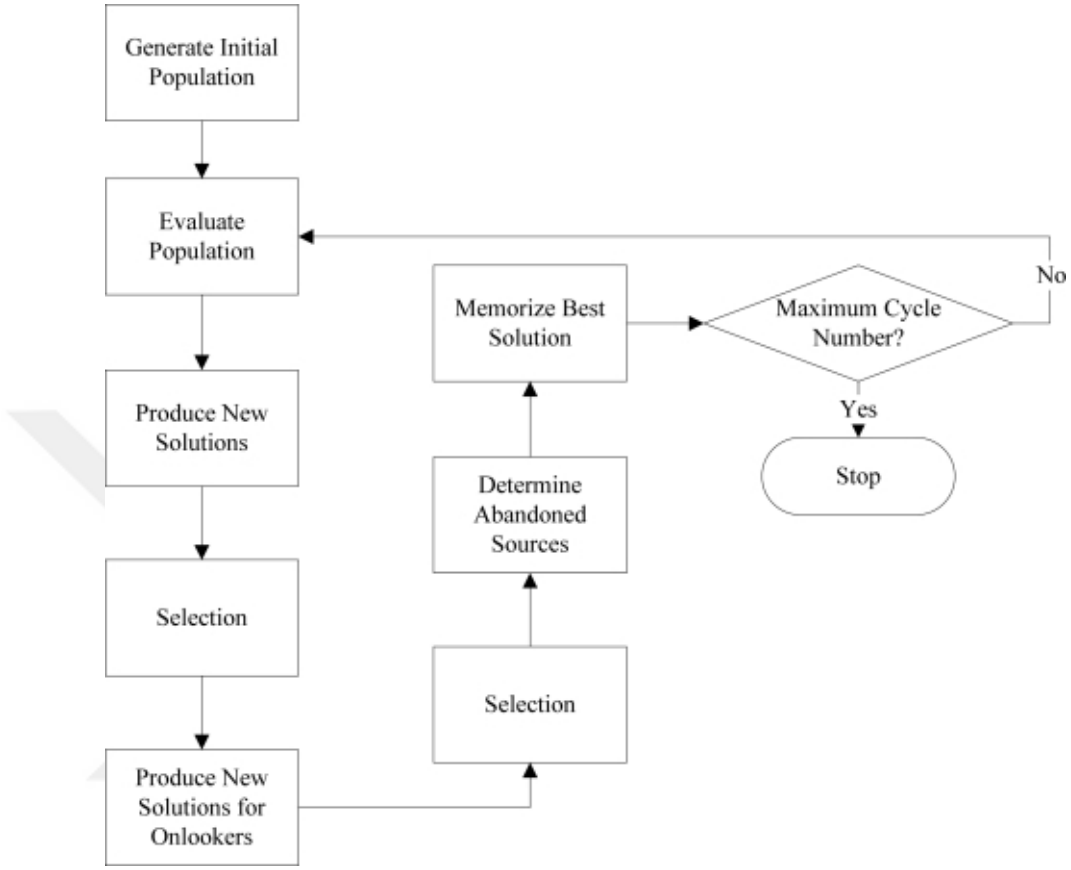

Figure 2.5. Flowchart of ABC algorithm.

Sonmez *et al.* (2017) offered ABC algorithm to estimate the transportation energy demand in Turkey. According to Sonmez *et al.* (2017) energy demand in the transportation sector is directly depends on GDP, population as well as total annual vehicle-km. With these data energy demand can be estimated; however, function of the demand is uncertain in the beginning. Sonmez *et al.* (2017) identify three mathematical forms about the function that are linear, exponential and quadratic.

$$F_{est-linear}\left(\overrightarrow{X}\right) = w_1 * X_1 + w_2 * X_2 + w_3 * X_3 + w_4 \tag{2.3}$$

$$F_{est-exp}\left(\overrightarrow{X}\right) = w_1 e^{(X_1 w_2)} + w_3 e^{(X_2 w_4)} + w_5 e^{(X_3 w_6)} + w_7 \tag{2.4}$$

$$F_{est-quad}\left(\overrightarrow{X}\right) = w_1X_1 + w_2X_2 + w_3X_3 + w_4X_1X_2 + w_5X_1X_3 + w_6X_2X_3 + w_7{X_1}^2 + w_8{X_2}^2 + w_9{X_3}^2 + w_{10} \tag{2.5}$$

Above formulas Equation 2.3, Equation 2.4 and Equation 2.5 are all constructed with three parameters which are X1 for GDP, X2 for population and X3 for total annual vehicle-km. Also, all equations have coefficients w_i. Sonmez *et al.* (2017) states coefficients can be found with observed historical data of parameters. These historical data are between 1970 and 2013. In addition to these data energy consumption of the transportation sector is known between these years too. Thereby statistical parameters could be computed, and the one with best outcome will be selected in the end. The linear model behaves better than other two models. Even so all of them can be used while estimating future demand. Figure 2.6 shows that the results of the TED, calculated with the three methods Sonmez *et al.* (2017) proposed, aligns with the observed data.

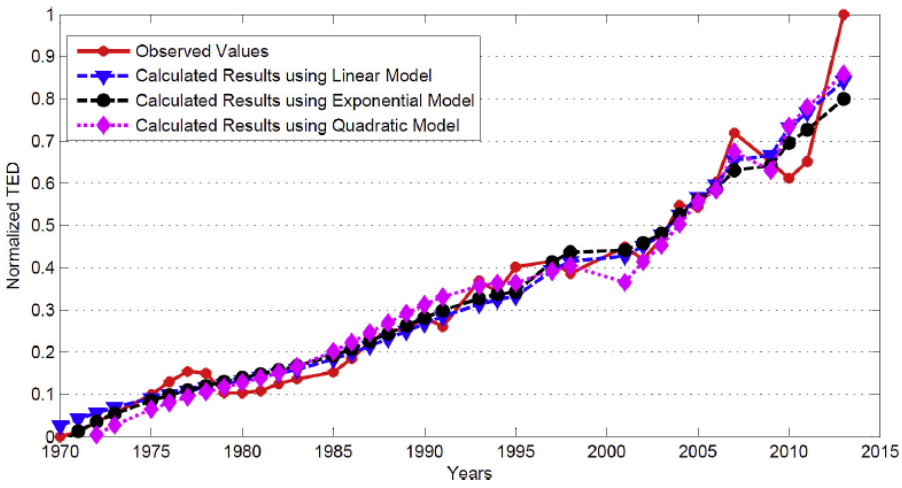

Figure 2.6. Performance of TED estimation models for the training set (Sonmez *et al.*, 2017).

Apart from coefficients Sonmez *et al.* (2017) properly estimates future value of GNP, population and total vehicle-km. Although finding coefficients via ABC algorithm is a vital step, forecasting data are equally important as coefficients for accurate estimation. Sonmez *et al.* (2017) prefer two scenarios about it. First scenario is basi-

cally focuses on curve fitting approach. Figure 2.7, Figure 2.8 and Figure 2.9 shows the curve fitting results of population, GNP and vehicle-km respectively. With the help of results, cubic equation is preferred rather than others because its performance is clearly better. In the second scenario, national and international sources play a role in calculating future parameters. The estimated data are taken by these sources without any change.

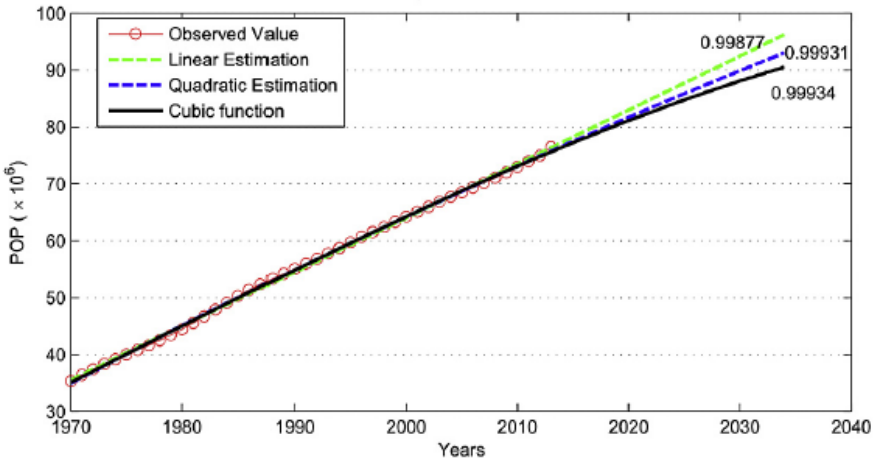

Fig. 5. Curve fitting for population of Turkey.

Figure 2.7. Performance of TED estimation models for the training set (Sonmez *et al.*, 2017).

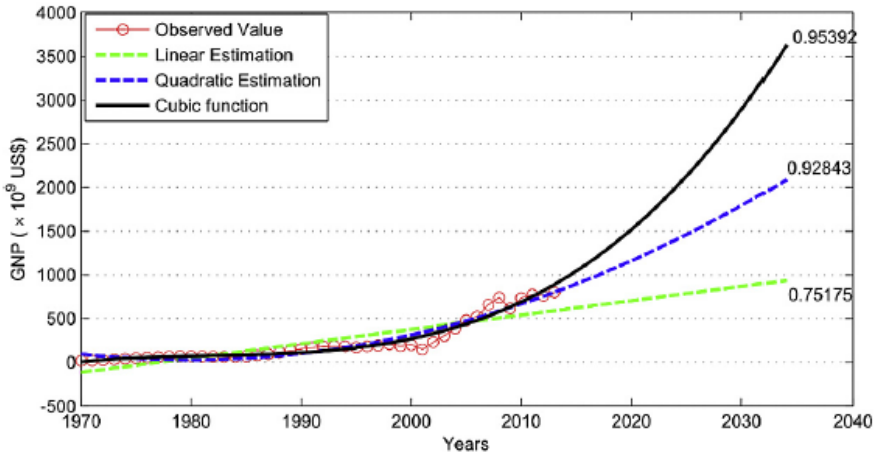

Fig. 4. Curve fitting for GNP of Turkey.

Figure 2.8. Curve fitting for GNP of Turkey (Sonmez *et al.*, 2017).

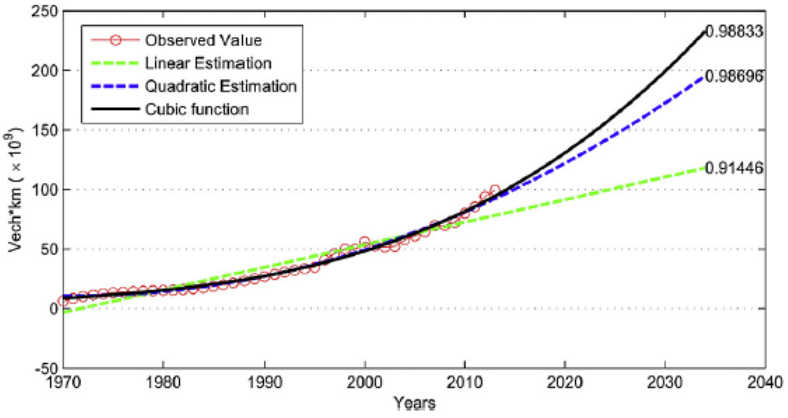

Fig. 6. Curve fitting for vehicle-km of Turkey.

Figure 2.9. Curve fitting for vehicle-km of Turkey (Sonmez *et al.*, 2017).

Behaviors in both scenarios are similar which can be seen in Figure 2.10 and Figure 2.11. In both scenarios, quadratic model increases drastically by the years and exponential and linear models have kind of a steady pace. According to first scenario transportation energy demand in Turkey vary from 30 MTOE to 160 MTOE. However, in the second scenario these values are between 35 MTOE and 115 MTOE. Namely in the second scenario the estimated values are closer than the first one.

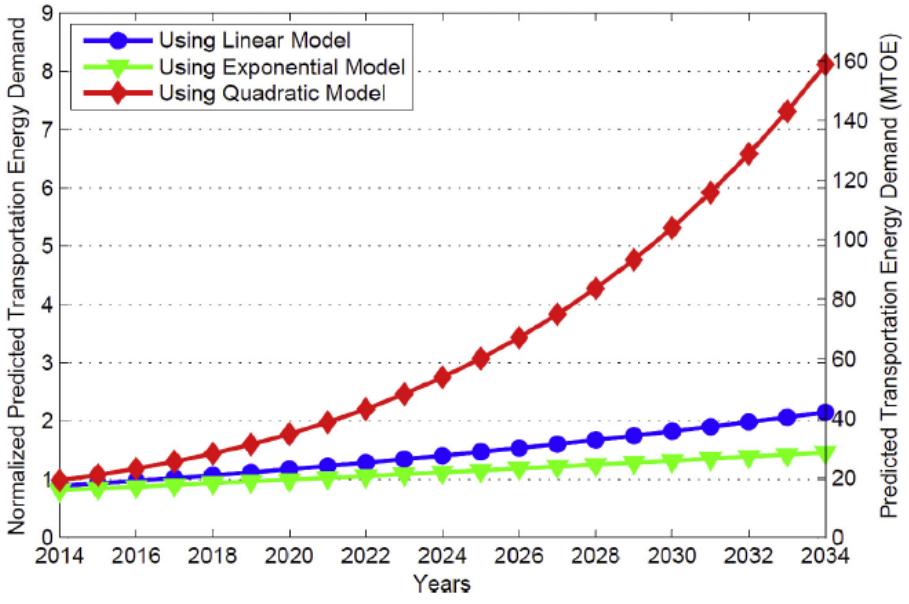

Figure 2.10. The TED estimations of Turkey from 2014 to 2034 based on Scenario 1 (Sonmez *et al.*, 2017).

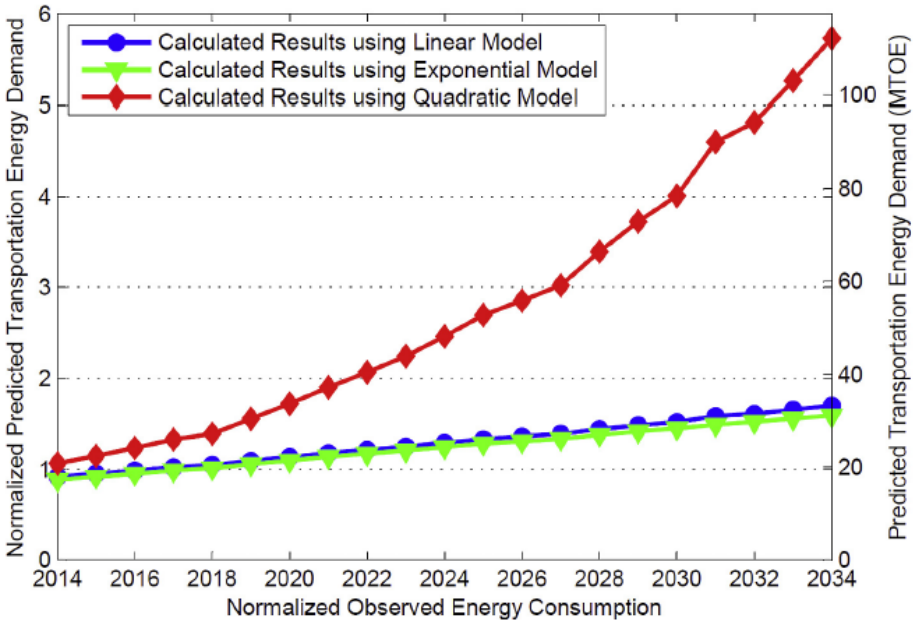

Figure 2.11. The TED estimations of Turkey from 2014 to 2034 based on Scenario 2 (Sonmez *et al.*, 2017).

Eren and Dogan (2017) handle the subject, energy demand in transportation sector, in a different way. Although there are many algorithms to estimate the energy demand, in the perspective of Eren and Dogan (2017) Markov model is very beneficial while estimating future energy demand.

Teaching-learning-based optimization algorithm (TLBO) is another algorithm to estimate the energy demand. Tefek *et al.* (2017) uses TLBO while calculating the energy demand in Turkey.

First of all, TBLO is a social optimization algorithm that bases on the interaction between teachers and students. Learning capability of students is directly related with the capacity of teachers. In every step of algorithm successful students are selected, and analyzed. There are three main parameters in TLBO which are number of students, number of class as well as number of iterations. Moreover, this algorithm consists of two phases that are students and teachers.

In the process of “teacher”, students try to learn from teacher. Namely, teachers should increase the knowledge of class. So, it means that the level of the knowledge in the class can come up to teachers‘ level at most. Thus, the difference between teachers and students can be calculated, and best functions are recorded to use in the second phase.

Students learn the knowledge by discussing and interacting together in the process of “student”. If one of the students is better than others, then other students update their knowledge. In this way, this algorithm approaches optimum values easily and quickly without any converging problem.

Tefek *et al.* (2017) estimate energy demand in Turkey with the help of five parameters that are population, gross domestic product, installed power, gross electric generation and net electric consumption. These parameters are used to estimate energy demand within linear, quadratic and exponential models. Energy demand is calculated by three different scenarios. These scenarios are created according to low,expected and high energy demands. Table 2.1 shows the findings of three scenarios approached by linear,quadratic and exponential models with five parameters mentioned above. Finally, energy demand in Turkey in 2030 varies from about 170 MTOE to 270 MTOE depending on scenarios.

Transport energy demand in Turkey is estimated by Ceylan *et al.* (2008) in different way. This way includes meta-heuristic harmony search algorithm (HS). This algorithm is firstly developed by Geem *et al.* (2001). This algorithm makes contact between orchestra and optimization technique. In fact, composing best melody directly bases on playing all of the instruments in a good harmony. In this algorithm objective function should approach to the best solution having the best result.

Table 2.1. Future projection of total energy demand in MTOE according to the LEH scenarios (Tefek *et al.*, 2017).

Years	Low scenario (Mtoe) HGT (models)			Expected scenario (Mtoe) HGT (models)			High scenario (Mtoe) HGT (models)		
	L	Q	E	L	Q	E	L	Q	E
2015	125.5	126.1	125.6	126.3	126.9	126.7	126.3	127.7	127.7
2016	128.4	129.2	128.7	130.1	130.9	130.8	130.1	132.6	133
2017	131.4	132.3	131.8	134.1	135.1	135.1	134.1	137.9	138.5
2018	134.4	135.5	135	138.1	139.4	139.6	138.1	143.5	144.2
2019	137.5	138.7	138.3	142.3	143.9	144.2	142.3	149.5	150.3
2020	140.6	142	141.7	146.6	148.7	149	146.6	156.1	156.7
2021	143.8	145.3	145.1	151	153.7	154	151	163.1	163.3
2022	147	148.7	148.7	155.6	159	159.2	155.6	170.8	170.3
2023	150.3	152.1	152.4	160.3	164.7	164.5	160.3	179.3	177.6
2024	153.7	155.5	156.2	165.2	170.6	170.1	165.2	188.5	185.3
2025	157	158.9	160	170.2	176.9	175.9	170.2	198.6	193.4
2026	160.5	162.4	164	175.4	183.6	182	175.4	209.9	201.9
2027	164	165.9	168.1	180.8	190.9	188.2	180.8	222.3	210.8
2028	167.5	169.4	172.4	186.3	198.7	194.7	186.3	236.2	220.2
2029	171.2	173	176.7	192	207.1	201.5	192	251.7	230
2030	174.9	176.6	181.2	198	216.2	208.5	198	269	240.3

HS algorithm is used in various engineering problems (Geem *et al.*, 2001). In this algorithm decision variables can be created without any need of initial solution. In addition, optimization procedures continue with many analysis simultaneously. Thus, the best result is searched in many points which protects against having local solution.

Ceylan *et al.* (2008) generate linear, exponential and quadratic models via HS algorithm. The parameters in the models are again GDP, population as well as the total annual vehicle-km. Hence weighting factors are found with the help of observed

data. Then expected data for the future are collected from national institutions. In the end, linear and exponential models have better value in R2. However, avoiding over or under estimation, all of the models can be used for future estimation. Finally estimated transport energy demand in 2025 can be seen in Figure 2.12 as between 30 and 47 MTOE according to models. Nevertheless, linear model shows almost the same behavior with the estimation of Ministry of Energy and Natural Resources (MENR).

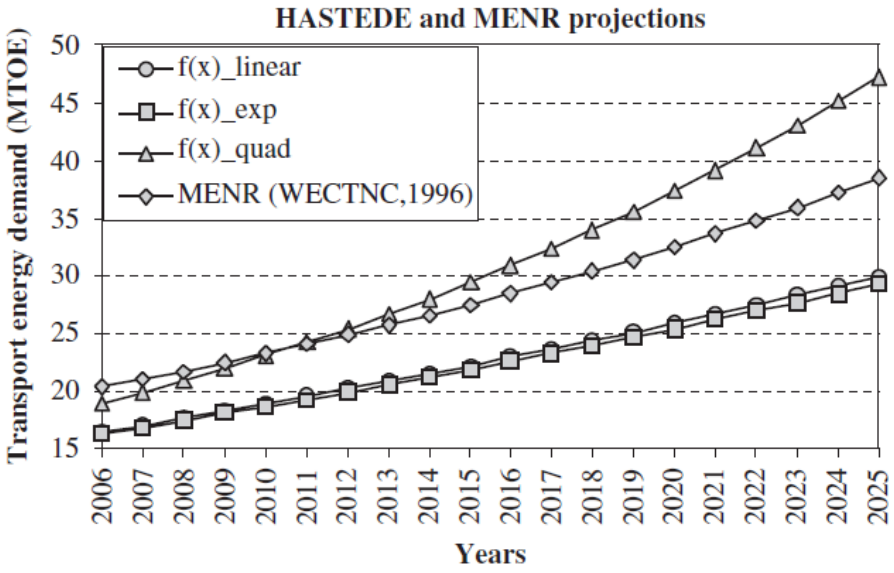

Figure 2.12. Future estimations of transport energy demand using HASTEDE and MENR (H.Ceylan *et al.*, 2008).

Genetic algorithm is one of the heuristic methods which originates directly from biological process. While creating new generation, there are crossing over and mutation processes between solutions. These processes enable to have better solution in every generation. In other words, solution sets converge, in every following generation, to the global solution.

Haldenbilen *et al.* (2005) uses this algorithm to forecast transport energy demand in Turkey. It is predicted that energy demand is dependent on GDP, population and total vehicle-km. Then these parameters are brought into linear, exponential and quadratic equations. To find coefficients of these equations, genetic algorithm is used. After obtaining coefficients, estimation of parameters is considered. National and inter-

national sources help them to find expected values of parameters. Lastly, they obtain the transport energy demand via different equation forms. In the maximum demand case which is in quadratic forms total energy demand is almost 85 MTOE. Figure 2.13 contains all of the equation forms, which estimates the transport energy demand, as well as the MENR projections.

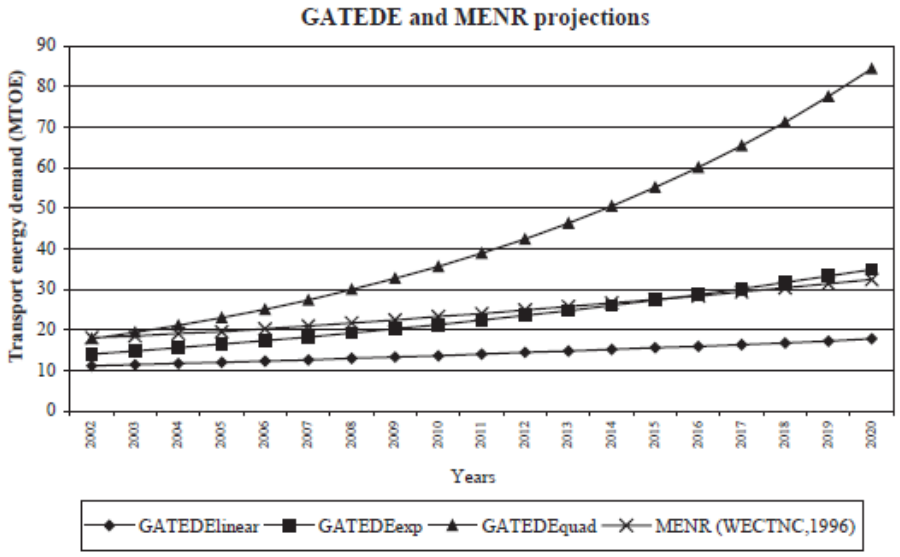

Figure 2.13. Future projections of transport energy demand using GATEDE and MENR (WECTNC, 1996) (Haldenbilen, Ceylan, 2005).

Markov model is a special stochastic model which claims that future states are affected only and only by the current state. The events that occurred before the current state has no impact on future states. In other words, future situation is estimated under favor of current states and all of the possibilities in future states.

Eren and Dogan say that all of the algorithms can be applied in estimation of energy demand successfully. However, under new energy policies these systems are not very qualified while analyzing and estimating the energy demand. Energy demand could change quickly under new energy policies. In addition, the behaviors of energy end users fluctuate randomly. Therefore, to show the impact of new policies and random fluctuations of energy end users, Markov model is selected by Eren and Dogan (2017).

2.2. GHG Emission From Transportation Activities

Energy is one of the primary needs in human life. In every part of life, people use energy like electronic devices, household appliances and transportation vehicles. Although intended purpose of energy changes, there are limited ways to produce energy. However, these methods generally create GHG emissions which have harmful effect on environment. Carbon dioxide is one of the vital GHG's, and is estimated to cause almost %70 of radiative forcing of climate in 21st century (IPCC, 2001a).

When people start to work for energy demand, they consider that industry, households and transport constitute main part of the energy demand. In that case it is obvious that these sectors are major source of GHG emissions as most of the energy is used in these areas Figure 2.14.

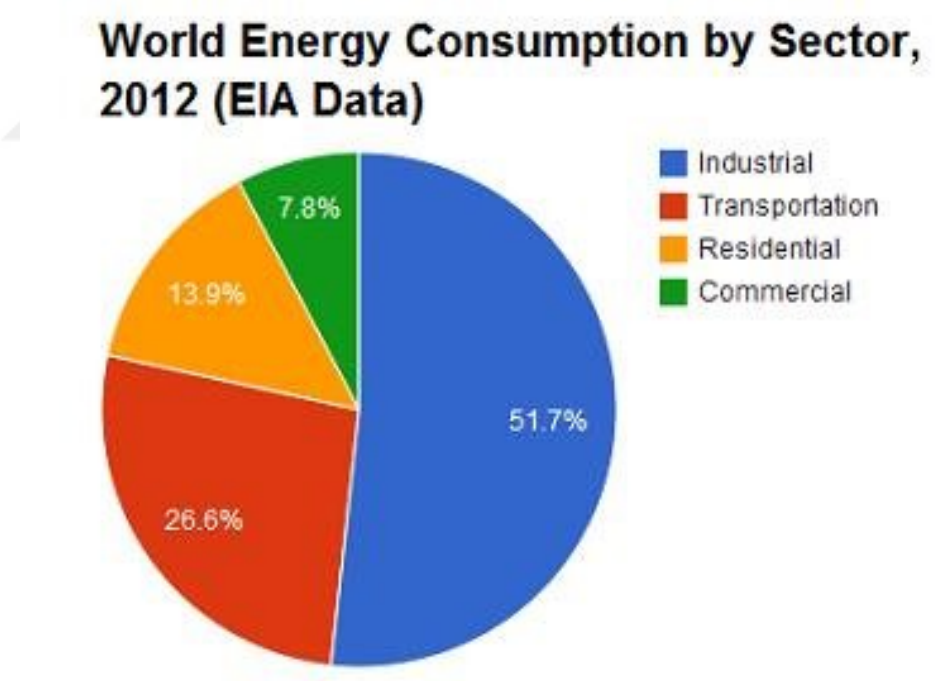

Figure 2.14. World energy consumption by sector (EIA Data, 2012).

According to Kyoto Protocol and Paris Agreement entire world wants to decrease GHG emissions. That's why people focus on evolving the sectors that use more energy, in the way that they emit less GHG.

Hickman *et al.* (2007) study about transportation sector to decrease GHG emission in UK. According to Hickman *et al.* (2007) in the future CO_2 emissions will rise in the UK. Similar to general behavior, CO_2 emissions from transportation sector increases as well. Moreover, the emission share of transportation sector rises year by year as can be seen in Table 2.2 below. This means that transport will have more influence on GHG emissions in the future. Namely transport will create more problems to the environment in future.

Table 2.2. Carbon dioxide emissions projection by end user in the UK (Hickman, Banister, 2007).

Carbon dioide emissions projection by end user in tht UK					
End user category	1985	1990	2000	2015	2030
Road transport	28	35	38	42	49
Railways	1	2	2	1	1
Civil aricraft (domestic)	0	0	1	1	1
Shipping (domestic)	2	2	1	1	1
All transport	31	39	41	47	52
all emissians	156	161	149	153	166
Units: million tonnes of carbon (MtC)					

In order to reduce CO2 emissions in transport Hickman *et al.* (2007) present policy packages like low emission vehicles, alternative fuels, pricing regimes etc. All of these policy packages have carbon reduction potential range. Two of the most effective reduction scenarios having the highest potential are low emission vehicles and alternative fuels. Change in fuel oil habits lead to falling GHG emissions substantially. Thus, Hickman *et al.* (2007) think that reducing GHG emission into acceptable value in transport sector depends on strong behavioral change and strong technological change directly.

Tight *et al.* (2005) study about sustainable level of CO2 emissions from transport activity in the UK in 2050. In this study, they have two situations which are

stabilization and scenarios. In stabilization, appropriate levels of atmospheric GHG is forecasted until 2050. Then with the help of some scenarios they make an assumption about GHG emissions from transport. The emission levels are between 8.2 to 25.8 MtC. Although in some scenarios the emission target is weak, it still generates a considerable reduction. GHG emissions cause global warming which jeopardize the environment and human life. Normally some of solar radiation is reflected from earth, and absorbed radiation warms the surface of earth. Nonetheless the amount of reflected solar radiation diminishes due to absorbing effects of CO_2. Namely CO_2 molecules absorb the solar radiation. For this reason, the temperature of the earth gets higher day by day. Human activities are, without a doubt, the main cause for the increase in temperature. This is all to say that GHG emissions owing to industry, household and transport causes drastic increase in earth's temperature (Karl and Trenberth, 2003).

Chapman (2007) examines the role of transport in climate change. Almost all of the vehicles are dependent on fossil fuels, i.e oil.. Fossil fuels have a negative influence on environment because they are one of the main reasons for GHG emissions. But the part it's seen up to this point is the tip of the iceberg as -wells to wheels' approach is overlooked. Focusing on the emissions that come from the vehicles is not enough, the reason is that producing and distributing oil influence the environment by emitting GHG significantly. (Weiss *et al.*, 2000; Mizsey and Newson, 2001; Johannsson, 2003).

According to Chapman (2007) motor vehicles take the first place in transport sector by GHG emissions. This means that cars have to be considered while searching a solution for GHG emissions. Thanks to advancing industry their mitigation effect will be perceived day after day. Chapman (2007) claims that alternative fuels and vehicles are parts of the solution. Nonetheless these parts have few disadvantages.

Battery powered electric vehicles and hybrid electric vehicles are two of the alternative fuels and vehicles. Their emission is almost zero at source. In addition to this they are more efficient in contrast to traditional internal combustion engines (Sperling, 2003). Moreover, electricity which is the main source of their kinetic energy is generated from some on-board generators and braking. On the other side of the coin,

source of the new fuel, namely electricity, is important because production process of the sources can still emit GHG unless they are renewable or nuclear.

Michaelis *et al.* (1999) suggest that CO2 emissions from transport sector might rise up to %150 from 1990 to 2025. This prediction shows that in order to decrease GHG emissions transport sector should be taken into account. Michaelis *et al.* (1999) states that although reduction in GHG emissions in other industries might compensate the amount of transport emission growth. But the continuing growth could not be compensated, and transport sector should be concerned for.

In addition to the articles national climate change action plan of Turkey which is published by Ministry of Environment and Urbanization (MoEU) indicates that GHG emissions from transport sector in Turkey have increased almost %80 between 1990 and 2009. According to Figure 2.15 road transportation plays a significant role on this rise. In fact, road transport causes the most CO_2 emissions generated by the transport sector. From another point of view there is a decrease in CO_2 emissions per vehicle-km. The most impressive reason in this decrease is changing and improving in vehicles and their engine technologies.

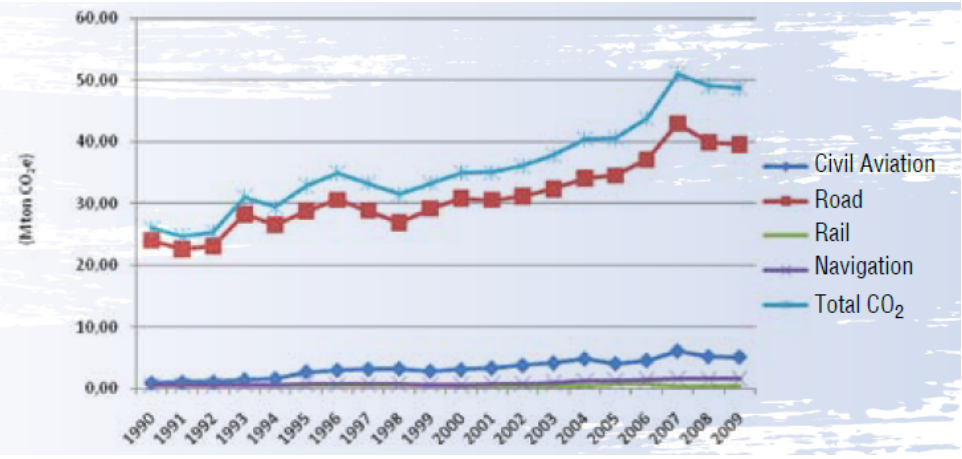

Figure 2.15. CO_2 emissions in transportation sub-sectors in Turkey in MT CO_2 equivalent (1990-2009) (NCCAP, 2011).

3. METHODOLOGY

3.1. General

Energy is vital for every form of life. Mankind has been in a search for energy from the first day up to today for different purposes. At first the sole intention was survival. Civilization process of the humanity created new areas for energy usage . The biggest fundamental change in human life was the industrial revolution. Industrial revolution has changed human life dramatically. It enabled people to use machinery like power engine, which uses different source for energy fossil fuels. Development process has not stopped with the fossil fuels, renewable energy sources were discovered and started to be used.

This vital change has affected human life positively. Their life quality has increased strikingly. People can produce and mobilize effectively compared to past. Thus, the usage of machines has raised extensionally. But this trend started to show its damaging impact later. While producing energy, these machines emit some gasses that are harmful for environment. These gasses are named greenhouse gasses. Energy is provided by burning the fossil fuels and releasing their internal energy. During energy generation process some gasses such as carbon dioxide, nitrogen oxide etc. are produced and emitted unfortunately.

Nowadays the effect of these gasses starts to become more frightening because these gasses damage the environment gradually, and finally they reveal a new phenomenon called global warming. If the number of these gasses accrues in the atmosphere, they absorb more sunlight.

Hence the temperature of the world increases naturally, and this situation causes climate changes all around the world. Climate changes are really dangerous for people since their living areas are affected damagingly. For this reason, they might lose their living space and nutritional sources.

Because of the fact that GHG emissions is a critical problem to solve, people should look for solutions. First of all, energy demand should be calculated for future. It is obvious that GHG emissions will get higher if the demand for energy increases. In the meantime, it is very hard to estimate the future energy demand, for there is not a formula which gives the exact value. Therefore, algorithms can be used generally. There are many types of algorithms, and all of them have some advantages and disadvantages differently. In addition to this, energy demands in every sector can depend on different parameters too. Due to these reasons, most appropriate one should be selected while estimating the future energy demand.

Additionally, parameters that will be used in algorithm should be selected correctly. Dominating factors that constitute energy demand can be different from one sector to another. As well as selecting right parameters, forecasting of parameters is important too. In order to find past and obtaining future parameter values, national and international reports are considered. Moreover, reports of corporations can be a better way to calculate future data too.

Although increase in energy demand causes many troubles like global warming, their solution ought to be considered in every sector separately. One of the main sources of GHG emissions is the transport sector. Especially road transport has a high share in GHG emissions. If a permanent solution can be found in every sector, harmful effect of GHG emissions diminishes dramatically.

Many scientists try to find a new energy source besides from fuel oil owing to excessive use of it by the highway transportation. Cars usually need diesel or gasoline to produce kinetic energy. In addition to these fuel types LPG is another way to provide energy for cars.

Nonetheless there is a new energy source recently. This energy source is electrical energy, and it emits almost zero GHG while driving. There are two types car in this way yet which are electric and hybrid car. Both of them use electric energy directly to produce kinetic energy.

On the other side of the coin these cars create new type of demand in energy sector. Much more electricity should be produced if the number of electric cars increase. Thus, the production process of electricity plays a vital role on GHG emissions. There are many ways to produce electricity. These ways are coal-fired, natural gas, hydraulic, nuclear, thermal, wind and solar power plants. However, GHG emissions amounts of all power plants are different. The maximum advantage of electric cars can be gained only by using environmentally friendly power plants. Namely there might not be a decrease in GHG emission although people use more electrical cars because their electric demand is supplied by power plants which emit a lot of GHG.

In summary, need for energy rises day by day, and this situation affects environment negatively. There are some solutions in order to reduce the negative effect of energy demand. Nevertheless, people should take careful steps while applying the solution since their approach might change just the methods of emissions.

3.2. Future Energy Demand in Highway Transport Sector

Transportation sector generally uses energy in the form of petroleum and other liquid fuels. These sources are fossil fuels, and they are on a limited scale worldwide. That's why transportation sector should find another source in a short notice. In addition to limited scale these sources have negative influence on environment and human health too. Therefore, energy demand should be estimated in order to find new solutions in transportation sector and forecast its influence on environment.

Calculating the energy demand needs models or algorithms to be used. One of the algorithms is Genetic Algorithm which performed well in the past studies. Genetic algorithm is adaptive heuristic search algorithm. While estimating the future demand, Genetic algorithm needs past data, and then it tries to optimize the energy demand.

It is known that energy demand in transport sector is influenced by GNP, population as well as total vehicle-km. These three parameters play an important role on energy consumption. Hence expected future values of these parameters should be

attained correctly. Scientific reports and some regression models are useful in this case.

3.2.1. Genetic Algorithm

In recent years, thanks to development in computer technologies solving process of the complex problems has simplified. Hence optimization and algortithms are being used in every aspect of researches. Genetic Algorithm is one of the methods in solving complex problems.

Genetic algorithm is an adaptive heuristic search method based on evolutionary ideas of genetics and natural selection. This algorithm was firstly developed by John Holland and their friends in University of Michigan. His works, Adaptation in natural and artificial systems, were published in 1975.Still the interest in Genetic Algorithm rises nowadays. Genetic Algorithm is useful for solving problems as well as modelling, and its area of usage extends day by day.

There are four differences of Genetic Algorithm from other optimization techniques:

- Firstly, Genetic Algorithm focuses on codes of parameters instead of parameters.
- Secondly, solution is searched in different points instead of one point. Therefore, Genetic Algorithm can operate without having local optimum.
- Thirdly in Genetic Algorithms objective functions are directly used in data processing in the place of its derivatives.
- Finally, Genetic Algorithms have accidental rules rather than deterministic rules.

Genetic Algorithm has some elements that help to manipulate the system. One of these elements is chromosome. Actually, chromosome is individuals of the population in the algorithm. Individuals are coded in chromosome with their values. The length of the chromosome depends on values of individuals. Fitness function is another vital element in Genetic Algorithm. This function enables the algorithm to calculate error of each individual. In addition to that, size of the population and number of generations

are another effective element of the algorithm. Their values are selected with respect to problems. However, Genetic Algorithm performs well even in small numbers.

The procedure of Genetic Algorithm is described as follows:

(i) Starting population is generated randomly. Generally, population is created as binary bits. Binary bits consist of 0 and 1. Population includes individuals, and the number of individuals depends on problems.

(ii) After generating population, the suitability of each individual is calculated with the help of the fitness function. This function is the brain of the algorithm. In order to have the successful algorithm the fitness function has to be productive and sensitive.

(iii) In this step chromosomes are selected from the population. There are some techniques to select chromosomes. Some of these techniques are roulette wheel, rank selection, steady state and elitism. While selecting chromosomes, fitness function is usually used in the algorithm. Values of the fitness function are rated according to limit values. If individuals perform well, in other words they have better limit values, they have more possibility to be chosen for the next generation. But this is not an obligation; other individuals might be chosen as well.

(iv) From the selected chromosome, new generation will be created again. In the generation process, there are some operators like crossover and mutation.

(v) After creating new chromosomes old individuals are annihilated. In this way, the size of population doesn't change with respect to generation.

(vi) The suitability of the population is calculated again. It continues until having the best value in the fitness function or reaching the maximum size of the population.

Operators of Genetic Algorithm, crossover and mutation, are crucial steps of the algorithm. Crossover is the most important operator in Genetic Algorithm. Generally, crossover occurs between two selected chromosomes via changing genes of two chromosomes. Changed point of the genes is totally random. Thanks to crossover, suitability of the population rises and they return better limit values in the fitness function.

In addition to crossover, mutation is an another important step for the algorithm. After some generations, variety of the population might decrease, so the algorithm can't generate new chromosomes. In other words, the system might start to be stable. At this point mutation has a key role in algorithm. Some genes might be changed due to mutation. Thus, mutation gives variety to the system. By the way, frequency of the mutation is dependent on the problem. It doesn't have any exact value.

Selection, crossover and mutation process are shown below:

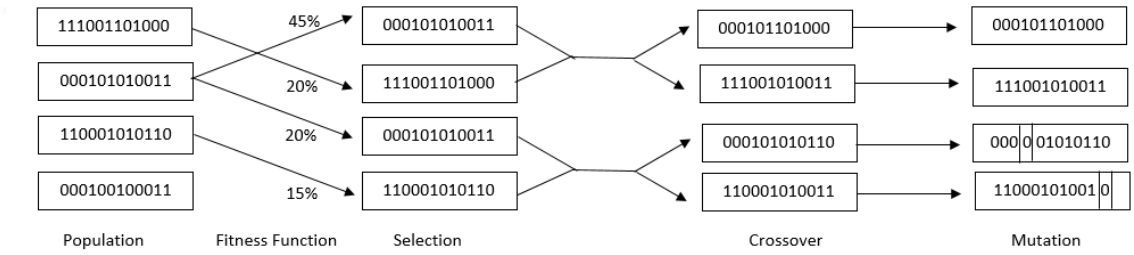

Figure 3.1. Flowchart of GA processes.

To sum up Genetic Algorithm is attractive for complex problems because it needs very few information about the problem. Biggest advantage of the Genetic Algorithm is that the optimization process does not get stuck in a local optimum when faced.

3.2.2. Genetic Algorithm Application on The Case of Turkey

As Turkey has been developing in the means of population, economics, industry etc. its need for energy grows relatively. Energy consumption increases in all sectors including transportation. Because of the fact that energy demand increases day by day, estimating future trends of energy demand is necessary in all sectors for making sustainable long termed plans.

With the help of observed data, Turkey's energy demand on highways is calculated via Genetic Algorithm. In the algorithm, a model is needed for the fitness function.

According to Haldenbilen *et al.* (2005) exponential form behaves better than other models. Therefore, exponential form is selected as follows:

$$E = w_1 {X_1}^{w_2} + w_3 {X_2}^{w_4} + w_5 {X_3}^{w_6} + w_7 \tag{3.1}$$

$$FitneesFunction = w_1 {X_1}^{w_2} + w_3 {X_2}^{w_4} + w_5 {X_3}^{w_6} + w_7 - E \tag{3.2}$$

In the Equation 3.1 and Equation 3.2, E represents energy demand in MTOE. X_1, X_2, and X_3 are GNP, population and the total vehicle-km respectively. In the exponential model, there are 7 weighting factors which are calculated by Genetic Algorithm. In order to calculate these weighting factors, observed historical data was used between 2001 and 2016.

All observed data are shown in the Figure 3.2 below. Turkey's GNP is collected from World Bank Open Data. Population of Turkey and total vehicle-km are gathered from Turkish Statistical Institute and its reports. It is clearly seen that almost all data tend to increase year by year. Only GNP fluctuates in recent years because of the economic crisis.

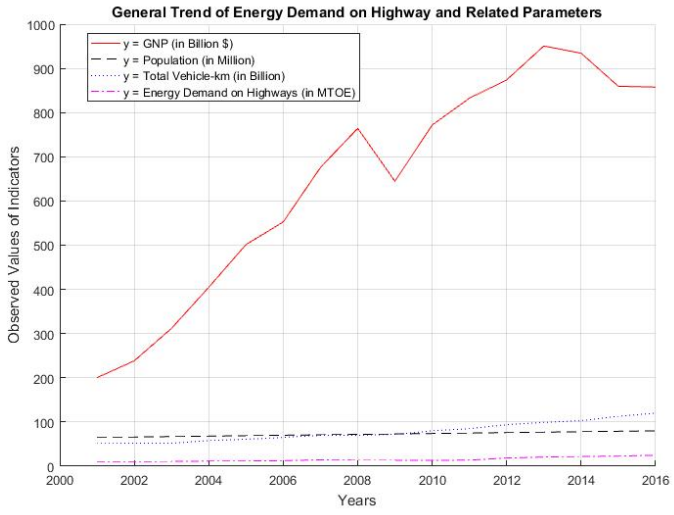

Figure 3.2. General trend of energy demand on highway and related parameters.

After identifying the data, the algorithm is designed properly. Number of generations and chromosomes are 5000 and 200 respectively. Chromosomes are in binary, and every weighting factor consists of 11 binary digits. It means that the weighting factors vary from 8 to -8 nearly. Then initial chromosomes are randomly generated for the first generation. These chromosomes are predecessors of the model. All produced chromosomes are converted from binary to decimals and performed in the Equation 3.2.

From the fitness function errors of the chromosomes are determined separately. These values are very important in this model, because they are used for selecting suitable chromosomes for the next generation. Selection properties of these chromosomes are identified according to their errors. The less error a chromosome has, the more possible it is to be selected.

Selection part repeats itself 50 times by selecting 2 chromosomes. In every selection 2 chromosomes produce a new chromosome with crossover and mutation. In general, there are 50 new baby chromosome that will be used in the next generation.

In this model, crossover and mutation are designed as the sinus formula of generation number. In this way, their frequency doesn't stay stable, and behavior of the population is seen clearly in Figure 3.4. Moreover, it allows to control accuracy of the model. There is a strong relation between the value of the frequency and the error of the population. Frequency of the crossover is maximum 0.8. The highest value of the frequency that can be taken for the Mutation is 0.7 which is less than the crossover. In addition, there is another mutation for sign of the weighting factors. However, its frequency is relatively less compared to others; it is less than or equal to 0.06. The aim of the limited frequency of the sign mutation is that changes in sign, i.e. from negative to positive or from positive to negative, affects the system redundantly.

This process repeats 5000 times. Namely Genetic Algorithm process continues until the last generation obtained. After the process, there are some important graphs of the system which shows errors and tendency of the population.

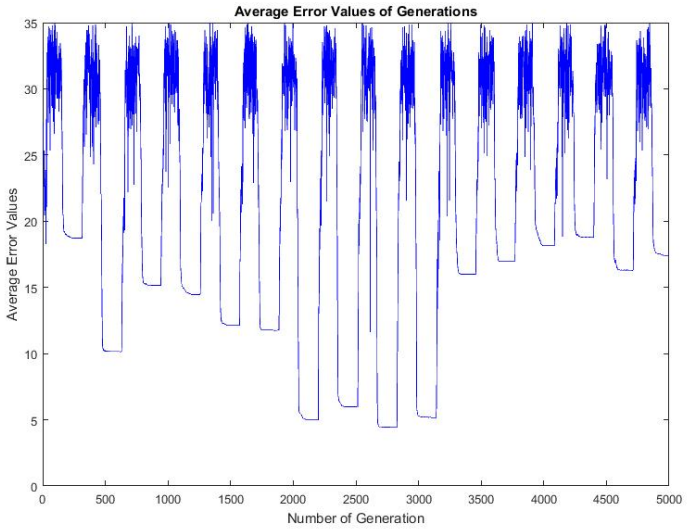

Figure 3.3. Average error values of generations.

Figure 3.3 explains average error values of all generations. As seen on the figure there is a fluctuation of average error. After some generations, the value of mutation and crossover increases which cause a significant change in errors. But then the algorithm converges the system to return better values again. Although values of some errors are over 10, some of them have error values less than 5.

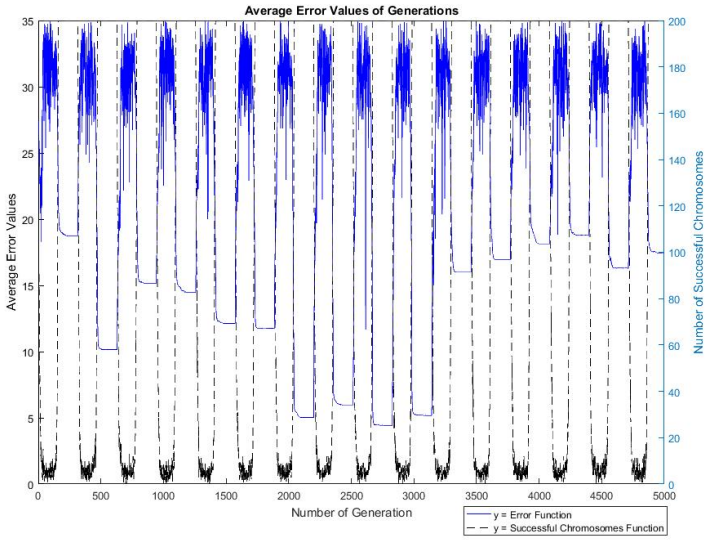

Figure 3.4. Average error values of generations and number of successful chromosomes.

Figure 3.4 involves successful chromosomes of every generation and error function. The figure shows that if errors of the chromosomes increase, then successes of the chromosomes decrease. Figure 3.4 includes the value of error between 0 and 35. In generations with high error, only about 10 out of 200 chromosomes behave successfully. With the help of this graph consistency of the system can be understood explicitly.

While analyzing Figure 3.5 it is obviously seen that generations between 2650 and 2850 have the best error value in comparison with the other generations.

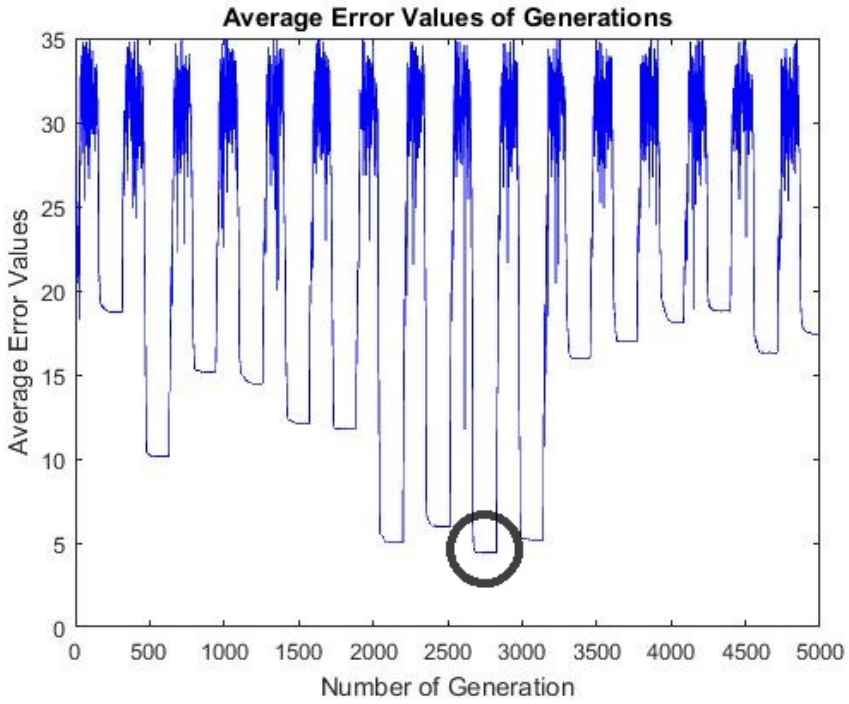

Figure 3.5. Average error values of generations and best generation.

Even though there are other generations with good error values, the best one comes at about the 2800th generation among the others. Therefore, solution is one of the chromosomes of these generations. When these generations are examined in detail, 2827th generation comes up with the best result. Sum of the errors of 2827th generation is 4.30.

After finding the best generation, weighting factors of Equation 3.1 are determined in the next step. Binary chromosome of 2827th generation is converted to deci-

mals, and then plotted as in Figure 3.6. On the Figure 3.6 numbers on x-axis are the weighting factors. Y-axis shows the value of the weighting factors. For the interval between 2650th and 2850th generation all of the weighting factors are drawn on Figure 3.6. After that, average value of these weighting factors is calculated separately. By this way weighting factors are calculated on Figure 3.6, and shown in Table 3.1.

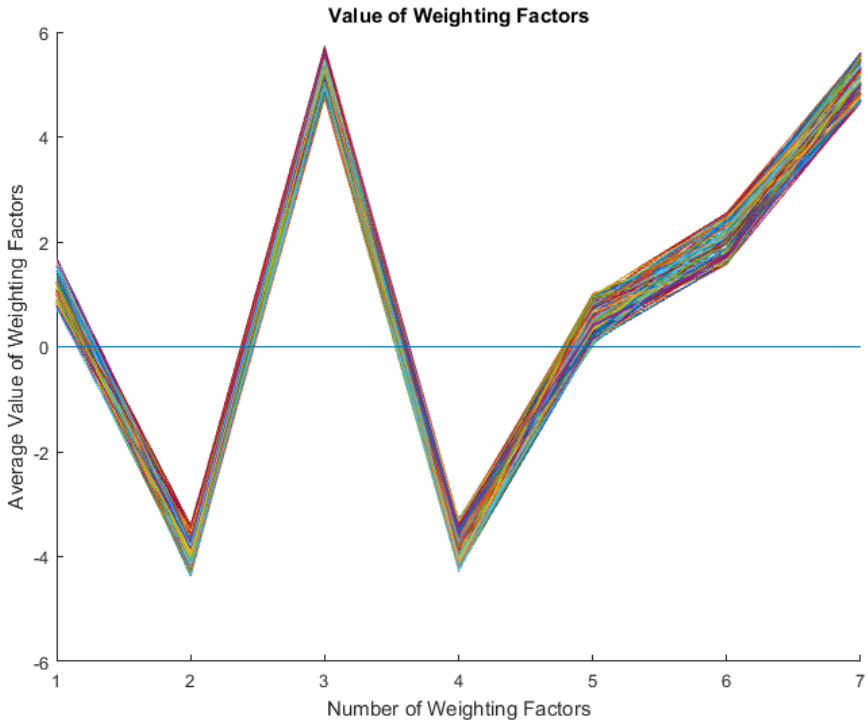

Figure 3.6. Values of weighting factors.

Table 3.1. Values of weighting factors.

Weighting Factor	Value
w1	0.717
w2	-4.384
w3	4.737
w4	-4.283
w5	0.012
w6	1.559
— w7	4.637

After all, Equation 3.1 takes its final form:

$$E = 0.717(X_1)^{-4.384} + 4.737(X_2)^{-4.283} + 0.012(X_3)^{1.559} + 4.637 \tag{3.3}$$

Now general behavior of the Equation 3.3and observed energy demand data might be compared in one figure so that their trends can be compared for a given time interval.

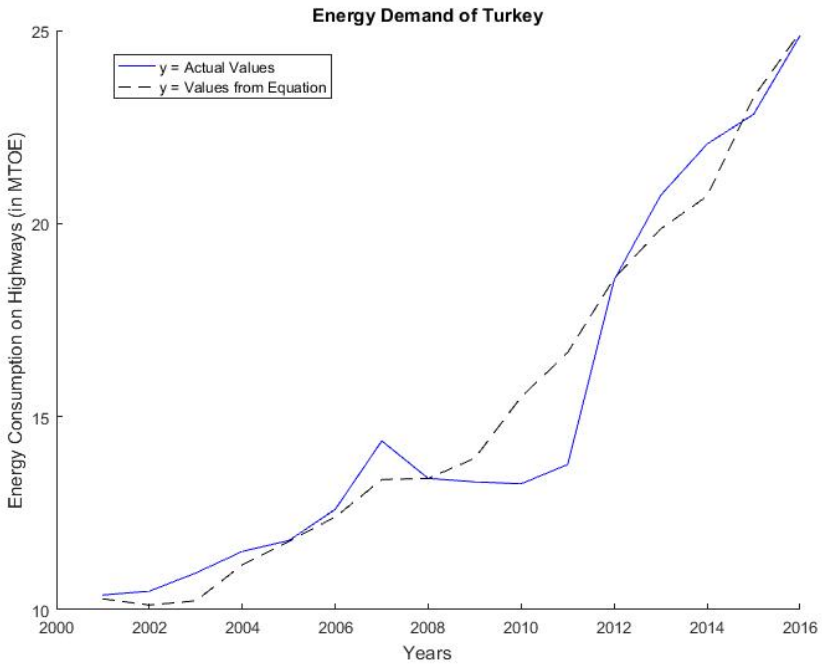

Figure 3.7. Energy demand of Turkey.

Observed energy consumption and calculated energy consumption lie on the Figure 3.7. Former is represented by straight line, and latter is seen as dashed line. Tendencies of both graphs are very similar. Energy consumption on highways increases generally even though it stagnates in some years. Demand for energy on highways has risen more than double almost in 15 years. It was about 10 MTOE in 2001, and approached about 25 MTOE in 2016. Coefficient of determination, R^2, means the relation between dependent and independent variables. In this model R^2 is calculated as 0.9479.

In addition, relative errors based on the observed values for the model are estimated for every year. As can be seen from Table 3.2, most of the relative errors are less than %5. On the other hand, in the years 2010 and 2011 absolute values of relative errors increase dramatically. In many years relative errors are negative which may result in under estimation of energy demand. Nevertheless, relative errors are positive in last two years and between 2009-2011. Therefore, over estimation of energy demand is found for these years in Equation 3.3.

Consequently, exponential model becomes available to estimate the future energy demand on highways in Turkey. After this point, parameters that are the GNP, the population and the total vehicle-km should be forecasted for the year 2050.

Table 3.2. Comparing the observed energy demand and GA values.

YEAR	OBSERVED VALUE (MTOE)	ENERGY FROM EQUATION (MTOE)	RELATIVE ERROR (%)
2001	10.383	10.282	%-0.98
2002	10.475	10.121	%-3.38
2003	10.95	10.235	%-6.53
2004	11.514	11.164	%-3.04
2005	11.785	11.765	%-0.17
2006	12.604	12.402	%-1.60
2007	14.368	13.366	%-6.98
2008	13.404	13.397	%-0.05
2009	13.309	13.924	%4.62
2010	13.258	15.506	%16.96
2011	13.757	16.663	%21.13
2012	18.543	18.577	%0.18
2013	20.734	19.856	%-4.24
2014	22.058	20.713	%-6.10
2015	22.833	23.285	%1.98
2016	24.866	24.953	%0.35

3.2.3. Turkey's Future GNP Estimation

Relation between GNP and energy demand has been a research topic for a long time. Firstly, Kraft *et al.* (1978) studied about it, and they suggested that there is a unidirectional flow from GNP to energy. Namely economic activities have an impact on consumption of energy. Despite of the fact that the relation between them is not recognized properly, there are many studies including this relation.

Turkey is one of the developing countries. That's why growth rate of the GNP of Turkey tends to be positive generally. On the other hand, its economy might be affected by global economic problems instantly. Therefore, it is not easy to forecast Turkey's GNP.

According to the report "The World in 2050" of a consulting company, PWC, it is expected that Turkey's GNP will be 1705 billion$ and 4087 billion$ in 2030 and 2050 respectively. However, from 2020 to 2030 and from 2030 to 2050 growth rates of GNP are calculated with the help of compound rate of growth formula. The formula is presented below:

$$A = P * \left(1 + \frac{R}{100}\right)^{N} \tag{3.4}$$

Starting value of GNP is represented by P, and A shows the final value of GNP. N is the number of the years desired to be projected. Lastly R is the growth rate in this formula. Rate of growth between 2020 and 2030 is 1.05 although from 2030 to 2050 rate of growth is calculated as 1.044. Hence general situation of Turkey's GNP between 2020 and 2050 is displayed below Figure 3.8.

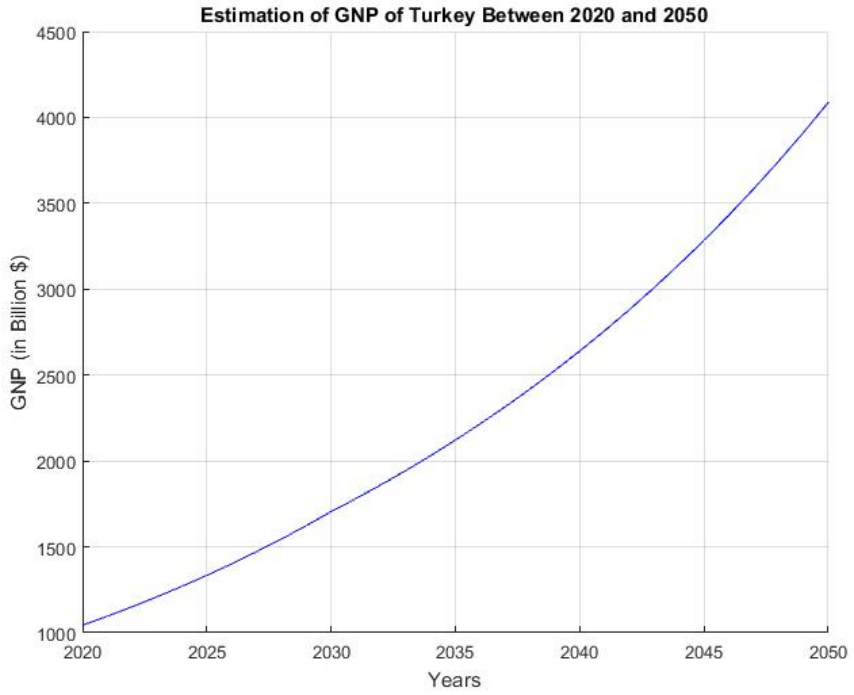

Figure 3.8. Estimation of GNP of Turkey between 2020 and 2050.

3.2.4. Turkey's Future Population Estimation

World population has been rising continuously, which results a growth in every aspect of life from consumption of goods to mobilization. To fulfill the needs, more and more energy is needed. Especially after the industrial revolution, machines were involved heavily in daily life which caused energy demand to increase extremely.

These conditions states that the relation between population and energy should be considered together. Nonetheless energy sources are limited in the world; and this situation will influence their relation in a different way. Hence their relation would not be proportional as the limited source would not meet the required energy level.

As mentioned above, to calculate the energy demand of Turkey one has to take into account of the population growth. Turkey has young population, and its population growth rate is positive. Hence number of population increases each year. With reference to Turkish Statistical Institute prediction of Turkey's population between

2020 and 2050 is shown as follows:

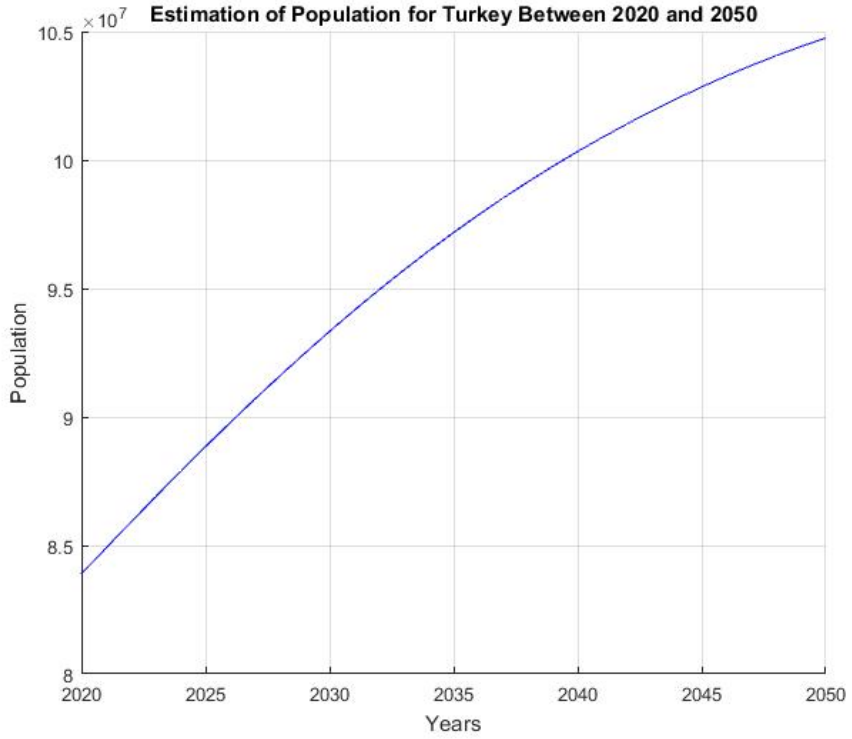

Figure 3.9. Estimation of population for Turkey between 2020 and 2050.

3.2.5. Turkey's Future Total Vehicle-Km

The more you drive, the more you consume. Therefore, consumption causes an increase in energy demand seriously. So, total vehicle-km becomes an important parameter for energy need.

In Turkey number of vehicles rises every year. Thus, total vehicle-km tends to increase as well. In order to forecast the future total vehicle-km, car equivalent approach is proposed.

Vehicle types consist of cars, coaches and trucks. Hence coaches and trucks will be converted to cars in terms of travel distance by Equation 3.5.

$$CEA = \frac{Coachesor\ Truck\ Travel\ Distance}{Car\ Travel\ Distance} \tag{3.5}$$

Equation 3.5 is the formula for transformation coefficients which is represented by CEA. Table 3.3 provides the coefficients of coaches and trucks thanks to observed data between 2010 and 2016. Data is obtained by Turkish Statistical Institute.

Table 3.3. Annual average travel distance and transformation to car equivalent.

YEAR	ANNUAL AVG TRAVEL DISTANCE (CAR)	ANNUAL AVG TRAVEL DISTANCE (COACH)	ANNUAL AVG TRAVEL DISTANCE (TRUCK)	CEA COACH	CEA TRUCK
2010	7.305	17.937	29.280	2.46	4.01
2011	7.240	17.680	31.394	2.44	4.34
2012	7.507	17.415	33.199	2.32	4.42
2013	7.468	18.955	34.301	2.54	4.59
2014	7.391	19.280	33.673	2.61	4.56
2015	7.704	19.387	34.175	2.52	4.44
2016	7.711	18.737	34.248	2.43	4.44
			AVG	2.47	4.4

3.2.5.1. Estimation of Cars' Number. Number of cars in Turkey has expanded rapidly in last 15 years. Habits of Turkish people have a vital impact on this trend. If this trend is appraised as a regression curve, it becomes quadratic equation as shown in Equation 3.6.

$$y = ax^2 + bx + c \tag{3.6}$$

y is number of cars where x is years. a, b and c are coefficients of the equations. Coefficients are found readily while using regression analysis. Finally, equation becomes as follows:

$$y = 4,621.75x^2 - 18,183,619.93x + 17,884,623,664.01 \tag{3.7}$$

Equation 3.7 gives us the expected number of cars which is expressed on Figure 3.10.

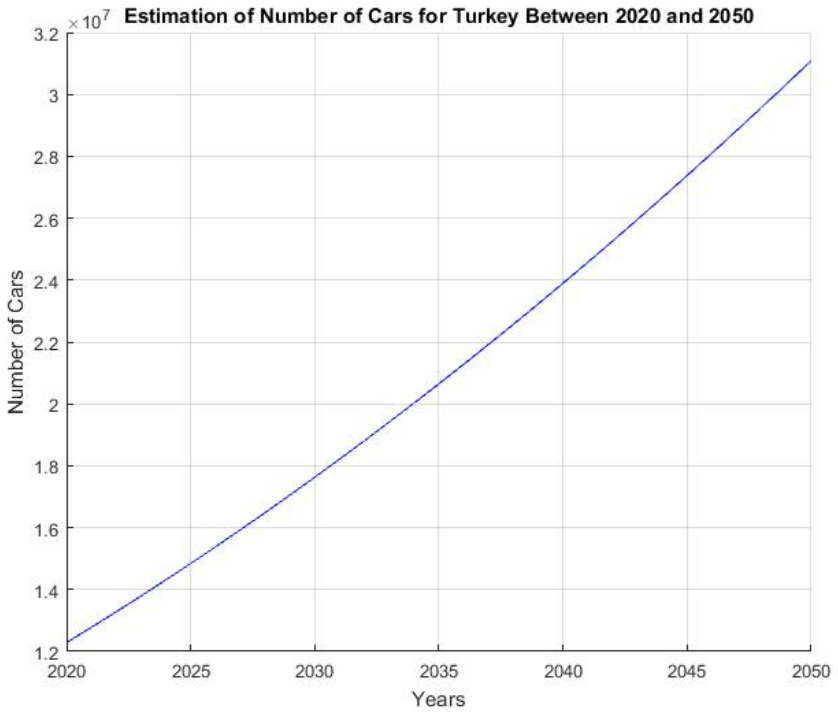

Figure 3.10. Estimation of number of cars for Turkey between 2020 and 2050.

3.2.5.2. Estimation of Coaches' Number. Although number of coaches in Turkey is less than cars, they are still effective on total vehicle-km. Number of coaches is evaluated via quadratic regression too. Equation of coaches' number is defined as:

$$y = 81.58x^2 - 319,994.55x + 313,804,757.98 \tag{3.8}$$

Equation 3.8 generates number of coaches from 2020 to 2050. Figure 3.11 represents the number of coaches.

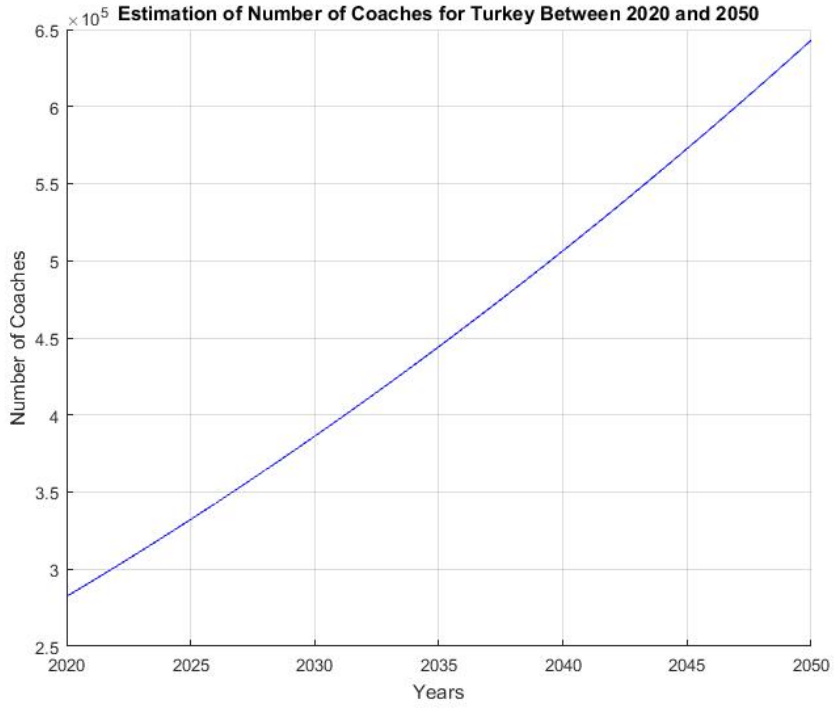

Figure 3.11. Estimation of number of coaches for Turkey between 2020 and 2050.

3.2.5.3. Estimation of Trucks' Number. Truck is the last type of vehicle to be considered. While approximating number of trucks, quadratic regression is examined again. The formula for number of trucks is found as noted below:

$$y = 285.05x^2 - 1,118,023.49x + 1,096,296,658.18 \tag{3.9}$$

By this way number of trucks is evaluated on Figure 3.12.

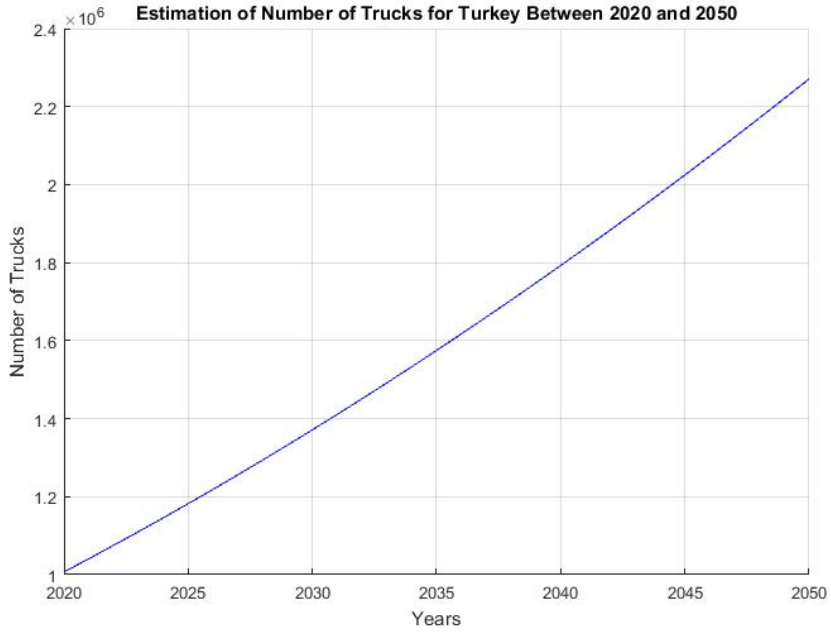

Figure 3.12. Estimation of number of trucks for Turkey between 2020 and 2050.

3.2.5.4. Estimation of Car Equivalent Number. Eventually total vehicle-km is determined with the help of the number of cars, coaches and trucks. Primarily correlation between car equivalent approach and total vehicle-km is plotted with observed data. Equation of line is found via linear regression. As seen Figure 3.13 their correlation is directly proportional, and the formula of line is expressed as:

$$y = 0.01x - 2,870.46 \tag{3.10}$$

X-axis shows car equivalent numbers, and Y-axis demonstrates total vehicle-km simultaneously. Moreover R^2 of the line is 0.9830.

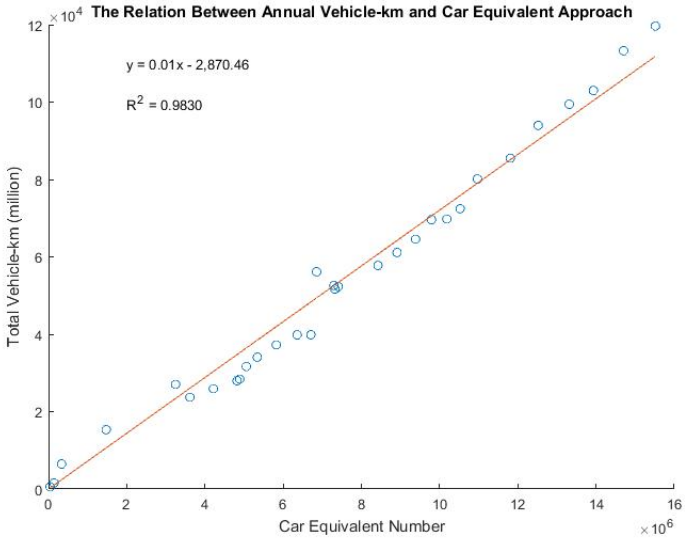

Figure 3.13. The relation between annual vehicle-km and CEA.

After finding their relation, future values of car equivalent number are computed with the coefficients. Car equivalent coefficients are 2.47 and 4.40 for coaches and trucks respectively. Hereby car equivalent number and total vehicle-km are figured on Figure 3.14.

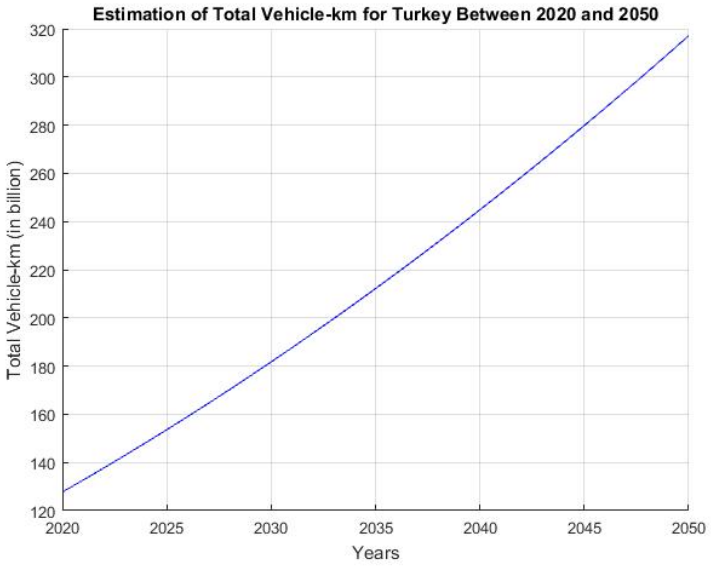

Figure 3.14. Estimation of total vehicle-km for Turkey between 2020 and 2050.

3.2.6. Energy Demand Estimation on Highways For Turkey

In order to use Equation 8 the GNP, the population and the total vehicle-km are forecasted from 2020 to 2050. Thus, energy demand of Turkey is determined on Figure 3.15.

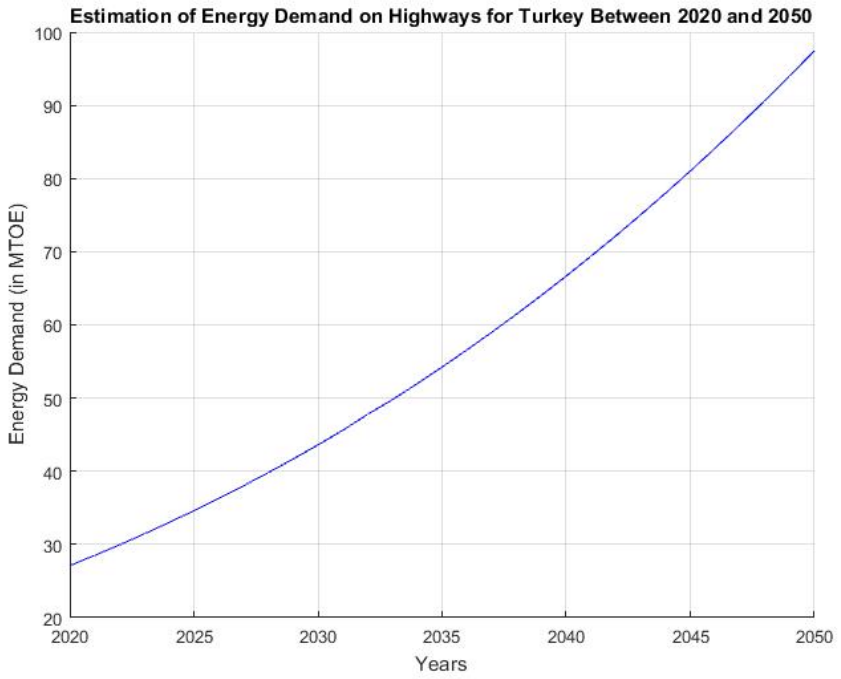

Figure 3.15. Estimation of energy demand on highways for Turkey between 2020 and 2050.

According to exponential model, energy demand on highways in Turkey expands almost 4 times from 2016 to 2050. As maintained before all of the parameters, i.e. GNP, population and total vehicle-km incline at positive slope. Namely their value rise; so, it seems reasonable for energy demand to increase as it seems.

3.3. Mitigation of Fuel Oil's Negative Effect

It is fact that number of cars in Turkey has a positive growth rate, as a consequence fuel oils are consumed more. In other words, energy demand on highways grows consequently.

Even though cars consume more energy in every year, innovations and improvements on automotive industry provide new fuel sources instead of gasoline, diesel and LPG. The most known phenomenon about new vehicles is electric car. This type of car supply energy from electricity directly. They use electric energy from battery or self-production in order to move vehicles.

This situation might break dependency of fuel oils sternly. Basically, fuel oils are limited sources for energy, and fossil fuel formation takes a long time. From another point of view electricity might be generated by a lot of different sources such as power plants and renewable energy sources. Hence electricity might be called unlimited source in contrast to fuel oil. Moreover, these vehicles are nature friendly since GHG emissions from electricity are very less compared to other sources.

Furthermore, Turkey focus on investing on electric cars. If Turkey happen to create a national brand in electrical car, it is obvious that this car would have a significant role on automotive industry in Turkey. Additionally, diesel cars might be banned from the roads completely under radical proposals to fight air pollution across the world. This will affect car selection habits as well. Namely, number of electric cars will increase day by day in a long period.

As mentioned before, electric cars produce kinetic energy via electric motors. Electric motors supply energy from battery or self-production methods like regenerative braking. There are two types of electric vehicles that are fully electric vehicles and hybrid vehicles.

3.3.1. Fully Electric Vehicles

This type of vehicles might be the main player of the automotive sector. They consume only electricity while moving. Due to this reason, they require charging. Travel distance of fully electric vehicles is dependent on the size of battery completely. On the other hand, manufacturing process lasts longer than the others due to enhanced technology, besides from the fact that having higher costs. Additionally, infrastructure

i.e. charging stations, for fully electric vehicles is insufficient yet which is another negative point about these vehicles.

Nevertheless, sales figures of fully electric vehicles rise in Turkey. The amount of electric car that sold in Turkey is shown below.

Table 3.4. Cumulative sales figures of fully electric vehicles in Turkey.

Year	Sold	Cumulative Sum
2012	184	184
2013	31	215
2014	47	262
2015	120	382
2016	44	426
2017	76	502

If the factors that mention above are considered, sales equation of fully electric vehicles might be derived as an exponential function. It is expected that due to policies, number of fully electric vehicles will increase. So, their numbers have similar tendency with the exponential function.

$$y = 146,06e^{0,2128(x-2011)} \tag{3.11}$$

x is the year and y is the cumulative number of electrical vehicles that is sold from 2012. R^2 is 0.9769 for the function. The expected number of the electric vehicles shown below.

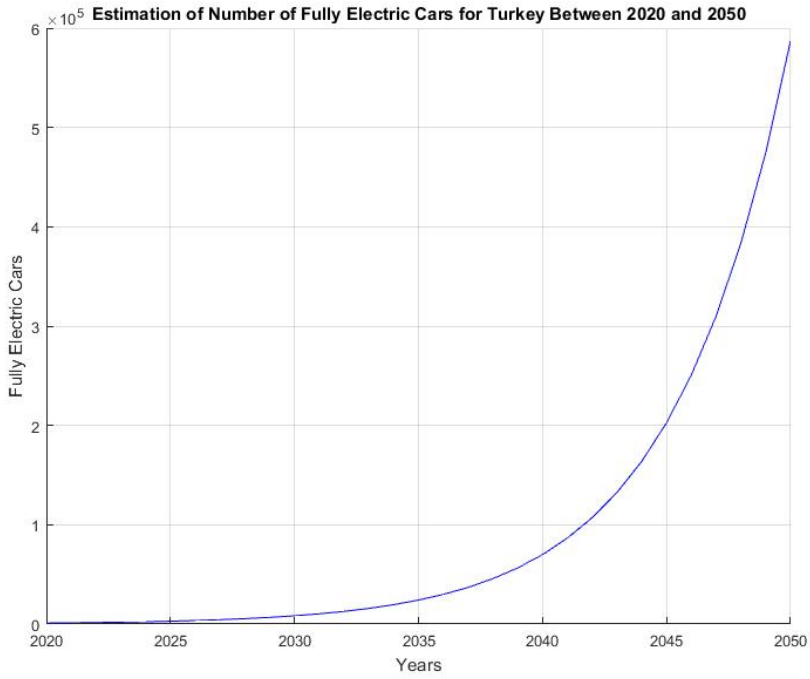

Figure 3.16. Estimation of number of fully electric cars for Turkey between 2020 and 2050.

3.3.2. Hybrid Vehicles

Hybrid vehicles are transition models between fully electric and gasoline or diesel vehicles. There are two different motors in these vehicles that are electric motor and internal combustion engine. By this way vehicles can use one of these motors depending on travel distance and charge. In addition to this, some models of hybrid vehicles can be charged like fully electric vehicles. This fact helps vehicles to travel further only with electric engine.

Because of the fact that driving habits of people changes slowly, these type of vehicles is preferred generally more than fully electric vehicles. It is seen that this trend will continue for some more time.

Turkey shows similar behavior with majority; hence the number of hybrid vehicles is much more than fully electrical vehicles even though they have been sold for a short

time. Sale figure of hybrid vehicles are shown below.

Table 3.5. Cumulative sales figures of hybrid vehicles in Turkey.

Year	Sold	Cumulative Sum
2015	105	382
2016	1010	1115
2017	4507	5622

Sales function of hybrid vehicles are modelled with quadratic regression. Expected number of hybrid vehicles in Turkey might be found with the following equation:

$$y = 14250,19x^2 - 57499658,92 + 58002862161,42 \tag{3.12}$$

where x is the year and y is the number of hybrid vehicles.

Finally amount of hybrid vehicles until 2050 is forecasted on Figure 3.17.

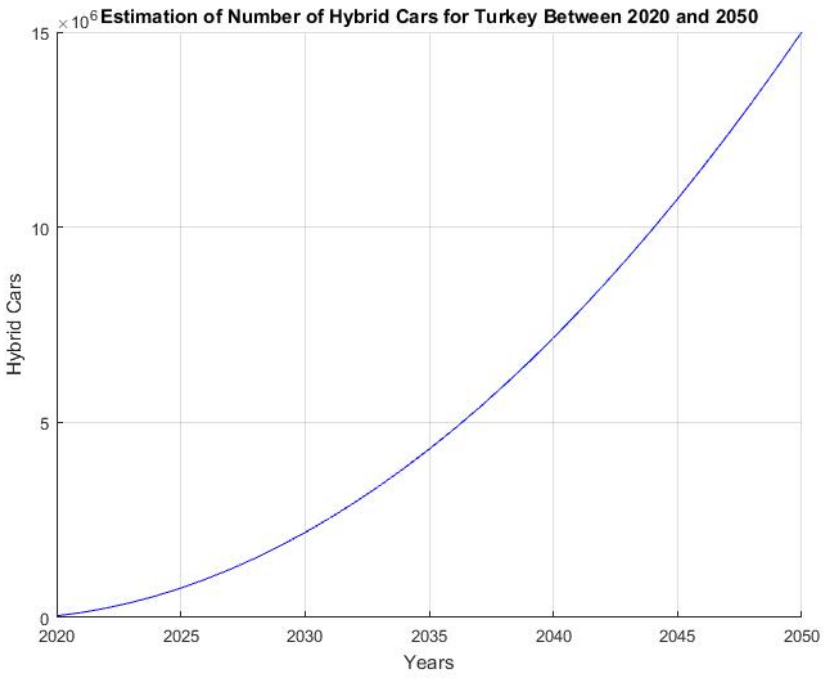

Figure 3.17. Estimation of number of hybrid cars for Turkey between 2020 and 2050.

3.3.3. Comparing Petrol or Diesel Engine Vehicles and Electric Vehicles

Though electric vehicles will have a considerable part of the transportation sector, their efficiency is important in the meantime as the efficiency has an impact on energy demand.

Consumption of electric vehicles is measured by kilowatt hours per hundred kilometers instead of liters per hundred kilometers. Naturally consumption of electric vehicles depends on manufacturers and properties of equipment. Nonetheless an average value is estimated for electric vehicles as 10kWh/100km.

This situation creates new demand for electricity consumption corresponding a drop in fuel oil. New electric demand is calculated as follows.

Firstly, average vehicle-km was calculated for every year. In this way, total vehicle-km of electric vehicles can be estimated by multiplying number of electric vehicles and average vehicle-km. As it mentioned before electric vehicles consume 10kWh for 100km. Thus, total electric demand for electric vehicles scenario is presented in Figure 3.18.

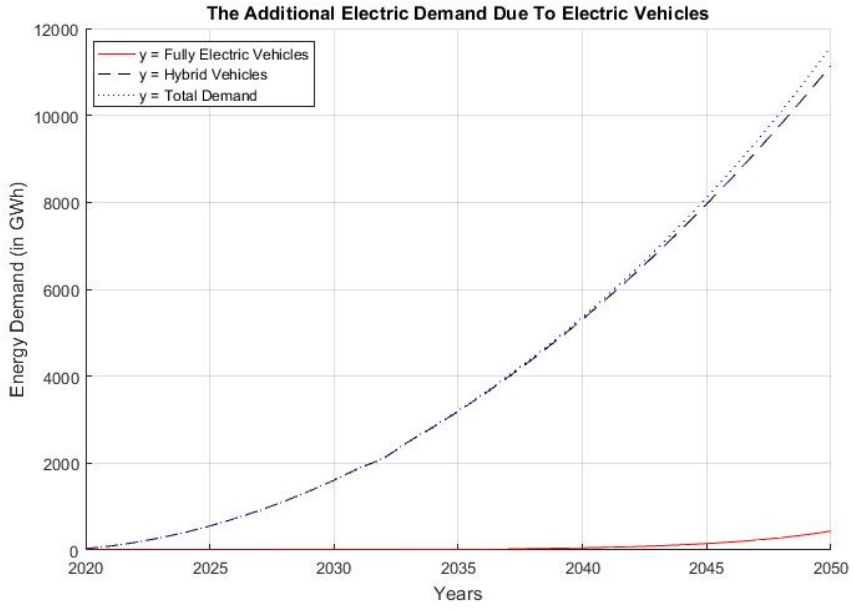

Figure 3.18. The additional electric demand due to electric vehicles.

Even though there is an additional demand for electricity due to electric vehicles, there will be significant decrease in fuel oil demand thanks to these vehicles. Number of vehicles which consume gasoline, diesel or LGP, will fall incrementally every year. Hence the impact of electric vehicles will be observed strikingly.

Using Equation 8 with expected numbers of vehicles decrease in fuel oil demand is shown on Figure 3.19.

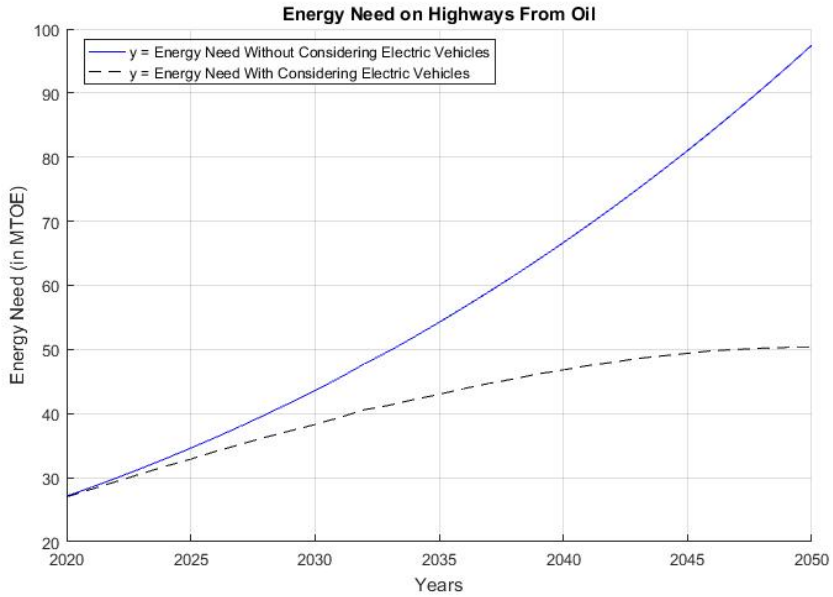

Figure 3.19. Energy need on highways from oil according to electric vehicles scenarios.

It is clearly seen that the influence of electric vehicles on oil fuels increases dramatically. In the long run these vehicles will reduce the need for fuel oils almost up to %50.

As a result, electric vehicles will change fuel habits on highway in the near future. This evolution reduces fuel oil addiction, but builds a new market for electric demand.

3.4. Effects of Electric Vehicle on Climate Change

Climate change is one of the vital troubles that the world faces. It is the change in the pattern of the climate for a long term, and there are many reasons for such trouble.

Nevertheless, people try to find solutions urgently. GHG emissions have an impact on climate change, and transport sector generates a large share in GHG emission.

GHG emissions from transport sector generally come from producing and consuming oil. From year to year GHG emissions from transport rise due to positive growth in number of cars and their energy demand.

Methods have been developed in order to reduce GHG emissions from the transport sector. These methods aim to change the fuel habit on transport sector from fuel oil to electricity with the help of electric vehicles.

In the case of Turkey, it is expected that number of electric vehicles increases. Thus, the need for fuel oil will decrease, and GHG emissions from fuel oil will diminishes. However, additional energy consumption might result in more greenhouse gasses depending on the generating processes. Because of this reason electricity generating processes should be considered besides oil production and consumption.

3.4.1. GHG Emission Due to Oil Production

While producing oil, there are many processes that occurs in refineries. These processes cause GHG emission predictably. The gases emitted from refineries can be classified as CO_2, CH_4, N_2 O and SF_6. According to environmental impact assessment report of Ministry of Environment and Urbanization, these gasses have an impact on GHG emissions variously. For 1.0 MTOE, amount of emissions of these gases is displayed on Table 3.6.

Table 3.6. Emission values of GHG per 1 MTOE.

GHG	FORMULA	EMISSONS PER 1.0 MTOE (TONNES)
Carbon dioxide		20000-820000
Methane		50-6000
Nitrous oxide		60-700
Sulphur hexafluoride		30-6000

Considering the values that are shown in Table 3.6, GHG emission savings from refineries are calculated as follows in Figure 3.20:

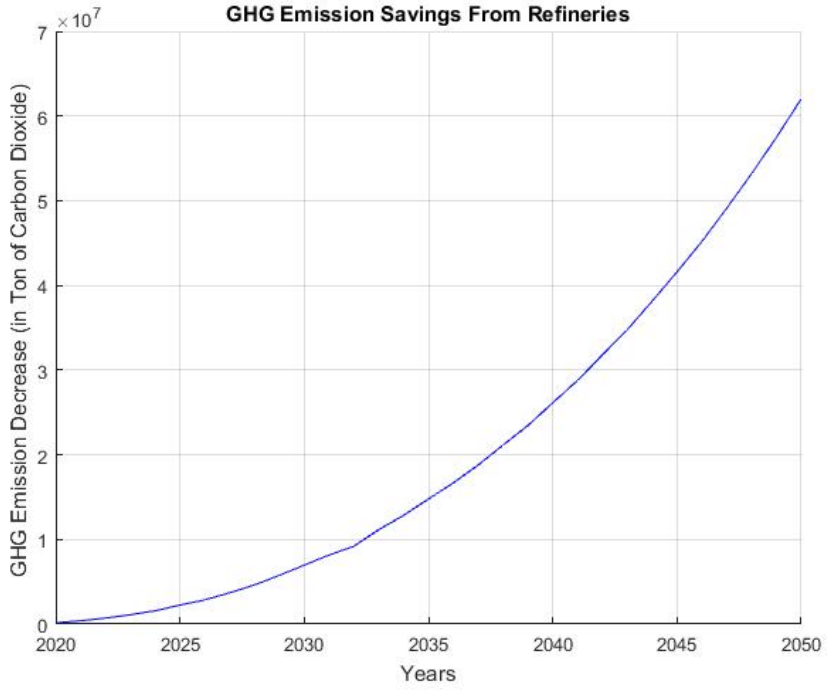

Figure 3.20. GHG emission savings from refineries.

As a result, GHG emissions from refineries decreases when the number of electric vehicles increases. In the long run, effect of decreasing emission will be recognized definitely. Moreover, this situation will affect economy of Turkey positively, because Turkey imports oil from other countries. Therefore, expense for oil will reduce naturally.

3.4.2. GHG Emission Due to Oil Consumption

If the driving habits change to electrical vehicles, then the need for fuel oil diminishes naturally. Normal vehicles produce GHG while converting fuel oils to kinetic energy. In this process, internal combustion engines play a mighty role in producing greenhouse gasses. On the other hand, electric vehicles do not need the same process. So, they use electricity directly to convert kinetic energy without producing GHG.

In the case of Turkey energy savings from electric vehicles are observed in terms of MTOE. However, it should be converted to CO_2 equivalents. By this way its effect on climate change might be determined easily.

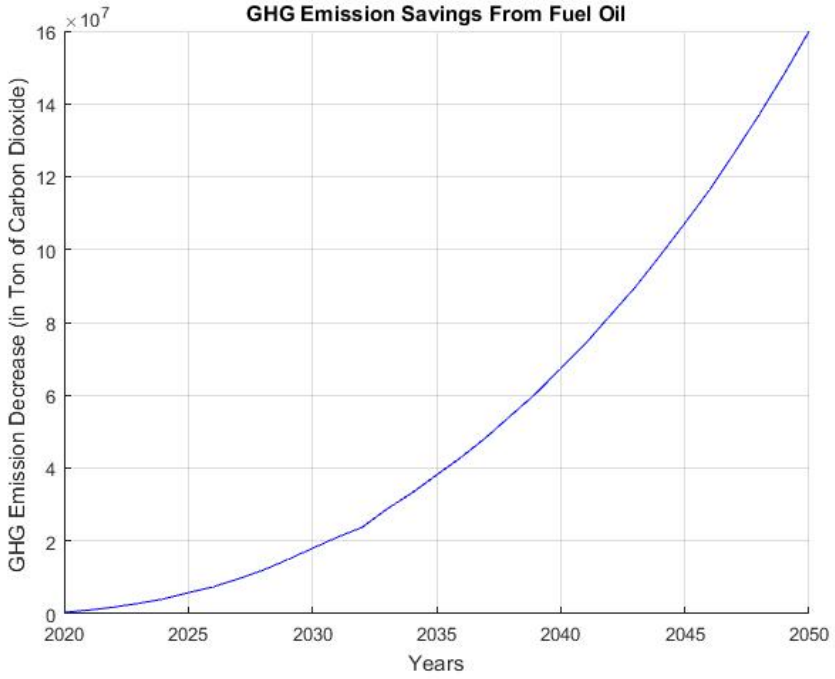

Figure 3.21. GHG emission savings from fuel oil.

Figure 3.21 shows that GHG savings from oil consumption are more than savings from oil production.

3.4.3. GHG Emission Due to the New Electric Demand for Electric Vehicles

Although electric cars do not emit GHG while transporting, they create additional electrical demand for the country. This additional demand will be compensated by power plants. However, type of power plants will affect GHG emission directly. There are some types of power plants such as coal, natural gas, hydro, nuclear and renewable. Whereas coal and natural gas power plants cause more GHG emissions, others emit less GHG. Therefore, the way in that the electricity is generated is very important for GHG emissions of the country.

Since Turkey is a developing country, energy need of Turkey rises incrementally. In order to balance energy demand and supply Turkey tries to build more power plants and improve the capacity of existing power plants.

In the case of electric vehicles, Turkey has to generate more electricity due to additional demand. In fact, Turkey generates electricity from coal, liquid fuels, natural gas, hydro as well as renewable energy and wastes. Nevertheless, additional demand on electricity obliges Turkey to diversify energy sources. The method of generating electricity has an important role on GHG emissions and climate change target of Turkey because Turkey will emit less greenhouse gasses when renewable energy sources are used to generate electricity. However, resources like coal and natural gasses reduce the positive effect of electric vehicles on environment.

3.4.3.1. Scenario 1-Business as Usual. Coal, natural gasses and hydro power plants have the largest share in electricity production in Turkey. Except for hydro power plants, all of the resources are not environmentally friendly while producing electricity. On the other hand, Turkey can obtain raw materials of the sources easily thanks to its location. Therefore, the shares of resources may be steady. Nuclear power plants will be solely a new shareholder of electric generation in the future. The shares of electricity generation between 2010 and 2016 is displayed on Table 3.7. It is clearly seen that the share of renewable energy sources is increasing. On the other side of the coin, total

share of thermal power plants is still more than %60. In other words, electricity in Turkey is mostly generated by thermal power plants.

Table 3.7. Annual electric generation shares of power plants in Turkey.

Year	Coal (%)	Liquid fuels (%)	Natural Gas (%)	Hydro (%)	Renewable Energy and wastes (%)
2010	26.1	1	46.5	24.5	1.9
2011	28.8	0.4	45.4	22.8	2.6
2012	28.4	0.7	43.6	24.2	3.1
2013	26.6	0.7	43.8	24.7	4.2
2014	30.2	0.9	47.9	16.1	4.9
2015	29.1	0.9	37.9	25.6	6.5
2016	33.7	0.7	32.5	24.5	8.6

Future condition of electricity generation is forecasted on Table 3.8. The share of thermal power plants is estimated %50 of the total share. A new participant, nuclear power plants, might produce almost %10 of total production.

Table 3.8. Estimated electric generation shares of power plants in Turkey.

Coal (%)	Natural Gas (%)	Hydro (%)	Renewable Energy and wastes (%)	Nuclear (%)
28	27	18	17	10

If the additional demand from electric vehicles is divided according to total production shares, CO_2 equivalent of emissions is exhibited on Figure 3.22.

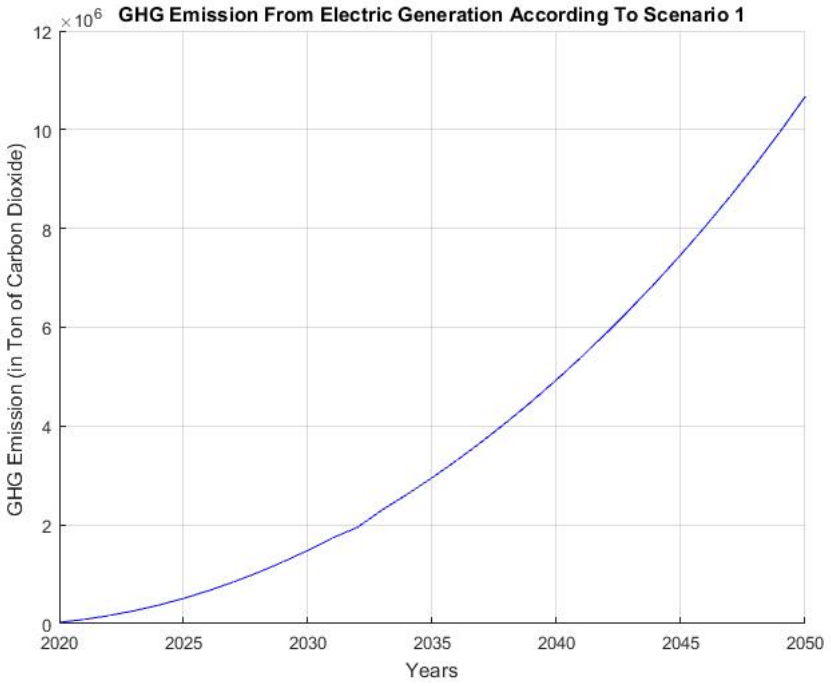

Figure 3.22. GHG emission from electric generation according to Scenario 1.

3.4.3.2. Scenario 2-Environmental Enemy. Although coal reserves of Turkey are on the average level across the world, Turkey starts to focus on coal reserves. There are several reasons for this situation. Firstly, with using own coal reserves Turkey might decrease dependency on foreign sources. After that number of thermal power plants in Turkey is relatively more than other power plants. Therefore, government wants to maximize their capacity. Moreover, coal is still cheaper than other sources. Developing countries, like Turkey, generally prefer coal as the primary source, due to economic reasons. Other resources such as natural gas and renewable energy require comparable big investments. In addition to Turkey's own coal reserves, Turkey might import coal easily thanks to the location and advanced import commerce.

According to these conditions, Turkey might meet the additional needs that comes from electric vehicles, with coal power plants. Even though coal power plants seem reasonable due to economic reasons and energy policies, their environmental impact will be harmful. Figure 3.23 presents GHG emissions due to new electricity demand from electric vehicles if all demand is supplied by coal power plants.

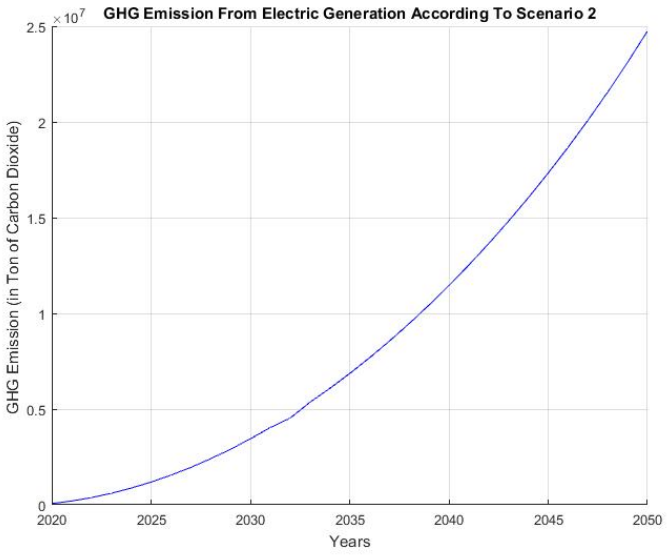

Figure 3.23. GHG emission from electric generation according to Scenario 2.

3.4.3.3. Scenario 3-Environment Friendly. The main purpose of electric vehicles is to find an eco-friendly solution for transport sector. The source of fossil fuels are limited and they also cause air pollution around the world. Electric vehicles are an important step in order to solve the critical problems.

These vehicles might be called totally environmentally friendly if and only if the electric energy is provided renewable energies.

In recent years Turkey has invested in renewable energy. The share of the renewable energies in electric generation rises incrementally. Nevertheless, renewable energies might be costly for the developing countries. Despite of economic difficulties, Turkey might have advanced renewable energy systems thanks to its geographical region. There is huge potential in Turkey for solar and wind energy. If Turkey continues to invest on sustainable and renewable energy, GHG emissions due to electric generation might fall decidedly.

Turkey might prefer to generate electricity from renewable sources in order to supply energy demand for electric vehicles. Hence negative effect of electric vehicles on environment might be minimized correspondingly. Figure 3.24 demonstrates the

impact of renewable energy sources explicitly.

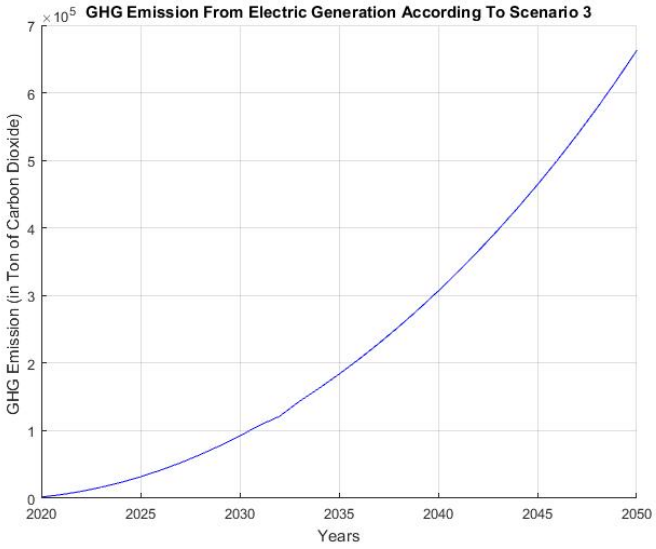

Figure 3.24. GHG emission from electric generation according to Scenario 3.

3.4.4. Paris Agreement Targets of Turkey and Effect of Electric Vehicles on Turkey's Target

After industrial revolution world has been using machine power. Though machine power improves the quality of life and welfare, its impact on environment is relatively damaging. Consequently, world has to deal with the problem, climate change.

For a long time, countries try to find new solutions for the environmental problems. However, they haven't been able to succeed unfortunately. In order to reduce GHG emissions, countries made an agreement in 2015 which is called Paris Agreement. The Paris Agreement is an international treaty which obliges every country to have its own targets to decrease GHG emissions.

Turkey's GHG emission and its mitigating targets have been correlated since the Paris Agreement. However, GHG emissions in Turkey has a tendency to diverge from the target. Therefore, Turkey should take an action about this problem. The emission reductions have to achieve almost 246 MT CO_2 equivalent in the year 2030 according to the mitigation scenario.

Due to the fact that transport sector is one of the major reasons for GHG emissions electric cars might be a suitable solution for the target.

Three different scenarios are considered in order to analyze the effect of electric vehicles on Turkey's target. All of these scenarios approach different ways to generate electricity for electric vehicles.

In the first scenario, additional electric demand is distributed proportionally according to their expected generation shares. In the second scenario, coal is the sole source for supplying the demand comes from electrical vehicles. This is the worst-case scenario. The last scenario is directly based on renewable energy sources.

As seen Figure 3.25electric vehicles will have a positive impact on GHG emissions in every scenario. Even though the initial effects of all scenarios are similar, third scenario will be much more effective than other scenarios in the upcoming years. In 2030 coal based scenario contributes only %8 of Turkey's mitigation target. However, %10 of Turkey's target is satisfied when only renewable energy sources are used to generate electricity for the electric vehicles.

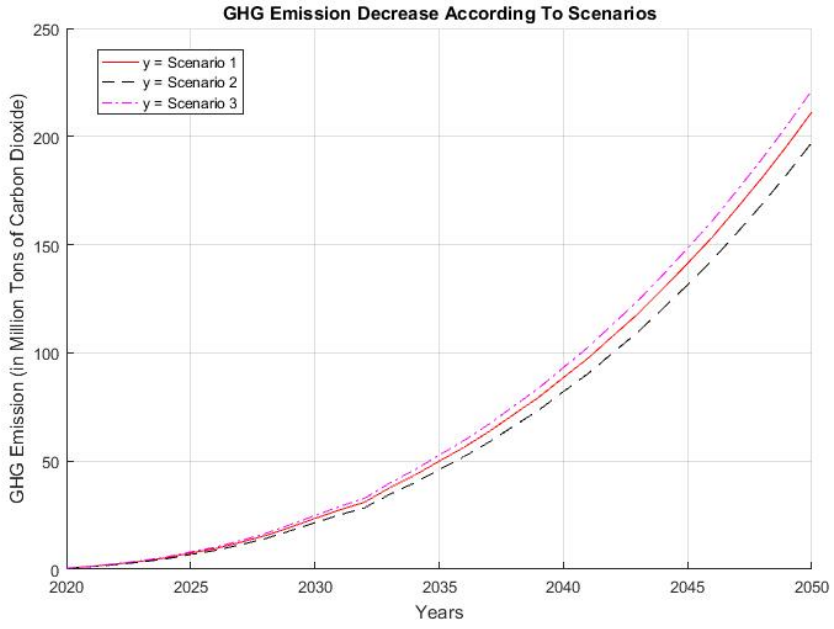

Figure 3.25. GHG emission decrease according to scenarios.

4. CONCLUSION

Energy is the most important resource for humanity, and demand for energy increases day by day. Every countries' main priority is to make amends of their increasing energy demand due to developing industrial activities, transportation sector etc. The main objective is the impact of the new phenomenon called electrical vehicles. While focusing on aspects of energy, this thesis also considers its effect on the environment. Research was based on Turkey considering thirty years ahead, regarding its adaptation process as well.

Turkey, as a developing country, take place among the countries which use the significant amount of the energy produced in the world. Moreover, Turkey's energy consumption trend grows incrementally. Therefore, the need for energy has become vital than before. In each year energy production in Turkey rises in order to supply the additional energy demand. However, energy production process is an expensive operation, and it has some negative results on environment. Rational and sustainable solutions has to be created while supplying the increasing energy demand.

Transport sector has one of the biggest shares in energy consumption in Turkey. With growing population and increasing welfare, the number of vehicles increases in every year. In this circumstances, energy is being consumed more and the need for it rises proportionally. Energy source of transport sector is fossil fuels which causes GHG emissions. According to Genetic Algorithm, which forecasts the energy demand from transport sector, consumption of fuel oil will exceed 45 MTOE after 2030 and exceed 90 MTOE after 2048. Namely transport sector will continue having its significant impact on energy sector in the future.

The crucial rise in energy demand from transportation sector has obliged automotive sector to change. The answer is electric vehicles. This type of vehicles transforms electric energy directly to kinetic energy. In this way dependency on fuel oil and its unfavorable impact decrease eventually. Electric vehicles emit less greenhouse gas than

other fuel types. This beneficial development in transport sector will affect Turkey positively, as an oil importer, economic pressure of fuel oil on Turkey will diminish definitely. Regarding to that Turkey may find one of the solutions about the environmental problems.

It is expected that electric vehicles in Turkey will reduce the demand for fuel oil to half of its estimated value until 2050. The fact that number of electric vehicles grows incrementally triggers decrease in fuel oil exponentially. In addition to this, the negative effect of refineries will shrink since amount of produced by the refineries will decrease according to the expected demand for fuel oil.

On the other hand, energy generation amount should increase due to electric vehicles. The additional amount of electric energy will be generated by different energy sources such as coal, natural gas and renewable energy. All of these sources have different impact on environment in terms of GHG emissions. Coal power plants emit most greenhouse gasses compared to other sources.

With all of these cases the general influence of electric vehicles is stated according to Paris Agreement. Paris Agreement is an environmental agreement between all countries, and these countries have some targets to decrease negative impacts on environment. Electric vehicles helps Turkey to decrease GHG emissions. Turkey's target is dropping GHG emissions from 1175 MT CO2 equivalents to 929 MT CO2 equivalents in the year 2030. 21.5 MT CO2 equivalents of GHG emissions would be supplied if only coal power plants are used to generate electricity. This amount will increase up to 24.85 MT CO_2 equivalents with the help of renewable energy sources. Although the effects of electric vehicles are positive on environment and economy, it is not easy to forecast the number of electrical vehicles since parameters may vary time to time and the approached methods should be improved. The electric vehicles have been in Turkey since 2012. Therefore, the trend of electric vehicles couldn't be understood easily. In order to forecast the number of electric vehicles correctly, an algorithm should be developed with the proper parameters. By this way, a direct impact of electric vehicles on climate change would be estimated accurately.

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