EMISSION REDUCTIONS AND FUTURE OF ENERGY POLICIES IN TURKEY. ARE RENEWABLES AN ALTERNATIVE?

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ABSTRACT

EMISSION REDUCTIONS AND FUTURE OF ENERGY POLICIES IN TURKEY. ARE RENEWABLES AN ALTERNATIVE?

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Climate change is considered one of the greatest threats that the world has ever faced. Human activities are the main cause of the excessive greenhouse gases (GHGs) in the atmosphere. GHGs created by the anthropogenic effects are far greater than the naturally present portions in the atmosphere and in charge of the alteration in the composition of the atmosphere.

Which human activity is responsible for global warming? The main contributor of the GHGs is the energy sector on which human activities are deeply relying. There is no other way to think that human activities are refined from the need of energy. Therefore, there is a strong need of improvement of the energy policies in order to fight with the global climate change.

A concrete step is taken as a conclusion of COP21 (21^{st} annual Conference of Parties, also known as the 2015 Paris Climate Conference). Over 20 years of United Nations (UN) negotiations it was for the first time to agree upon a universal and a legally binding agreement keeping the average global temperature rise below 2°C compared to the pre-industrial level.

In this study, cross-country panel data analysis is conducted in order to forecast electricity demand of Turkey for the period 2018-2040. By utilizing this forecast results, different scenarios for energy policy design for Turkey is investigated in order to indicate how we can shape our future energy policies regarding the mandatory reduction of CO_2 emissions. In addition to the first one, the study explores whether renewables can be a solution in the medium term or whether nuclear power is a must for our future energy policies in order to satisfy the growing electricity demand. The main result of the thesis highlights that renewable energy sources can be considered as a solution to cope with the two constraints (to supply the increasing electricity demand and to keep emission on target) scrutinized in this thesis.

Keywords: Energy-Policies Analysis, GHG Emissions, Energy Transition, Electricity Demand Forecast, Panel Data

ÖZ

EMİSYON AZALTIMI VE TÜRKİYE'NİN GELECEK ENERJİ POLİTİKALARI. YENİLENEBİLİR BİR ALTERNATİF Mİ?

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Bugün dünyanın karşı karşıya kaldığı en büyük tehditlerden birisi iklim değişikliği olarak değerlendirilmektedir. İnsan eylemleri/aktiviteleri, atmosfere yayılan aşırı sera gazlarının temel nedenidir. Antroponejik (insan kaynaklı) etkiler nedeniyle ortaya çıkan sera gazları atmosferde doğal olarak bulunan orandan ayrı olması sebebiyle atmosferde meydana gelen değişimin ana sebebidir.

Hangi insan eylemi küresel ısınmadan sorumludur? İnsan eylemlerinin en fazla yoğunlaştığı enerji sektörü sera gazlarının ortaya çıkmasındaki temel unsurdur. Enerjiden arındırılmış insan eylemlerini düşünmek mümkün değildir. Bu nedenle küresel iklim değişikliği ile mücadele edebilmek için enerji politikalarının iyileştirilmesine ihtiyaç duyulmaktadır.

Bu bağlamda hâlihazırda en güncel ve somut adım COP21 (21. Yıllık Partiler/Taraflar Konferansı ayrıca 2015 Paris İklim Konferansı olarak bilinen)'in bir sonucu olarak 20 yılı aşkın bir süredir devam eden Birleşmiş Milletler (BM) müzakereleri neticesinde elde edilmiştir. Bu çerçevede ilk defa evrensel ve yasal olarak bağlayıcılığı olan ortalama küresel ısınma derecesinin endüstri öncesi seviyeye kıyasla 2 derecenin altında tutulması yönünde ortak karara varılmıştır.

Bu çalışmada Türkiye’nin elektrik talebi 2018-2040 dönemi için 41 ülkeye ait panel veri seti kullanılarak öngörülmüştür. Bu öngörü sonuçları kullanılarak, farklı senaryolar üzerinden Türkiye’nin gelecekteki enerji politikalarını şekillendirmek adına zorunlu karbon emisyonu azaltımı hususu göz önünde bulundurularak; giderek artan elektrik talebinin karşılanmasında yenilenebilir enerjinin orta vadede çözüm olabilmesi veya nükleer enerjinin gelecek için bir zorunluluk olup olmadığı konuları ele alınmıştır. Bu tezin temel sonucu, yenilenebilir enerji kaynaklarının tezde irdelenen iki kısıtın (artan enerji talebini karşılamak ve emisyon hedeflerini tuturmak) üstesinden gelmek için bir çözüm olabileceğini vurgulamasıdır.

Anahtar Kelimeler: Enerji Politikalari Analizi, Sera Gazı Emisyonları, Enerji Dönüsümü, Elektrik Talep Tahmini, Panel Veri

To My Parents, To Mother Earth and To All Philomats,

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LIST OF ABBREVIATIONS

APEC	Asia Pacific Economic Cooperation
ARDL	Autoregressive Distributed Lag Bound Test
ASEAN	Association of Southeast Asian Nations
BAU	Business-as-Usual
BP	British Petroleum
CCS	Carbon Capture and Structure
CO_2	Carbon dioxide
CO_2e	Carbon dioxide Equivalent
COP	Conference of Parties
EKH	Environmental Kuznets Curve
EMRA	Energy Market Regulatory Authority
ESMAP	Energy Sector Management Assistance Program
EU	European Union
FE	Fixed Effects
F-i-T	Feed in Tariff
FX	Foreign Exchange Rate
GDP	Gross Domestic Product
GHG	Greenhouse Gas Emission
GMM	Generalized Method of Moments
$GtCO_2$	Gigatonnes of carbon dioxide
Gtoe	Gigatonne Oil Equivalent

GW	Gigawatt
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPPC	International Panel Protection Convention
km^2	Kilometer square
kW	Kilowatt
kWh	Kilowatt hours
LEAP	Long-range Energy Alternatives Planning System
LSDV	Least Square Dummy Variable
MENR	Republic of Turkey Ministry of Energy and Natural Resources
Mtoe	Million Tonnes of Oil Equivalent
MW	Megawatt
NDC	Nationally Determined Contributions
NPP	Nuclear Power Plant
OECD	Organization for Economic Co-operation and Development
PV	Photovoltaic System
REPA	Wind Energy Potential Atlas
RMSE	Root Mean Square of Errors
RTSPV	Rooftop Solar Photovoltaic
SEF	Specific Emission Factors
TEIAS	Turkey Electricity Transmission Corporation
TPES	Total Primary Energy Supply

SIS	Turkish Statistical Institute
TWh	Terawatt hours
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
UNGC	United Nations Global Compact Leaders’ Summit 2018
VAR	Vector Autoregressive
VECM	Vector Error Correction Model
WWS	Water, Wind, Solar

CHAPTER 1

INTRODUCTION

The main objective of this thesis is to explore whether renewable energy can be considered as a solution to meet the emission reduction targets and satisfy the growing electricity demand of Turkey. My motivation for writing this thesis lies under the moral responsibility of humankind to cope with climate change which is a global environmental tragedy for which we are all responsible. The significance of this thesis is based on the conclusion of each scenario that leads to start thinking outside the box focusing on the energy transition, energy efficiency, and new solutions to cope with this global phenomenon which will be discussed in the conclusion chapter. The electricity power consumption, gross domestic product (GDP) and population data of countries are obtained from World Development Indicators database of the World Bank Group for cross country panel data analysis. SIS projections for population, IMF and OECD projections for GDP growth are used for the electricity demand forecast. Our main findings are listed as: electricity demand is closely linked to GDP growth and population growth, which will be further discussed in Chapter 4; Turkey has the potential to meet its growing demand in a different energy generation mix which is less CO_2 intensive that is demonstrated in Chapter 5. In addition, this thesis highlights the importance of the prudent electricity demand forecast for the energy policy design.

1.1. Background of the Study

Climate change is considered one of the greatest threats that the world has ever faced. Climate change will have harmful and unavoidable impacts in the near future. It will lead to rise in temperature, cause extreme weather events and increase the number of diseases. Even now, the Earth is experiencing this dramatic change in the frequency of weather events such as floods, draughts, and forest fires. These extreme weather events are significantly the results of greenhouse gas emissions (GHGs), and the main reason behind these disasters is humankind itself. According to the report of the Intergovernmental Panel on Climate Change (IPCC)'s Fifth Assessment Report (AR5), with a 95% probability, the reason of the global climate change is the activities of post-industrial society. (IPCC, 2013) CO_2 emissions related with the energy sector are the majority of the GHGs. Therefore, it is the conventional wisdom that GHGs are created by the anthropogenic effects. Climate change is a global reality. GHGs can have climate effects anywhere on the planet, irrespective of the location of the sources (IPCC, 2007). Hence, some precautions should be taken by people to deal with this global problem. Moreover, IPCC's recent special report on global warming of 1.5 ºC scrutinizes the severity of the problem and addresses urgent and more strict actions as the global response to the threat of climate change. (IPPC, 2018 Masson-Delmotte et al., n.d.)

Climate change is a global problem and has a full potential for catastrophic outcomes and its main cause is energy production and use which accounts for around two-thirds of GHGs. Energy is a global issue as well. It is not possible to annihilate the reason of this global problem i.e. "energy" itself, because of rapid population growth and urbanization. By urbanization, reliable and secure supply of energy is the foremost requirement of the modern societies; therefore, world needs energy to continue its sustainable development. Since no country is an energy island and thus solely responsible for this global phenomena, energy policies of countries to address climate change are closely interrelated. With looming energy security and environmental challenges, international cooperation on energy is vital.

1.1.1. Background of Climate Policies

The history of international environmental policy began with the UN Conference on Human Environment in Stockholm in 1972. This was the turning point of the global environmental policy issues. Next, the release of Brundtland Report in 1987 pointed out the human impacts on environment. Then, IPCC was established in 1988 to produce scientific evidence of aforementioned human impacts on environment.

In 1992, The Rio Earth Summit was held and was accepted as the most significant UN Conference because it drew attention to the urgency of the measures to tackle the problem of global climate change. Nations are classified and assigned with different roles by common but differentiated responsibility according to their respective development levels. Annex-I parties, developed countries, should implement emission reduction targets, where Annex-II parties, developing countries, should implement emission reduction targets while receiving technical aid and Non-Annex-I parties are only required to develop emission inventories without any binding measures. Moreover, an annual meeting of the Conference of Parties was one result of the conference so that effective implementation of the convention could be ensured. At the third one of these annual meetings in Kyoto, The Kyoto Protocol was approved in 1997. It sets the legally binding targets for Annex-I parties in order to reduce emission level at least 5% from 1990 level at the end of the first commitment period which is from 2008 to 2012. Obviously, the protocol sets legally binding level for the developed countries which are deemed responsible for the current climate change. However, United States of America did not ratify the protocol. At that period this global problem could still be considered as a tragedy of commons, since governments prefer to act in accordance with their self-interest which is in contradiction to the global interest regarding the allocation and use of the natural resources.

Finally, the 21st Conference of the Parties (COP 21) which was held in Paris in December 2015, could be considered a real effort to change the global climate problem for the first time in two decades. All the nations of the world agreed on a text in this conference but there will not be meaningful change if none of the countries take necessary actions. 187 countries which are responsible approximately 90% of GHGs have submitted pledges. COP 21 which has provisions both legally binding and nonbinding considered as hybrid was a historic milestone and seems a catalyst for more innovation, research and investment in clean energy technologies. It was agreed that the Paris Agreement will enter into force once 55 countries covering 55% of global emissions have acceded to it. On 5 October 2016, the above mentioned threshold was achieved and the Paris Agreement entered into force on 4 November 2016. As of 12 August 2018, the Paris Agreement have been ratified by 183 parties of 197 to the Convention. The two main outcomes of the COP 21 can be summarized as below:

- 187 countries committed to reduce their emissions starting from 2020.
- Global temperature increase limited below 2 degrees Celsius, while urging effort to limit the increase to 1.5 degrees.

Regarding the energy sectors inputs commitments to “Nationally Determined Contributions” (NDCs) are made. (Turkey, 2015) Turkey is committed to decrease GHGs emissions 21% by 2030 compare to the business-as-usual (BAU). It should be noted that although Turkey signed the Paris Agreement in 2016, the Agreement has not been ratified.

A recent IPCC special report on the impacts of Global Warming of 1.5 ^{0}C emphasized that the global warming of 1.5 ^{0}C will still have unavoidable drastic effects on climate and environment. Therefore, “rapid and deep deviations” in emission pathways are indispensable. (Masson-Delmotte et al., n.d.)

In Table 1.1., a snapshot of Turkey's participation, role and responsibilities in the international climate change policies are given.

Table 1.1. *Milestones of Turkey in Climate Policies*

Year	Turkey's Position
1992 UNFCCC	Listed in Annex-1 Annex-2, Turkey was reluctant to sign
1997 Kyoto Protocol	Observer
2001 COP 7 Marrakesh	Moved to Annex-1 with exceptions
2004 Framework Convention	Became party of Framework Convention
2005	Kyoto Protocol put into force
2006	Issued 1st Greenhouse Gas Emissions Inventory
2007	1st National Communication on Climate Change and established the Global Warming Research Commission
2009	Turkey ratify Kyoto Protocol w/o commitment
2009 COP 15 Copenhagen	Turkey declared certain amount w/o any commitment
2010 COP 16 Cancun	Turkey's special circumstances under Annex-1 recognized by all parties
2012 COP 18 Doha	Not signed Kyoto Protocol's 2nd commitment period
2013 COP 19 Warsaw	Agree to become a party with a different target
2014 UNCC Leaders' Summit New York	Turkey announced that it will be part of the new process
2015 COP 21 Paris	Intended Nationally Determined Contribution (INDC) prepared, targeted 21 % reduction in emissions which refers to 246 Mt CO_2e
2016	Turkey signed the Paris Agreement
2018 COP 24 Katowice	Turkey negotiated to be classified as developing instead of developed due to the access for financial aid

Apart from above mentioned international attempts; there are several studies on climate change mitigation policies, which need a deep analysis of constraints in the design and their effects. Climate change mitigation policies will increasingly affect the destination of the energy sector.

Historically, world energy demand has constantly increased since 1950's. It is driven first mainly by industrialization in Europe, North America and Russia until 2000, since then by Asia and recently mainly China.

World energy demand reached 14 Gtoe in 2017 ($*2.5$ compared to 1971), and represents 32.5 $GtCO_2$. It is estimated that fossil fuels and industrial processes cause 65% of GHGs emissions. Fossil fuel is still the predominant source with 81% in 2017 in the energy mix. The components of this 81% may differ from country to country (31% oil, 29% coal and 21% gas). This ~81% global share of fossil has remained extremely stable for the last three decades. (IEA, 2017)

As per IEA New Policies Scenario "*energy demand is still expected to increase although more slowly than today but an expected increase of 30% by 2040 meaning that adding China or India to the current demand of today*".(IEA, 2017) Hence, the inevitable conclusion of the increase in the demand side is the additional CO_2 emission by 2040 as well.

World energy demand is driven by three main pillars; activities (population, gross domestic product (GDP) growth and structure), substitutions and efficiency.

1. Activity (population, GDP growth & structure): the switch towards increasing services and less industry strongly impacts energy demand growth. Industry is considered to be approximately 7[1] times more energy intensive than services in 2014.

2. Substitutions: the generation mix evolves according to evolution of prices, technological disruption (solar PV and battery) or cost cutting in Exploration and

[1] Data derived from https://wec-indicators.enerdata.net/services-energy-intensity.html

Production (E&P) (shale gas and oil), which will have huge impacts on the generation mix and energy demand.

3. Efficiency: all the improvements of organization, processes, buildings insulation, demand side management increase efficiency. Energy efficiency helps to avoid GHG emission, peak demand reduction, avoided additional generation capacity, GDP and total primary energy supply (TPES) decoupling, reduction in energy subsidies, reduction in utility debt, reduced pressures on scarce domestic resources.

There are mainly two possible ways to reduce CO_2 emissions arising from energy sector. The first one is on the energy demand (consumption) side, and the second one is on the energy supply (generation) side.

1.1.2. Statement of the Problem

Designing an energy policy excluding nuclear energy and relying on renewables could be an alternative way to supply Turkey's growing electricity demand and reducing CO_2 emissions. This thesis aims to clarify that there is a widespread interest in the crucial question: Can renewable energy be considered as a solution to keep the emission targets and satisfy the growing demand?

This thesis put forth the effort to create different scenarios to satisfy two main constraints; supplying the growing electricity demand and keeping CO_2 emission on targets.

The scenarios are designed to satisfy the estimated electricity demand of Turkey in 2040 by allocating the different generation resources and its effect on the level of CO_2 emissions and each scenario's feasibility is evaluated after checking these two constraints.

This thesis is organized in six chapters. A literature review is presented in Chapter 2. The main aim of this literature review is to present first of all, the most relevant and recent studies regarding the role of renewables for the future's energy policies to achieve CO_2 emission targets and also includes review of energy policy analysis. Chapter 3 recapitulate the general energy outlook of the world and then Turkey. The electricity demand forecasts of Turkey are introduced in Chapter 4 of the thesis following by our cross country panel data analysis for the electricity demand of Turkey. Chapter 5 is dedicated to the scenarios trying to figure out to supply the demand forecasted by the cross country analysis in Chapter 4 in four different scenarios, i.e.; base case, maximize local, generation mix with nuclear, and minimize GHGs scenarios. This thesis will not aim any intervention to the energy demand or supply side. The final chapter highlights the prominent issues that need further studies. The thesis will end by questioning whether it is possible to supply the growing demand in a carbon free-way.

1.1.3. Significance of the Study

The significance of the Study is neither the forecast of the electricity demand of Turkey by using cross-country panel data analysis, nor the design of scenarios. The significance of this thesis lies under the conclusion of each scenarios that lead to start thinking outside the box focusing on the energy transition and new solutions to cope this global phenomenon for further studies.

CHAPTER 2

LITERATURE REVIEW

In this chapter of the thesis a literature survey considering most related studies are presented.

2.1. Review of Recent Studies

Jacobson et al put forth to indicate economic feasibility of 100% energy transition to wind, water and solar (WWS) in 139 countries by using existing technologies plus few additional developments aiming to eliminate air pollution and GHGs. The starting point of the paper is the estimation of yearly averaged power demand for 139 countries in 2050. After that, analysis of renewable resources is done for each country in order to determine composition of the supply in the estimated/projected demand in an environmental friendly CO_2 free-way. Among the technologies preferred, all commercially available ones are considered except tidal and wave power. After determination of composition of supply, a study on energy storage is done in order to eliminate the drawbacks of renewables and the additional energy storage capacity investigated. As a final step, comparison of WWS vs business as usual (BAU) scenarios is done considering land and ocean footprint and spacing areas plus energy cost, climate cost and job creation/loss. One of the primary highlights of the study indicates that WWS electricity plus improving energy efficiency instead of burning fossil fuels means that much less energy is needed; on average 42,5 % demand decrease is foreseen compared to BAU scenario. In this paper there are 4 main outcomes foreseen to be achieved by 2050. These are, to provide all electricity supply from WWS which help to avoid 1.5°C global warming and negative effects of air pollution, reduce the need for electricity, decrease power disruption, increase accessibility by decentralization and creates long term jobs 24,3 million. As a conclusion, using available resources and existing and developing technologies provides the demand in 139 countries in 2050 economically and technically and on top of these provides environmental benefits and jobs. This roadmap is a solution for world's climate change, air pollution and energy security problems. On the road to achieve this picture there are still barriers which are mainly political and social. (Jacobson et al., 2017)

This paper estimates Turkey's total end-use load (installed capacity-GW) as 140,6 in BAU and 82.2 in WWS scenario corresponding approximately 42% decrease in the demand side except the transport sector's percent of total end-use load; the other sectors i,e; residential, commercial, industrial and agriculture&fishing percent of total end use will increase. The decrease in total end-use load in WWS scenario is due to electrification of end uses, changes in upstream energy use and additional efficiency measures. (Jacobson et al., 2017)

In other respects, "Evaluation of a proposal of reliable low cost grid power with "100% WWS" by Clack et al.is a criticism to the study of Jacobson claiming that there should be a flourishing study behind any transition roadmap relying on WWS at reduced cost. (Clack et al., 2017)

Due to their dependence on the weather and time conditions, it is stated that continuous supply is not practically sustainable although to meet the demand in terms of load is possible. It is summarized that three options that could provide instantaneously still need to be improved technically and economically. These are curtail load, energy storage and supplemental energy sources.

This reality highlights the significance of variability in electricity generation. The best way of transition was concluded to be diversification of the resources in the previous studies.

However, Jacobson's study is criticized because of errors and usage of inappropriate methods. Also, constraining variety of energy resources does not show any superiority compared to keeping the wide variety policy.

One of the main objections to Jacobson et al study is that it eliminates several commercially available technologies; for instance, nuclear and bioenergy both support the reliability and decarbonization. Another shortcoming of the study is its lack of considerations of CCS for fossil fuel generation and bioenergy integrated CCS technologies. As per Clack et al. (2017), with all available technologies decarbonizing %80 is challenging and these challenges even deepen by putting limits for generation options.

Jacobson's study doesn't include the associated cost for the physical infrastructure. It is concluded that Jacobson's study is not proven in terms of technical, practical or economic feasibility.

Affordable cost and reliable supply of energy can not be met by the scenarios of Jacobson. There is no consideration of costs and barriers in this study. Main shortcomings of Jacobson's study are listed as;

1. There are modelling errors with respect to hydropower availability and demand responsiveness
2. Storage technologies and their feasibilities are not mention in detail.
3. There are modelling gaps in transmission of electricity.
4. The assumptions for climate modelling simulation are not accurate and do not include margins. (Clack et al., 2017)

Jacobson's study is criticized as not having supported adequate and realistic analysis and a roadmap indicating the cost of transition, in contrast narrowing energy options does not provide support for an affordable transition.

More studies, researches and energy institutions started to prove that renewable energy is the future solution to supply the increasing demand in a CO_2 freeway. National Renewable Energy Laboratory of USA states that renewable electricity able to meet 80% of total U.S. electricity demand in 2050. This will be achievable by using generation technologies that are commercially available today further improved with a new flexible system. In addition to this, it is emphasized that electricity demand is supplied on an hourly basis in every region of the US.(NREL, n.d.)

Ari and Yikmaz elaborated on the effects of renewable energy sources to meet emissions reduction targets given in the INDC of Turkey. Three scenarios are designed to asses the impacts of renewable energy sources, i.e. Low-INDC, Reference-INDC and High-INDC. In order to make a cost comparison, levelized cost of electricity (LCOE) tool is used. It is concluded that renewable energy sources have a crucial role in achieving emissions targets. By the support of renewable energy sources, Turkey can reduce its total GHGs emissions 566, 511 and 428 million tons of CO_2 in Low-INDC, Reference-INDC and High-INDC Growth scenarios in comparison to 1798 million tons of CO_2e which is the total reduction between 2018 and 2030. Ari and Yikmaz highlighted the necessity to revise national emission targets with new renewable energy targets (Ari & Yikmaz, 2019).

Another recent publication A CGE Model Assessment for Turkish Energy Sector Development and Paris Agreement Goals conducted by Kat, Paltsev and Yuan. In this paper in order to achieve the targets set by Paris Agreement, Turkey needs to shift from the fossil reliance to less CO_2 production styles which require additional investment in low-carbon energy sources (Kat, Paltsev, & Yuan, 2018).

Alkan et al. proposed a Social Accounting Matrix (SAM) Multiplier Analysis in which they use an environmentally extended SAM and analyze scenarios including shocks in agriculture, industry, energy and transport sectors as well as waste management. The authors claimed that it seems to be impossible to satisfy the emission targets with the current INDC policies and Turkey needs more conceivable ones. (Alkan, Binatli, & Değer, 2018)

Kolsuz and Yeldan developed an applied general equilibrium model to assess the benefits of coupling environmental abatement instruments and policies towards sustaining green jobs. Their results showed that nearly 20% decrease in CO_2e emissions is possible while satisfying significant increase in GDP and employment by 2030. (Kolsuz & Yeldan, 2017)

Kilickaplan et al. used an hourly resolved model to asses 100% energy transition in Turkey to renewables in the light of supply security, environmental impacts, and impacts on Turkish energy policy. 100% energy transition to renewables for 2015-2050 is evaluated via two scenarios which are a power sector scenario and an integrated scenario. Integrated scenario refers to power sector plus desalination and non-energetic industrial gas demand. The integrated scenario aims to present the economic effects on the power and water sector. Both scenarios utilize from solar potential, 287 GW installed solar capacity in the power scenario whereas 387 GW installed solar capacity in the integrated scenario. Both correspond more than % 70 of the total installed capacity and including rooftop PV installations. The installed capacity in 2014 is taken into account and their lifetime is considered during the period of the study. Scenarios do not add new coal investment due to COP 21 targets. Electricity consumption per capita and population growth are used for electricity demand projections. Total electricity demand is estimated 641.3 TW h_{el} for the power scenario and 894.5 TW h_{el} for the integrated scenario. As a conclusion, it is highlighted that transition to 100% renewables is achievable by 2050. There should be a shift from gas and coal to solar and wind between 2015-2030. After 2030, capacities of storage facilities need to increase to achieve this target. (Kilickaplan et al., 2017)

Another study focus on the environmental impacts of removing coal subsidies in Turkey. A regional CGE model is porposed to assess the indicators related to growth, employment, investment and capital accumulation, welfare and trade balance. Their results indicated that the subsidies can be removed without a significant loss in GDP and these subsidies could be transferred to green policy alternatives (Acar & Yeldan, 2016).

A Computable General Equilibrium (CGE) model for Turkey responding to three crucial queries has been presented in the Low Carbon Development Pathways and Priorities for Turkey Report prepared by Yeldan and Voyvoda. These queries are summarized as follows; to disclose the features of economic growth and CO_2 emissions for medium and long term, to design low carbon policy by taking into account the fiscal and external restrictions and situation of labor market, to choose the reasonable combination of policies ameliorate workforce and growth. This study covers the 2015-2030 period and base year of the model is 2010 and the Input/output statistics were used for the analysis (Yeldan & Voyvoda, 2015).

Another study has been completed to compare the economic feasibility and environmental effectiveness of nuclear energy and solar energy options for Turkey by Karaveli focusing on the two case studies in Karapınar and Akkuyu (Karaveli, 2014).

A multi-sector energy-economy-environment model for Turkey has been studied by Kat. This thesis set forth not only energy-economy interactions but also reveal the environmental impacts of each scenario especially in terms of GHG emissions. Kat set a macroeconomic model as an optimization problem and representing both sectorial detail and energy specifics. So his mathematical model comprises three modules; macroeconomic, energy and environment (Kat, 2011).

Therefore, this study is considered a pioneer in energy-economy-environment modelling including activity analysis with the sectorial classification; i.e. agriculture, energy-intensive Industry, Other Industry, Services and Transportation. The study deeply investigates energy modelling for policy analyses, by the use of large-scale nonlinear optimization model in order to investigate macroeconomic and multi-sectorial energy policies from the point of technological and environmental verities and scenarios. His model serves as a guideline for regulatory authorities and policy makers to set a benchmark and evaluate policy options that are considered to be implemented by the government. There are four groups of scenarios as no-abatement, abatement general, abatement sectorial and price scenarios with several sub-scenarios. The base case scenario of Kat refers to the official governmental policy of implementing 3 nuclear power plants respectively in 2020, 2022, 2025 and not considering any emission-abatement policies.

A study conducted by Ari and Koksal demonstrated the amount of CO_2 emissions arising from fossil fuel power plants in Turkey operated between 2001 and 2008. The calculation of the CO_2 emissions is done referenced to the IPCC methodology. The study foresees an annual increase in the demand of electricity as 7 % until 2019 and put forth that there will be shortage in terms of electricity supply between the years 2011-2019 by taking into account existing and planned power plants. Therefore, the aim of the study is to design four different scenarios which provides the security of supply and is to explain the mitigation measures of each scenario in terms of CO_2 emission. As a conclusion Renewable Energy Scenario makes the CO_2 emission reductions feasible by a total amount of 192 million between 2009 and 2019 (Ari & Aydinalp Koksal, 2011).

Another study focused on the causal relationship between emissions, nuclear energy and renewables in the United States. It is supposed that generation mix including nuclear have an irrefutable impact to mitigate GHGs emissions by highlighting that without nuclear the level of global emissions would have reached 10% higher and OECD countries' emission level would have reached additional one-third of their present emission level. The causal relationship between CO_2 emissions, renewable energy consumption and nuclear energy consumption is explored in the US between 1960 and 2007. It is stated that there is a bi-directional causality between CO_2 emissions and GDP, no causality in any direction between nuclear energy consumption and GDP, unidirectional causality exists from GDP to renewable energy, additionally there exists unidirectional causality from renewable energy to nuclear energy. The findings of the study summarized that the generation mix including nuclear energy help to reduce CO_2 emissions. Because there is a unidirectional negative causality from nuclear energy consumption to CO_2 emissions. Conversely, the impact of renewable energy consumption on combatting with CO_2 emissions could not be observed as there exists no causality running from renewable energy consumption to CO_2 emissions.There is a unidirectional causality running from CO_2 emissions to renewable energy consumption (Menyah & Wolde-Rufael, 2010).

CHAPTER 3

ENERGY OUTLOOK

In this section of the thesis information regarding world energy outlook and Turkey's energy outlook is given relying on the sectorial resources, i.e., International Energy Agency (IEA), Exxon, BP and Enerdata.

3.1. World's Energy Outlook

It is not surprising to say that global energy demand continues to increase in today's world; we are more dependent on electricity ever than before; it is not only for the lightening but it is imbedded in everything in our daily life.

It is expected that the world's population will have additional 2 billion by 2050, to reach 9.8 billion from todays 7.7 billion. On the other hand, GDP is expected to be doubled as well, especially non-OECD countries are expected to have high levels of economic growth. One of the main outcomes of this economic growth is an eventual increase in the number of middle class population which has an appetite for increasing energy consuming services such as air conditioning etc. Population and GDP are two main drivers of the energy demand, so the energy demand will continue to increase as well. According to IEA's main scenario in 2016, global energy demand continues to increase and is estimated to increase by 30% by 2040. This estimation implies that depletion of all modern fuels will continue in order to supply the increasing demand.

3.1.1. Sectorial Reviews for Energy Demand

GDP growth and population growth both lead to an increase of energy demand by 2040 by 25% as per Exxon Mobil 2017 outlook for energy: A view to 2040. Main points of this report is summarized below : (Exxon Mobil Corporation, 2016)

- GDP growth accelerates energy consumption.
- Non-OECD countries shape the way for the energy demand since they are the ones where urbanization still continues and where GDP is continuing to grow.
- Emission reduction policies lead the diversification of energy sources; nuclear, renewables and natural gas keep the big portion of the pie.
- Oil is considered the world's primary energy resource due to the demand driven by transportation and chemical industries.
- By 2040, natural gas is considered to provide ¼ of global energy demand since it helps the energy transition to a less carbon intensive way of production.
- Energy efficient solutions and technological developments will support less carbon intensive energy.

As per the BP's Statistical review of World Energy it is stated that three consecutive years before 2017, CO_2 emissions from energy consumption was stable. Three main pillars of this fact were listed as: increase in the energy efficiency, which leads to the decrease in the demand side; increase the share of renewables; decrease the share of coal in the energy mix. There are two challenges: the first one is to supply the world's growing energy demand and the second one is to reduce global carbon emissions.(BP, 2018)

In 2017, global primary energy consumption growth was led by natural gas and renewables and the share of coal continued to decrease.

Another crucial information that needs to be highlighted during the review of global energy outlook is the position of China. Energy consumption of China increased by 3.1% in 2017; it was the 17th times since 2000 that China was the largest growing market for energy consumption.(BP, 2018)

BP's highlights of 2017 are summarized as below:

- CO_2 emissions from energy consumption increased by 1.6% after three stable consecutive years between 2014-2016.
- In 2016, the price of oil increased for the 1st time since 2012 reaching from $43,73 per barrel to $54,19.
- The fastest growth in natural gas consumption was 3% since 2010.
- The fastest growth in global primary energy consumption is as 2.2% since 2013.
- Coal consumption incrased for the first time since 2013 by 1%, mainly because of India and to a small extent China.
- The fastest growth rate in coal production since 2011 happened driven by China and US.
- There is 17% growth in renewable power which is higher than 10-year average.
- Wind corresponded to more than half of the growth while solar accounted for 1/3 of the growth.
- Slight growth happened in hydroelectric power as 0.9%.
- Growth in nuclear energy generation is as 1.1%; China and Japan are the driving countries.

2.8% power generation growth was considered as stable compare to previous 10-year average. Power generation use became 40% of the primary energy consumption in 2017. Big portion of this increase arose from developing countries. On the other hand, the decoupling of economic growth and power demand continued same as the last 10 years in OECD countries. (BP, 2018)

Wind and solar (renewables) were drivers of the increase in global power generation, corresponding to half of the total growth in power generation but constituting still %8 of the total generation. (BP, 2018)

One of the achievements that needs highlighting is the increase of solar capacity by 100 GW in 2017. Half of this increase was created by China.

One of the striking outcomes of the BP's statistical review is the 20-year analysis of the fuel mix which shows that the share of coal is precisely same as in 1998.

According to Enerdata Global Energy Statistical Yearbook 2017, world total energy consumption corresponded to 13,903 Mtoe in 2016 (see Figure 3.1.). According to the same data Turkey's total energy consumption in 2016 was recorded as 139 Mtoe (see Figure 3.2.) which is approximately 1% of world total energy consumption .

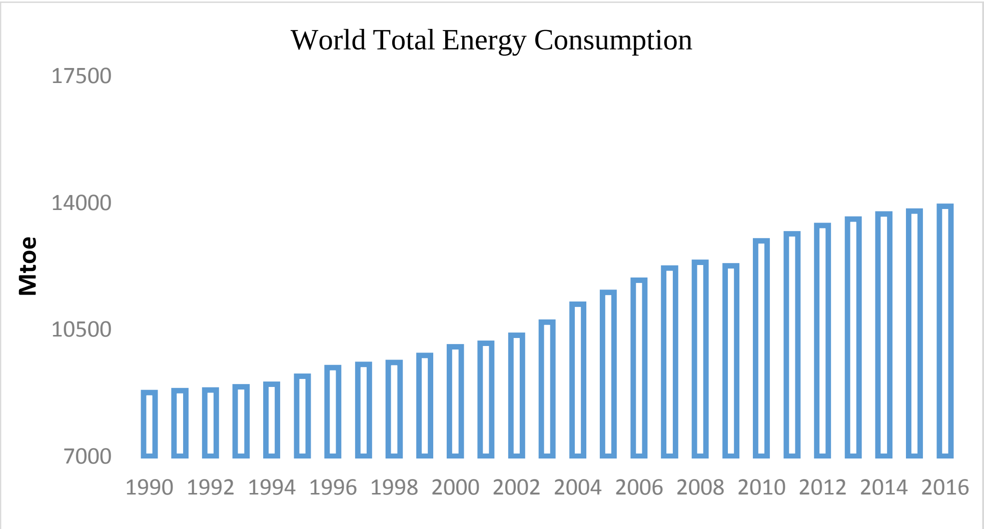

Figure 3.1. World Total Energy Consumption (Mtoe) 1990-2016 (source: Enerdata Global Energy Statistical Yearbook 2017)

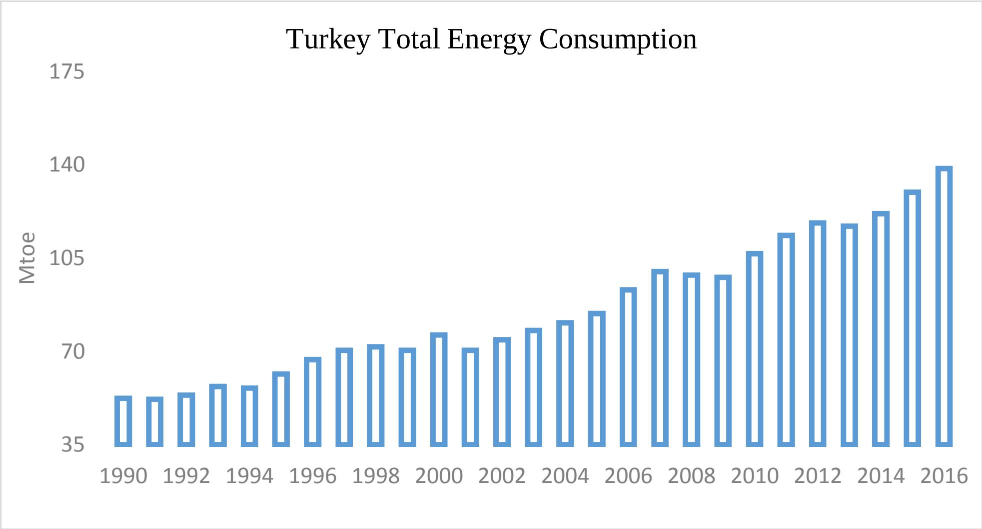

Figure 3.2. Turkey Energy Consumption (Mtoe) 1990-2016 (source: Enerdata Global Energy Statistical Yearbook 2017)

World total energy consumption increased by 1% in 2016, while the corresponding increase for Turkey happened as 6.8 %.

Total energy production is classified as crude oil, coal, gas, biomass, electricity and heat. World total energy production (Mtoe) corresponded to 13,910 Mtoe (see Figure 3.3.) and Turkey energy production was 38 Mtoe (see Figure 3.4.) which is 0.273% of world total energy production.

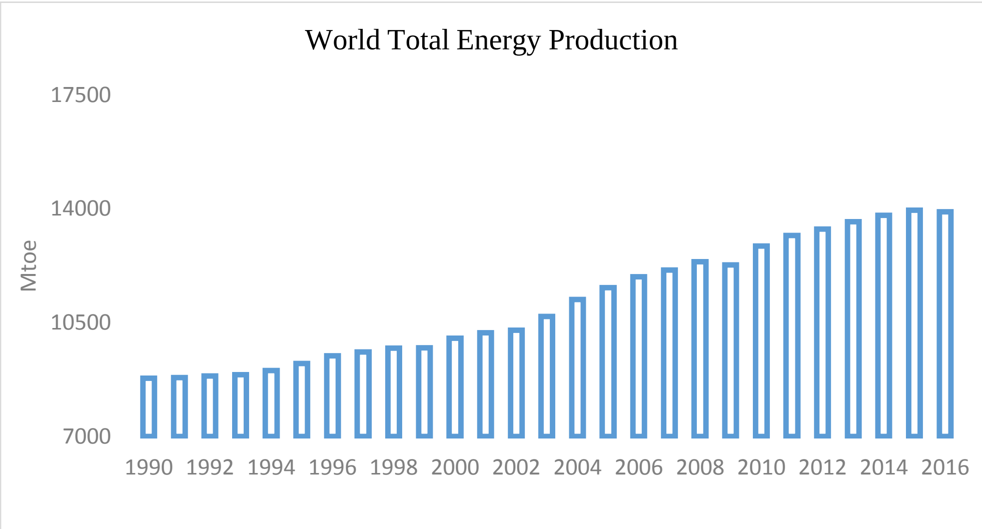

Figure 3.3. World Total Energy Production (Mtoe) 1990-2016 (source: Enerdata Global Energy Statistical Yearbook 2017)

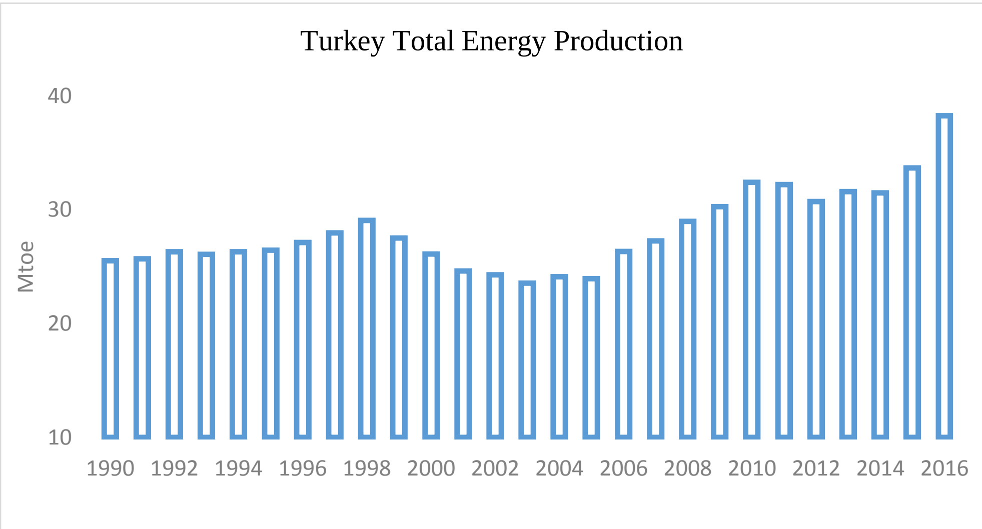

Figure 3.4. Turkey Total Energy Production (Mtoe) 1990-2016 (source: Enerdata Global Energy Statistical Yearbook 2017)

Although world total energy production decreased by 0.4% in 2016, Turkey's total energy production, on the other hand, increased by 13.6 % in 2016. World energy production decrease was recorded for the first time that since 2009; the reason behind the fact were new climate policies and transition to decarbonized economy respectively in EU states and China, in addition to this production slowdown of the fossil fuels in USA due to low commodity price.

Another crucial fact is the differences between the consumption and production amounts in Turkey. Turkey imports 105 Mtoe corresponding to crude oil, oil products, gas and coal because of the gap between demand and supply. This fact should be taken into account by policy makers for the future energy policies of Turkey to create sustainable and robust policies which can satisfy the increasing energy demand of Turkey.

In addition, energy intensity needs to be considered. Energy intensity is defined as the total energy consumption per GDP. It accounts for the total energy consumption of the country per its GDP. This indicates the necessary amount of energy in order to generate one unit of the GDP. Total energy consumption refers to coal, gas, oil, electricity, heat and biomass, in order to be consistent as per the data of Enerdata. The GDP data was analyzed at constant exchange rate and purchasing power parity in order to eliminate the effect of the inflation. One result of using the purchasing power parity instead of exchange rate is arriving at a higher value of GDP in the countries where the low cost of living is low. As a result, their energy intensity decreases.

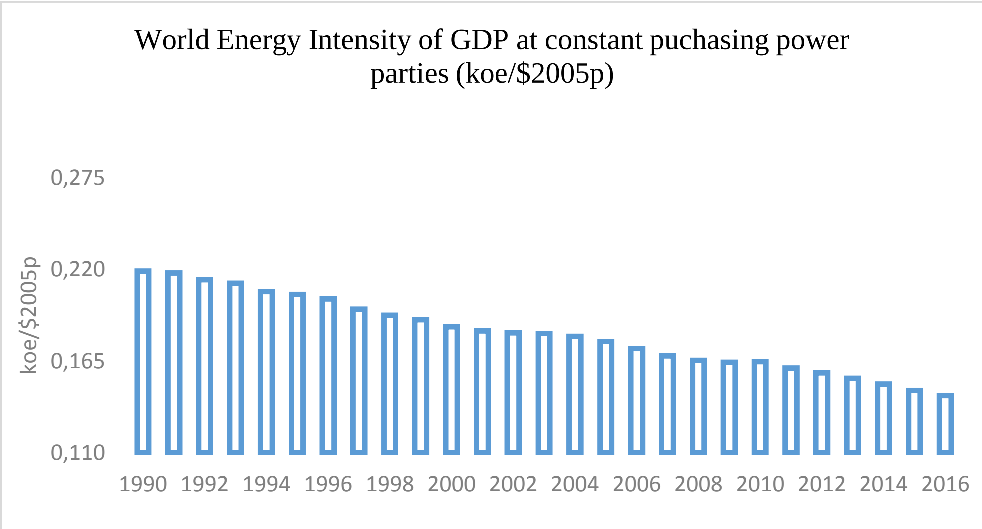

Figure 3.5. World Energy Intensity of GDP at constant purchasing power parties (koe/$2005p) 1990-2016 (source: Enerdata Global Energy Statistical Yearbook 2017)

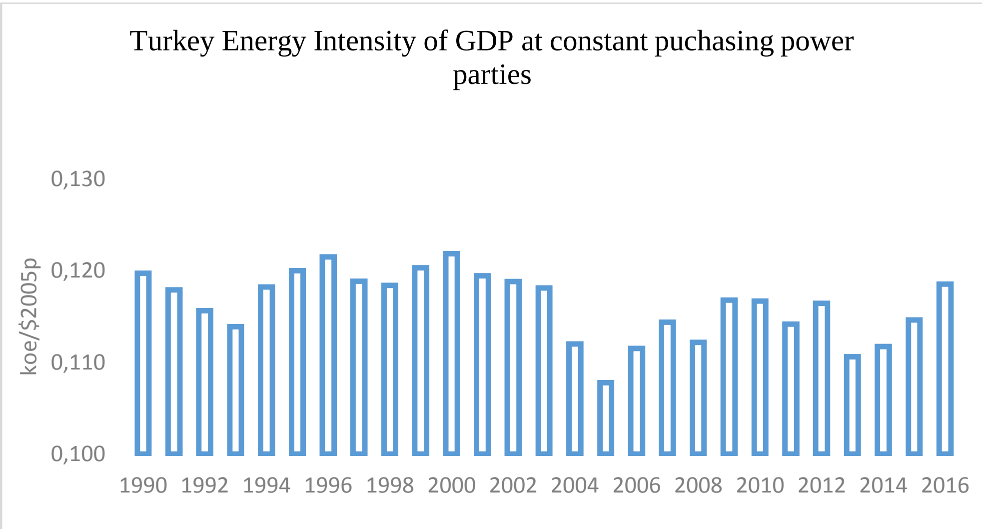

Figure 3.6. Turkey Energy Intensity of GDP at constant purchasing power parties (koe/$2005p) 1990-2016 (source: Enerdata Global Energy Statistical Yearbook 2017)

According to above statistics (Figure 3.5.), world's energy intensity per GDP is decreasing and there was a 2% decrease in 2016, slightly above the historical trends.

The trend in energy intensity is country and region specific and very much depends on the economic structure and energy efficiency improvements of the country.

In order to assess world energy outlook, the method followed is to analyze the energy consumption, energy production, energy intensity and last but not least the amount of the CO_2 emissions taken into account together with its intensity as well. Figure 3.6. depicts World CO_2 emission from fuel combustion. The main aim of this thesis is not to forecast solely Turkey electricity demand for the medium term, its focal point is how this demand will be satisfied and to underlie the point whether it is feasible to provide this growing demand in a carbon freeway keeping the emission reduction targets on track.

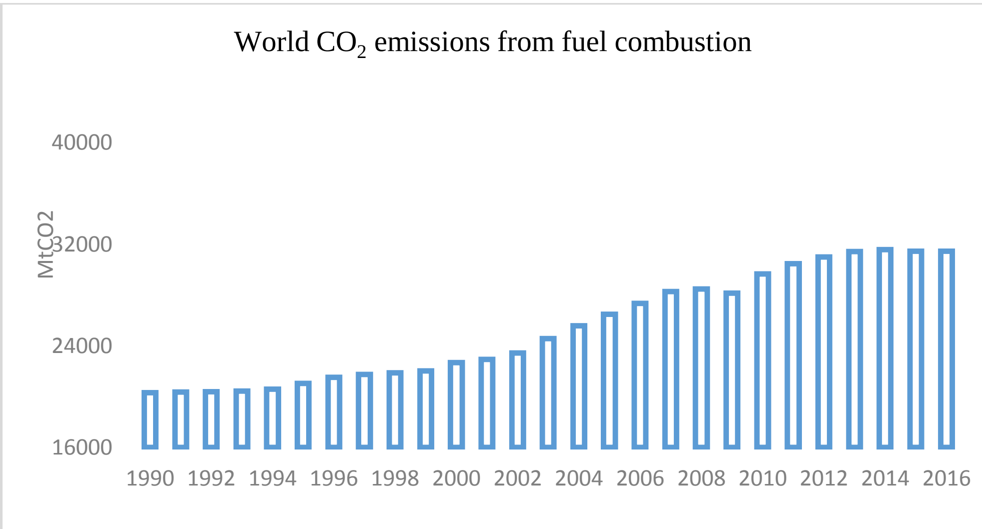

Figure 3.7. World CO2 emission from fuel combustion (MtCO2)

In 2015, global economic growth was 3 %. The emissions were stable which can show that economy might develop and emissions can still be under control. The drivers were mainly China (because of less coal) and US (with 1st Obama Clean Air Act), replacing coal with gas. Renewables accounted for over 90% of new generation in 2015 according to International Energy Agency (IEA). The statistics presented above indicate that global emissions stalled for third consecutive years in 2016. There are several reasons coming to standstill of world CO_2 emissions. As indicated in the above graph, global energy intensity is decreasing. This conclusion led by the change in the energy generation mix, increase the use of renewables and less coal use of two huge consumers.

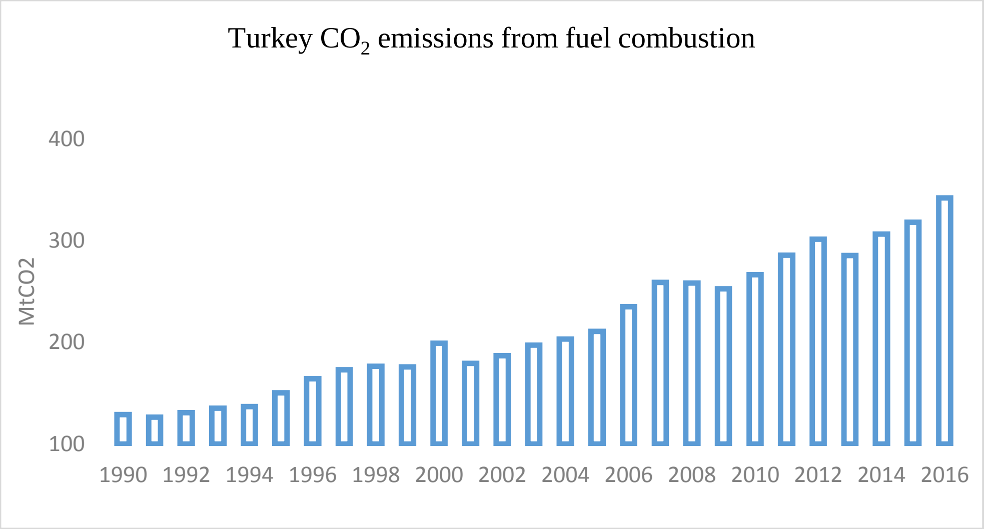

Figure 3.8. Turkey CO2 emission from fuel combustion (MtCO2)

If we look at the trend in Turkey and compare this with the above graphic of the global one, it is obvious that there is an increase in the CO_2 emissions in Turkey (see Figure 3.8.). It is due to the increase of energy generation by the recent energy investments.

As a conclusion of this chapter; all the actual data point out that the energy demand will increase mainly due to population and GDP growth, which is the same for electricity demand as well.

3.1.2. Installed Capacity of Turkey

According to TEIAS latest report, total installed capacity was 85.2 GW for 2017 and 87.14 GW for the first half of 2018. Installed capacity per resource for year 2017 and for the 1st half of 2018 is given in Figure 3.9. below. In summary, installed capacity by resource is as follows; hydraulic 32.01%, natural gas 27.07%, coal 21.91% wind, solar and other renewables 13.59%.

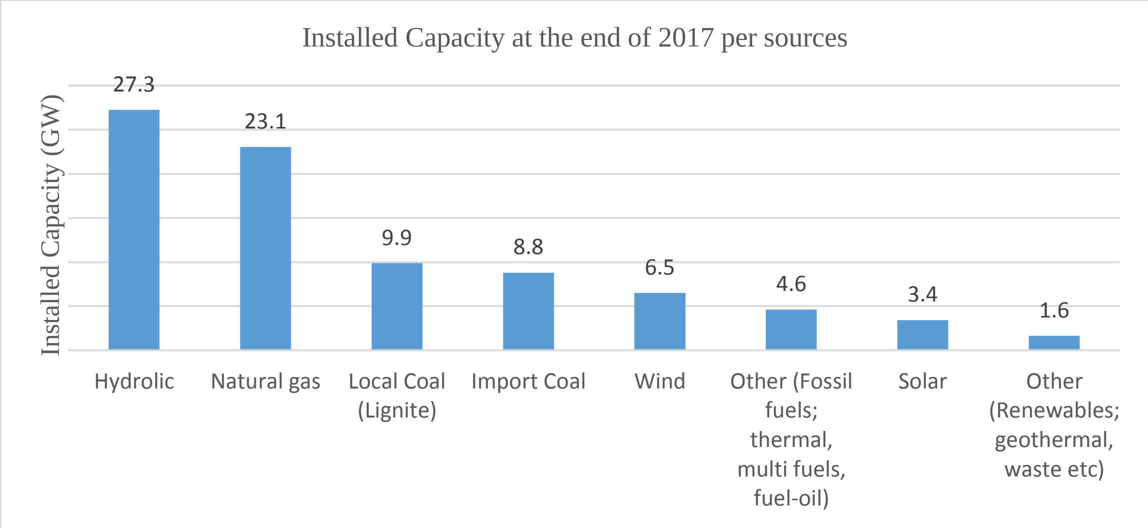

Figure 3.9. Installed Capacity per sources (TEIAS-2017)

By the end of the1st half of the 2018, share of hydraulic was 32.03%, natural gas 26.17%, coal 21.42% wind, solar and other renewables 15.11%. The increase arose from solar, indicating that solar share will continue to increase exponentially in the near future considering the fact that the solar capacity was 40 MW in 2014 and reached 4,726 MW by the mid of 2018.

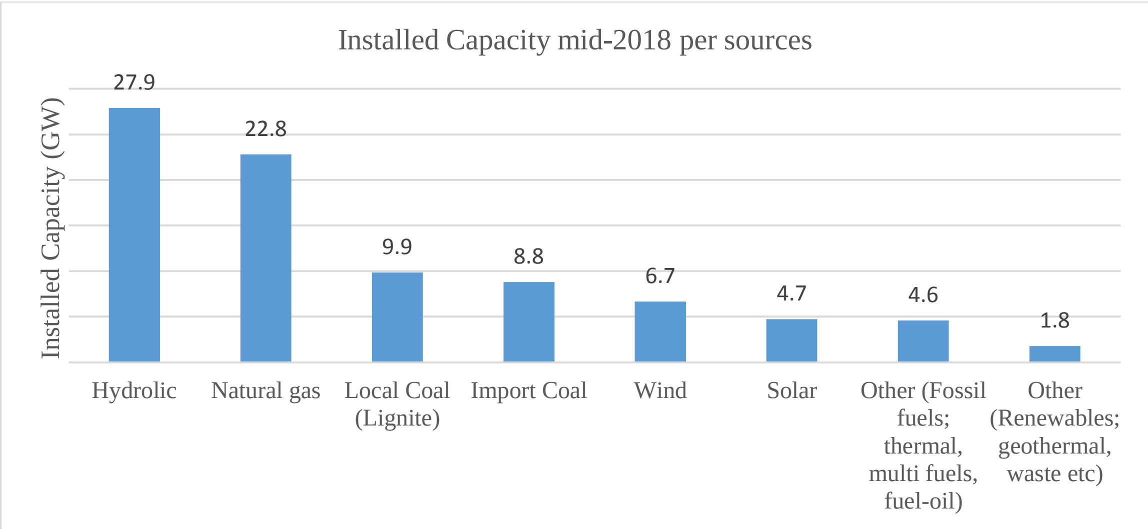

Figure 3.10. Installed Capacity per sources (TEIAS-mid 2018)

3.1.3. Potential of Turkey by Resources

In this part of the thesis, Turkey's potential in terms of electricity generation resources is evaluated in order to design the scenarios in the following chapter in a realistic and robust way. The key players of the electricity generation resources for Turkey is evaluated in terms of their potentials, i.e.; local coal, hydro, solar and wind which support the security of supply with no price risk. Nuclear and natural gas are not evaluated in this part since these are imported and not locally supplied.

3.1.3.1. Local Coal

Turkey possesses lignite and hard coal. Lignite with its high moisture content and low calorific value compared to hard coal results in higher emissions. Lignite reserves and production amounts of Turkey are considered as medium, hard coal reserves and production amounts are evaluated as low. Ministry of Energy and Natural Resources state that 3.2% of world reserves regarding lignite and sub-bituminous coal are located in Turkey. Afşin-Elbistan hosts 46% of the lignite and Zonguldak and its surroundings holds considerable amount of hard coal located in Turkey. However, approximately 68% of total lignite reserves of Turkey are of low calorific value. Potential investment sites and additional capacities to the existing power plants are evaluated by Deloitte. In this report it was targeted to use full lignite and hard coal potential until 2023. The potential areas are listed as below:

Table 3.1. *Potential New Sites*

Potential New Sites	Capacity
Konya-Karapınar	5,800 MW
Kahramanmaraş-Elbistan	1,000 MW
Trakya Site	1,400 MW
Additional Capacity in Existing Sites	
Afşin-Elbistan	
C Site	1,440 MW
D Site	1,440 MW
E Site	1,440 MW
Soma	500 MW
Tunçbilek	400 MW
Seyitömer	150 MW
Orhaneli	100 MW
Total	13,670 MW

3.1.3.2. Renewable Energy

Turkey has significant potential for renewable energy due to its geographic location. This potential may help the country to generate the electricity locally and reduce its dependence on imported fossil fuels consequently helping to reduce GHGs emissions. Therefore, Republic of Turkey has committed to reach 10 GW in solar power and 16 GW in wind power until 2030 and presented this in the Intended Nationally Determined Contribution (INDC) in order to keep the UNFCCC’s target on track.

3.1.3.2.1. Hydro

Ministry of Energy and Natural Resources (MENR) declared that the theoretical potential of Turkey corresponds to 1% of world's potential and 16% of Europe's economic potential. State Hydraulic Works (SHW) are the responsible authority for the hydraulic energy generation. In its strategic plan covering the years 2017-2021, SHW stated Turkey's theoretical hydroelectric potential as 433 TWh, and the technical realized potential as 216 TWh. In this strategic plan total hydraulic potential of Turkey was presented at approximately as 46 GW, the breakdown of this capacity as, 26,161 MW in operation, 13,984 MW to be constructed, 5,927 MW under construction. There are two types of power plants; run-of the river plants and massive hydroelectric dams. Although they are generating electricity in carbon free-ways both have other environmental impacts that need to be evaluated diligently in the planning phase associated with them.

3.1.3.2.2. Solar

Turkey is located on the solar (sunny) belt between 36^0 and 42^0 N latitudes. Despite its geographically well situated location with respect to solar energy potential, solar photovoltaic (PV) power interest of Turkey does not date back a long time except solar flat plate collectors. The main reason behind this is believed to be the lack of reliable legislations, incentives and political willingness. With the support of efficient and robust legislation a country receiving less solar radiation might outperform the countries located on the solar belt.

Solar irradiance refers the amount of solar energy which is available at a given location per unit area and time. It directly affects the power generated by a solar PV system at a given moment. It is the main variable that affects the output considering the two other variables (PV array area, efficiency) are constant, therefore, it is crucial in the phase of decision making before installing of a PV system. Solar irradiation (insolation) is the energy received by a solar system in a day. Thus, this energy impacts the system output (kWh/day) as per the below formula;

$$\text{System Output} = \text{PV Array Area (m2)} * \text{Efficiency (\%)} * \text{Solar Insolation (kWh/ m2/day)} \tag{3.1}$$

On the other hand, solar irradiance refers to the instantaneous solar power per unit area which varies throughout the day, the unit is kW/m^2. The formula for Solar PV system power in kW is formulated as below;

$$\text{Power} = \text{PV Array Area (m2)} * \text{Efficiency (\%)} * \text{Solar Irradiance (kW/ m2)} \tag{3.2}$$

As per the information given by MENR through Solar Energy Potential Map[2], Turkey has on average yearly 1,527 kWh/m^2 (this value corresponds approximately to4.18 hours of sunshine per day) potential solar energy radiation yearly and 2,737 hours/year (~7.5 sunshine hours/day) of solar insolation. Unlicensed PV Power projects can not exceed 1 MW due to legislation. Therefore, instead of having ground mounted larger solar farms, Turkey’s huge amount of solar projects are under 1 MW which can have the advantages of unlicensed feed-in-tariff (F-i-T). Only 0.03% solar power plants are licensed and over 1 MW. Approximately 200 MW rooftop solar photovoltaic (RTSPV) were installed as of the end of 2017.

In order to evaluate Turkey’s development in terms of solar energy, a comparison is made between the countries, i.e.: China, Germany, Japan, India, Italy, Spain, Portugal and France. Italy, Spain and Portugal are chosen because they have similar solar energy potential in terms of solar insolation as Turkey. India is included due to the

[2] http://www.enerji.gov.tr/tr-TR/Sayfalar/Gunes

spike of solar energy generation in the last few years France is included due to its dependence on nuclear and the other three have been included since these are the leading countries in solar sector. The below table indicates the development of installed capacity in 2008, 2011 and 2015. These data are taken from World Energy Council; in addition, surface area data are taken from Nation Master in order to evaluate the relation between the size of the country and its installed capacity. Also, data for 2016 and 2017 are collected since these two years are crucial considering the rapid development in the solar sector.

Table 3.2. *Development of Installed Capacity by Countries (2008-2017)*

	Installed Capacity in Solar (GW)					**Total Installed Capacity (GW)**	**Share of PV in Total Installed Capacity**	**Surface Area (km^2)**
	2008	**2011**	**2015**	**2016**	**2017**	**2017**	**2017**	
China	0.130	3.300	43.100	77.190	130.250	1,777.030	7%	9,600,000
Japan	2.140	4.910	33.300	42.750	49.000	231.484	21%	377,910
Germany	5.880	25.000	39.600	40.720	42.980	203.220	21%	357,030
Italy	0.432	12.800	18.900	19.283	19.700	114.000	17%	301,340
India	0.160	0.941	5.170	6.763	18.300	344.002	5%	3,290,000
France	0.180	2.760	6.549	7.300	8.000	130.761	6%	551,500
Spain	3.350	4.330	7.130	7.300	5.600	104.122	5%	505,370
Turkey	0.004	0.004	0.249	0.833	3.420	85.200	4%	783,562
Portugal	0.059	0.172	0.451	0.500	0.577	21.343	3%	92,120

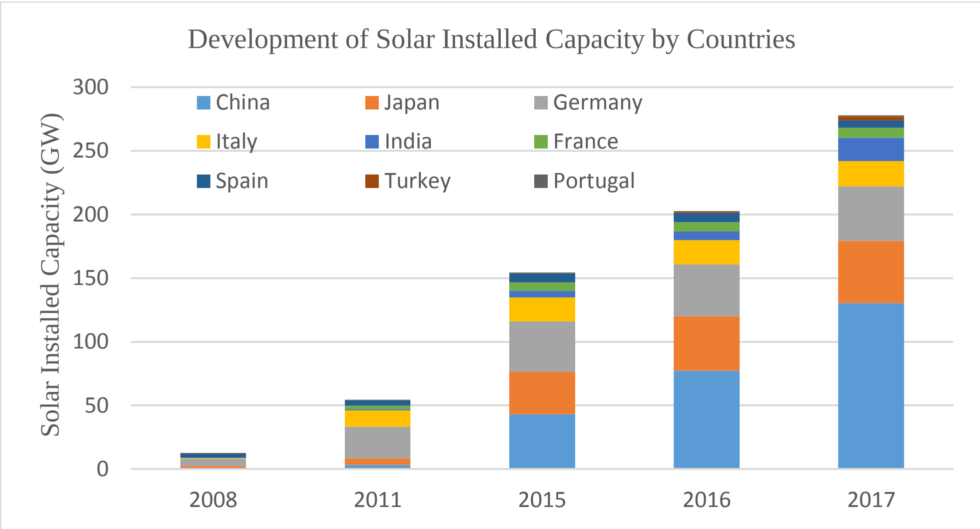

Figure 3.11. Development of Solar Installed Capacity by Countries (source: World Energy Council Data: https://www.worldenergy.org/data/resources; https://www.nationmaster.com/country-info/stats/Geography/Surface-area/Sq.-km#2005)

RTSPV of Turkey

The countries having higher percentage of solar in their energy generation mix, such as Germany, Japan, US, use considerably the RTSPV technology. It is a common sense that there is a huge potential to increase the share of the solar energy in the energy mix by utilizing RTSPV potential. In order to assess Turkey's potential for RTSPV, a study was carried by the financial and technical support of the World Bank and ESMAP (World Bank Group Energy and Extractives Global Practice Group Europe and Central Asia Region, n.d.). In this report, a market assessment was carried for four main sectors; residential buildings, commercial buildings, industrial facilities and governmental buildings considering the fast urbanization. One of the key components of this study is the estimation of the available rooftop area. Accurate estimation of the usable rooftop area is a complex matter and critical, considering the role of the RTSPV solutions in the future energy mix.

The useable rooftop area was determined by measuring the solar polygon areas of 909 random rooftops in seven selected provinces of Turkey. This selection was performed according to solar radiation, sun availability, urban density and roof type of 81 provinces of Turkey. The ratio of the solar polygon to main polygon of these 909 polygons obtained was then applied to the overall building data in order to arrive at the total useable rooftop area, which was calculated as 1.1 billion square meters in the aforementioned report. There is a differentiation between technical potential and market potential. Market potential is economically feasible and practical technical potential. Total useable rooftop area and an access factor considering shading, installation and other occupied spaces on the roof, result in the technical potential calculated as 46.8 GW, not taking into account physical or economic practicality. Market potential estimation is based on four pillars; grid capacity, financing opportunities, growth in the sales of equipment and income of users. (World Bank Group Energy and Extractives Global Practice Group Europe and Central Asia Region, n.d.)

3.1.3.2.3. Wind

As per the information provided on the MENR website[3], 7.5 m/s wind speed 50 meters above the ground level are potential areas for wind power in Turkey. It is further assumed that the installed capacity of each wind power plant can reach 5 MW/km^2. In the light of these two facts, the Wind Energy Potential Atlas (REPA) was prepared where the wind source information was generated by using mid-scale digital forecasting model and micro-scale wind flow model. As a result, Turkey’s wind energy potential was determined to be 48,000 MW. The area corresponding to this potential is 1.30% of Turkey's surface area.

[3] http://www.enerji.gov.tr/tr-TR/Sayfalar/Ruzgar

As a conclusion of this section, the threat of increasing GHGs emissions linked to electricity generation can be partially offset by utilizing different renewable energy resources available in Turkey in the energy generation mix. This section reaches to the vital conclusion that with the feasible decentralized solutions such as RTSPV, there will be a decrease in the dependency on centralized solutions especially on nuclear and fossil fuel power plants. The design of the scenarios will be evaluated in Chapter 5.

CHAPTER 4

ELECTRICITY DEMAND FORECASTS OF TURKEY

In this chapter, the official and reliable studies regarding electricity demand forecast of Turkey are investigated. In the subsequent sections of this chapter, electricity demand forecasting with cross country panel data is performed and presented.
This chapter begins with the list of the resources given in Table 4.1., continues with the forecasts of these resources and ends with our own forecasts by using the more recent data.

4.1. Review of Electricity Demand Forecast

There are both academic and governmental forecast studies for electricity demand of Turkey. This section focuses on the electricity forecast studies conducted by the government institutions. The official studies are listed below in Table 4.1. The list includes the name of the report or study, the institutions conducted the study with the years as well as the projection period. The Ministry of Energy and Natural Resources (MENR) is in charge of preparing electricity demand projection of Turkey in every two years for a 20-year period as per Electricity Market Law (No: 6446).

Table 4.1. *List of Electricity Demand Forecast Studies*

	Name of the Report/Study	**Institution**	**Year of the Report**	**Period of Forecast**
1	Stratejik Plan Türkiye Talep Tahmini (Strategic Plan, Turkey Demand Forecast)	MENR		2017-2037
2	Türkiye Elektrik Enerjisi 5 Yıllık Üretim Kapasite Projeksiyonu (Turkey 5-Year Electricity Power Generation Projection)	TEIAS	August 2017	2017-2021
3	10 Yıllık Talep Tahminleri Raporu (10-Year Demand Estimation Report)	TEIAS	December 2016	2017-2026

MENR's forecast is named as "Stratejik Plan Türkiye Talep Tahmini" (Strategic Plan, Turkey Demand Forecast). Economy, population, calendar effect, temperature, electrical vehicles, energy efficiency, transmission loss, internal consumption and MENR Energy Balance table are considered as constraints for their electricity consumption forecast.

MENR uses five models for this projection. These are;

1. Sectoral Regression Model
2. LEAP Model
3. Artificial Neural Networks&Regression (Monthly Demand Model)
4. Regression and Monte Carlo Model
5. Flexibility Model (Esneklik Yönetimi Modeli)

All the models are applied to the three scenarios. These are namely, low demand, reference demand and high demand. As a result, 15 different demand series are created. In order to determine ultimate series of the report as low, reference and high, a distance matrix is identified to analyze the differences of the results for each model. Distance matrix for each scenario is summed and final distance matrices are obtained. For selected models, the final results of the projections are determined by weighting the results on the basis of the scenarios equally. The results obtained on an annual basis are shown in Table 4.2. and Figure 4.1. Annual average electricity demand growth rate for the next 20 years is calculated as 3.5% for Scenario 1 (low), 4.2% for Scenario (reference) 2 and 5.3% for "Scenario 3 (high)".

Table 4.2. *Results of Electricity Demand-yearly demand and changes, Source: "Stratejik Plan Türkiye Talep Tahmini" (Strategic Plan, Turkey Demand Forecast).*

Years	**Scenario1 (TWh)**	**Scenario2 (TWh)**	**Scenario3 (TWh)**	**Scenario1 (Differences)**	**Scenario2 (Differences)**	**Scenario3 (Differences)**
2017	288.21	290.24	292.12			
2018	301.51	304.43	307.21	4.6%	4.9%	5.2%
2019	315.81	319.46	323.79	4.7%	4.9%	5.4%
2020	328.41	334.98	343.24	4.0%	4.9%	6.0%
2021	341.04	350.7	363.44	3.8%	4.7%	5.9%
2022	354.16	367.26	384.85	3.8%	4.7%	5.9%
2023	367.88	384.64	407.89	3.9%	4.7%	6.0%
2024	381.81	402.31	431.66	3.8%	4.6%	5.8%
2025	396.14	420.51	456.47	3.8%	4.5%	5.7%
2026	410.53	439.17	482.26	3.6%	4.4%	5.6%
2027	424.97	457.88	508.61	3.5%	4.3%	5.5%
2028	439.5	477.04	535.94	3.4%	4.2%	5.4%
2029	454.14	496.5	564.13	3.3%	4.1%	5.3%
2030	468.4	515.96	592.84	3.1%	3.9%	5.1%
2031	482.75	535.51	622.22	3.1%	3.8%	5.0%
2032	497.11	555.22	652.38	3.0%	3.7%	4.8%
2033	511.42	575.05	683.21	2.9%	3.6%	4.7%
2034	525.3	594.87	714.61	2.7%	3.4%	4.6%
2035	539.01	614.64	746.52	2.6%	3.3%	4.5%
2036	553.14	635.06	779.74	2.6%	3.3%	4.4%
2037	567.68	656.16	814.47	2.6%	3.3%	4.5%

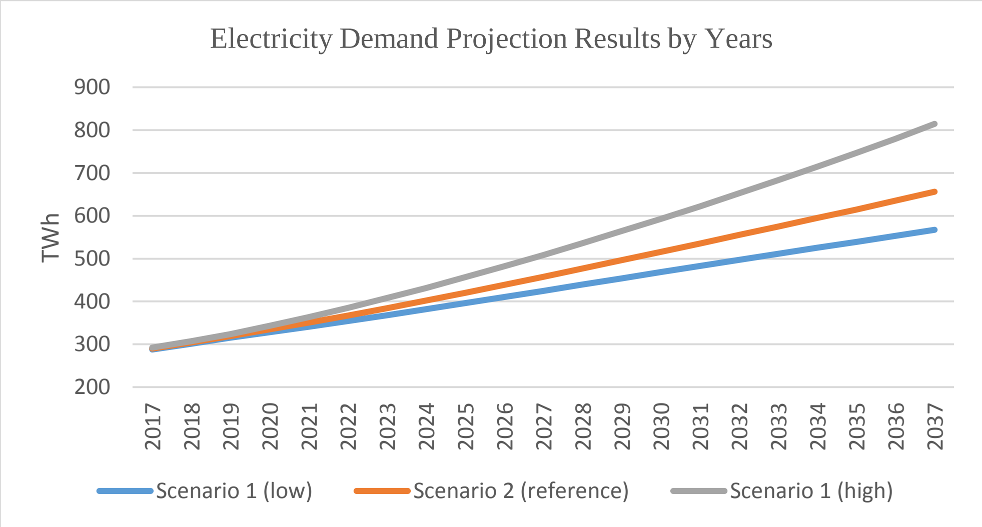

Figure 4.1. Electricity Demand Projection Results by Years

As per the information given by "enerjiatlasi" website[4] in 2017 the annual electricity consumption of Turkey is 289,637,395 MWh corresponding 289.64 TWh which is in between Scenario 1 (low) and Scenario 2(reference) scenarios of the official projection of MENR.

The third report named as "10-year Demand Forecast Report (10 Yıllık Talep Tahminleri Raporu)" in Table 1 is prepared by Turkey Electricity Transmission Company (TEIAS) on the basis of Articles 9 and 20 of the Electricity Market Law No. 6446. As per the Electricity Market Demand Forecasting Regulation published in Official Gazette dated 07.05.2016 and numbered 29705, TEIAS is responsible for presenting Turkey's Demand Estimates to Energy Market Regulatory Authority (EMRA) by combining estimation of the consumers who are directly connected to the transmission system and estimation of the distribution companies. According to the Electricity Market Demand Forecasting Regulation, distribution companies are responsible to prepare demand forecast report for their distribution region each year

[4] http://en.enerjiatlasi.com/electricity-consumption/turkey/

for the 10-year period, supplier companies are responsible to prepare their reports for a 5-year period. This report relies on these assumptions and present three scenarios as low, reference and high for the period between 2017-2026. The results obtained on an annual basis are shown in Table 4.3 and Figure 4.2. 10-year Demand Forecast Report 2017-2026 report, and TEIAS's reference demand scenario predict power demand growth to accelerate and to reach to 376.78 TWh in 2026 which is estimated as 439.17 TWh for the same year in MENR's reference scenario.

Table 4.3. *Electricity Consumption Forecast by TEIAS*

Years	**Scenario1 (TWh)**	**Scenario2 (TWh)**	**Scenario3 (TWh)**	**Scenario1 (Differences)**	**Scenario2 (Differences)**	**Scenario3 (Differences)**
2017	278.06	284.55	289.93			
2018	285.63	294.75	302.26	2.7%	3.6%	4.3%
2019	293.75	305.29	315.28	2.8%	3.6%	4.3%
2020	301.67	315.62	328.31	2.7%	3.4%	4.1%
2021	309.68	326.11	341.72	2.7%	3.3%	4.1%
2022	317.64	336.52	355.27	2.6%	3.2%	4.0%
2023	325.45	346.78	368.88	2.5%	3.0%	3.8%
2024	333.04	356.89	382.56	2.3%	2.9%	3.7%
2025	340.18	366.85	396.08	2.1%	2.8%	3.5%
2026	347.15	376.79	409.68	2.0%	2.7%	3.4%

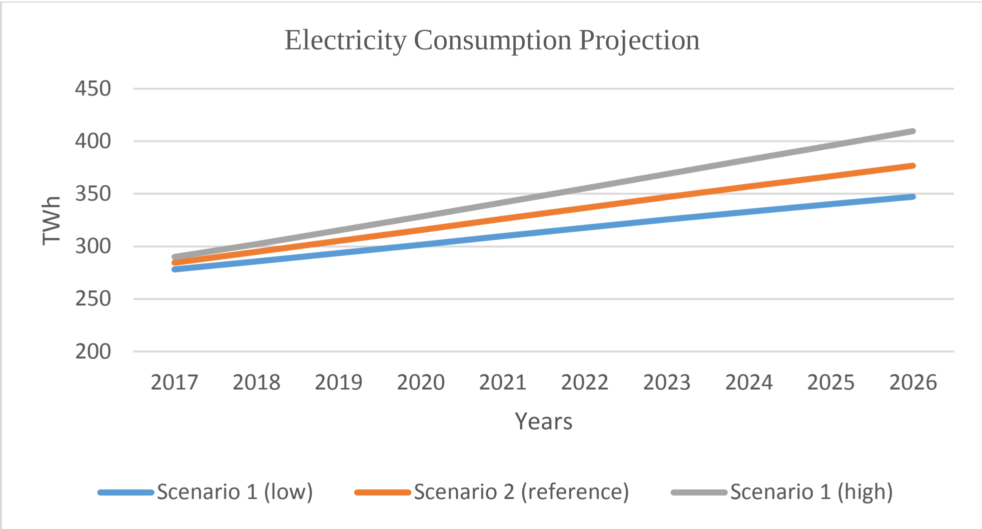

Figure 4.2. Electricity Consumption Projection by TEIAS

Compared to the MENR official projection for 20 years both in 2023 and in 2026, the electricity demand projection values of TEIAS are below than those of the low scenario. One of the reasons may be the differences of the reference data of both studies or the differences in the other implicit assumptions in each approach.

In addition, two official projections are compared for the same years and found to be inconsistent.

Table 4.4. *Comparison of Electricity Demand Projections in TWh (low scenarios)*

Years	**MENR**	**TEIAS**
2017	288.21	278.06
2018	301.51	285.63
2019	315.81	293.75
2020	328.41	301.67
2021	341.04	309.68
2022	354.16	317.64
2023	367.88	325.45
2024	381.81	333.04
2025	396.14	340.18
2026	410.53	347.15

4.1.1. Demand Forecasting

It is vital to consider the evolution of the future energy demand in order to maintain sustainable development considering that sustainable development is a process. As per the definition of the United Nations World Commission on Environment and Development in 1987, development is considered as sustainable if it “meets the needs of the present without compromising the ability of future generations to meet their own needs”. Therefore, sustainable development has three main pillars that are economic, social and environmental. All three must be in balance within the same generation and among generations by achieving intergenerational equity.

Considering the scarcity due to resource limitations and environmental impacts associated with the use of energy, how can current nation effectively allocate the resources without harming the future generations? To be able to achieve this, robust energy demand forecasting is essential.

If there is a relationship between two variables, *x* and *y*, finding the relationship is estimation that is uncovering the relationship. This estimation gives prediction, where prediction about future is projections that can be used for structural analysis, policy analysis and forecasting. In addition, judgments will be reflected together with this projection which is forecasting in all steps using mathematical techniques and based on scenarios.

The relationship between economic growth, energy demand and GHGs, which corresponds to three essentials of sustainable development is put forth in many different ways throughout literature.

It is stated that there is a correlation between energy demand, population and economic growth, however the spatial differences could not be disregarded. (Sorrell, 2015)

Wide varieties of empirical studies indicate that there is a relationship between energy, economy and environment which can be presented with energy consumption, income, and emissions or with other parameters. However, the relationship between them for each country are not identical. (Sari, R., Soytas, U., 2009)

The relationship between emissions and income shown by Environmental Kuznets Curve (EKH) reinvestigated by Stern, concluding that although the income elasticity of emissions is less than one in developed countries, the value is not negative as highlighted in EKH hypothesis. In addition, the performance of the developing countries for the implementation of the new environmental policies are with a short time lag, therefore developing countries may attain better results.(David I. Stern, 2004)

The relationship between energy, growth and pollution cannot be disregarded. Nevertheless, the relation between these three depends on many other dynamics, quality of fuels, technological improvements, increasing energy efficiency lead to economic growth by creating less emissions. (D.I. Stern, 2004)

Özokcu focuses on the relationship between economic growth and CO_2 emissions from the view point of EKC in order to demonstrate the relationship between economic growth and CO_2 emissions assumed as an inverted U-shape. She utilizes cross-country panel data techniques in order to analyze the relationship between per capita income, per capita energy use and per capita CO_2 emissions. As an outcome of the estimation, the relationship described in the Environmental Kuznets Curve could not be attained.(Özokcu, 2015)

The below figure indicates the annual installed capacity (MW) development by energy resources mainly as hydro, thermal and renewables of Turkey starting from 1960 until 2016 taken from TEIAS. In addition, the historical development of CO_2 (kt) is shown in the below graph starting from 1960. As per the definition of World Development Indicators, CO_2 emission refers to "*Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring*". This figure shows the relationship between the development of installed capacity and the total CO_2 emissions.

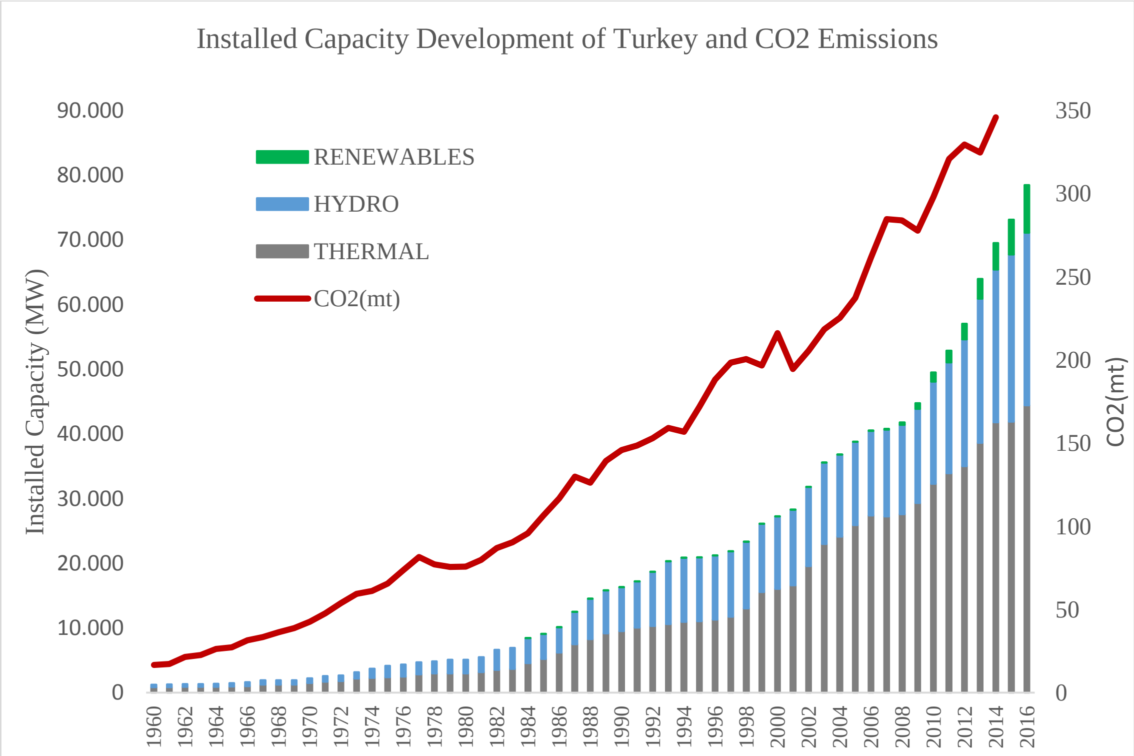

Figure 4.3. Installed Capacity Development of Turkey and CO2 Emissions

In Table 4.5., the relevant literature is summarized to explain the relationship regarding economic growth, energy demand and GHGs using time series methods.

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Table 4.5. *Review of Literature regarding the relationship between economic growth, energy demand and emission by time series*

	Authors& Year Name of Publication	Indicators&Variables	Regions&Period	Estimation Techniques	Outcomes
1	(Ramazan Sari & Soytas, 2009) Are global warming and economic growth compatible? Evidence from five OPEC countries?	Carbon emission, income, energy and total employment	Algeria, Indonesia, Nigeria, Saudi Arabia, and Venezuela 1971-2002	Time series ARDL, Granger causality	Except Saudi Arabia there is no cointegration between income, employment and energy consumption. Long-run granger causality between emissions, energy use and income indicates that no long run negative effects on economic growth and emission although type of policies may differ in each country. In addition, it is highlighted that this study should not be generalized for other countries and further research including capital stock should be studied.

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	Authors& Year Name of Publication	Indicators&Variables	Regions&Period	Estimation Techniques	Outcomes
2	(Ugur Soytas & Sari, 2009) Energy consumption, economic growth, and carbon emissions: challenges faced by an EU candidate member	Energy consumption, carbon dioxide emission, labor, gross fixed capital investment, the real GDP per capita	Turkey 1960-2000	Time series, Granger causality, The Toda and Yamamoto	Unidirectional causality from carbon dioxide emission to energy use concluded in Turkey There is no long run causal link between income and emission which is indicating that emission reductions will not harm economic growth.
3	(Ramazan Sari & Soytas, 2007) The growth of income and energy consumption in six developing countries	Growth rates for energy consumption, real GDP, growth rates of capital stock, total labour force	Indonesia, Iran, Malaysia, Pakistan, Singapore, Tunisia 1971-2002	Time series, unit root test (Dickey-Fuller, Phillips - Perron, Kwiatkowski-Phillips-Schmit-Shin) Variance Decomposition, Impulse Response Methods	Energy production also including energy efficiency solutions targeting to lower the energy intensity accelerate the growth in the developing countries. The difference results of each country implies the importance of investigate individual countries by taking into account its own dynamics.

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	Authors& Year Name of Publication	Indicators&Variables	Regions&Period	Estimation Techniques	Outcomes
4	(Ugur Soytas & Sari, 2006) Energy consumption and income in G-7 countries	Real GDP per capita, capital stock, total labor force, total energy use Supply-side analysis of economic growth production function	G-7 countries Years of data varies depending on the availability. (1960-2004, 1971-2003, 1970-2002)	Time series Multivariate cointegration (Johansen, Johansen-Juselius)-VECM, generalized variance decompositions (Koop, Pesaran-Potter, Pesaran-Shin), unit root test,Granger causality	Not unified causality between energy consumption and income, depends on each country's own dynamics
5	(R Sari & Soytas, 2003) Energy consumption and GDP: causality relationship in G-7 countries and emerging markets	Annual energy consumption, GDP per capita	G-7 and Argentina, Brazil, India, Indonesia, Mexico Poland, South Africa, South Korea, Turkey Difference period for some countries but generally 1950-1992	Time-series Unit-root (Dickey-Fuller, augmented Dickey-Fuller, Phillips-Perron, multi-variate Cointegration, VEC	Differences among the countries regarding causal relationship between GDP and energy consumption.

	Authors& Year Name of Publication	Indicators&Variables	Regions&Period	Estimation Techniques	Outcomes
6	(Uğur Soytas, Sari, & Özdemir, 2001) Energy consumption and GDP relation in Turkey: a cointegration and vector error correction analysis	GDP, energy consumption	Turkey 1960-1995	Time-series multi-variate Johansen-Juselius Cointegration Methodology and Vector Error Correction Modeling	a unidirectional causality running from energy consumption to GDP.

Summary of the above table indicates that there is a relationship between economic growth, energy demand and emission although each article uses different time series estimation methods. In addition, the studies which examine more than one country concluded that the relationship between these three subject is country specific.

In the following section, thesis will focus on cross-country panel data analysis for electricity demand forecast.

4.1.2. Cross Country Panel Data Analysis for Electricity Demand Forecast

There are several studies putting forth the relationship between income, energy demand and emissions through cross-country panel data analysis method.
In this thesis, electricity demand forecasting is performed using cross country panel data technique. The reason to use cross country panel data analysis is the advantage in comparison to pure time series and pure cross-sectional analysis. Panel data provides more variability and less collinearity. Therefore, it is considered that estimation by panel data is more reliable. The advantages to use panel data is summarized as a list below (Baltagi, n.d.).

- Panel data allows to analyze larger data set compare to cross sectional and time series analysis.
- Cross-section dimension of panel data provides variability and add more informative data which provides more reliable estimation.
- Panel data provides less collinear, more degrees of freedom and more efficiency.
- It is easier to track multitude changes due to its time dimension therefore dynamics of adjustment is easier to study.
- It allows for the estimation of intertemporal relations.

- Individual heterogeneity of entities is under control.
- Panel data allows controlling unobserved variables, such as technological developments in time, behavioral changes of consumer, increase of environmental awareness, national policies and regulation.
- Panel data controls the effects with a lag period (which could not be observed immediately), such as the effect of implemented new policies.

The relevant literature review dedicated on cross-country panel data analysis on electricity demand is given below in Table 4.6.

Table 4.6. *Review of Literature regarding the relationship between economic growth and energy demand by using panel data*

	Authors& Year Name of Publication	Indicators&Variables	Regions&Period	Estimation Techniques	Outcomes
1	(Pérez-García & Moral-Carcedo, 2017) Why Electricity Demand Is Highly Income-Elastic in Spain. A Cross-Country Comparison Based on an Index-Decomposition Analysis	Electricity intensity, electricity consumption (residential and non-residential), GDP	EU-28 1996-2012	Index Decomposition	Developed countries elasticities is going to decrease due to energy efficiency, developing countries income elasticity > 1 due to electrification
2	(Osman, Gachino, & Hoque, 2016) Electricity consumption and economic growth in the GCC countries: Panel data analysis	Electricity consumption per capita, real GDP per capita	GCC countries 6 countries of the Gulf Cooperation Council 1975-2012	PMGE, Panel cointegration, causality	Bidirectional causality between electricity consumption and GDP, unidirectional causality from GDP to energy consumption
3	(Karanfil & Li, 2015) Electricity consumption and economic growth: Exploring panel-specific differences, December	Electricity consumption per capita, GDP per capita, Covariates; urbanization and electricity trade	160 countries Grouped as income levels, geographical locations and OECD membership 1980-2010	cointegration	There exists a long run cointegration relationship between these two variables, implying the feedback hypothesis. Electricity growth is highly sensitive, region, income, urbanization and supply risk

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	Authors& Year Name of Publication	Indicators&Variables	Regions&Period	Estimation Techniques	Outcomes
4	(El-Shazly, 2013) Electricity demand analysis and forecasting: A panel cointegration approach	Domestic price of electricity disaggregated by sector, domestic price of foreign products, general index of domestic prices, real income by sector, population size	Egypt 1982-2010	Unit root, panel cointegration, panel causality, ARDL	Not unified causality between energy consumption and income, depends on each country's own dynamics
5	(I. Ozturk, Aslan, & Kalyoncu, 2010) Energy consumption and economic growth relationships: Evidence from panel data for low and middle income countries	Energy consumption, economic growth	51 countries (grouped as low income, lower-middle income, lower-upper income group), 1971-2005	Panel cointegration, panel causality, Pedroni	Differences among the countries regarding causal relationship between GDP and energy consumption.
6	(Lee & Lee, 2010) A Panel Data Analysis of the Demand for Total Energy and Electricity in OECD Countries	Total energy price, electricity price, real total energy, real electricity price indices for industry and households	25 selected OECD countries 1978-2004	Panel unit root, panel cointegration, panel causality	a unidirectional causality running from energy consumption to GDP.

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	Authors& Year Name of Publication	Indicators&Variables	Regions&Period	Estimation Techniques	Outcomes
7	(Huang, Hwang, & Yang, 2008) Causal relationship between energy consumption and GDP growth revisited: a dynamic panel data approach	Energy consumption, GDP	82 countries Low income group, lower middle income group, upper middle income group, and high income group 1972-2002	GMM-SYS approach for Panel VAR	No causal relationship between energy consumption and economic growth for low income group
8	(Lee & Chang, 2008) Energy consumption and economic growth in Asian economies: A more comprehensive analysis using panel data	Capital stock, labour input	16 Asian countries Presented in two cross sectional groups APEC and ASEAN 1971-2002	Panel unit root, heterogeneous panel cointegration panel based error correction	Long-run unidirectional causality running from energy consumption to economic growth
9	(Narayan, Smyth, & Prasad, 2007) Electricity consumption in G7 countries: A panel cointegration analysis of residential demand elasticities	real income per capita, residential electricity consumption per capita, real residential electricity price	G7 countries 1978-2003	Panel unit root, panel cointegration	Residential electricity demand for long-run is price elastic and income inelastic. Therefore, pricing policies provides restriction in residential electricity demand cause limitation in CO2 emissions.

	Authors& Year Name of Publication	Indicators&Variables	Regions&Period	Estimation Techniques	Outcomes
10	(Lee, 2005) Energy consumption and GDP in developing countries: A cointegrated panel analysis	Energy consumption, GDP	18 developing countries 1975-2001	Panel unit root, heterogeneous panel cointegration, panel based error correction models	Economic growth triggered by the energy consumption in the developing countries
11	(Liu, 2004) Estimating Energy Demand Elasticities for OECD Countries a Dynamic Panel Data Approach,	Income, consumption, price for energy goods in the residential sector	OECD 1978-1999	GMM estimation, OLS	There is long run GDP elasticities of several energy goods. Price elasticities of electricity, natural gas and gas oil demand are in larger. The results show that for electricity, natural gas and gas oil demand, price elasticities are in general larger (in absolute value) while GDP/income elasticities are lower in the residential sector than in the industrial sector. This paper yields lower values for price elasticities compared to the results from earlier studies. The long run GDP/income elasticities found in this paper, however, are quite similar to those found in earlier studies, and are around unity in general.

The studies regarding the relationship between economic growth and energy demand by using different independent variables for different clusters of countries/regions summarized in the Table 4.6. above. This table shows that the relation between these two variables are country specific and countries having the same development level show a similar tendency.

Official forecasts for electricity demand in Turkey are not very robust and most of the studies overestimate the future electricity demand as summarized in Table 4.1. This is underlined by Keleş stating that there are three grounds of this insufficiency in the official forecasts; i.e technical deficiencies of preferred model, imperfectly built assumptions and not having transparency in the process.(Keleş, 2005) Policy makers take irreversible steps due to the overestimated demand which leads to unsuccessful policies.

Öztürk et al investigated the electricity demand projection for Turkey between 2012-2035. This study takes the official demographic projections, the effect of energy efficiency, the progress of each sector analyzed as industrial, residential, service/commercial, transport and others into account. In this study, bottom-up modeling is used. In addition to this bottom-up modelling carried out under the LEAP model benchmarking with EU and Asia is performed in order to achieve a more reliable conclusion. The results of benchmarking with EU and Asia indicate that in terms of electricity demand distribution on sectorial basis, the figures are in line with EU and the demand forecast value is within the range of EU27+ countries. Considering benchmarking with Asia, the annual growth rate for demand seems in line with Asian trend which is high. This study reaches to the conclusion that the base year which is 2012 the electricity consumption is as 197.5 TWh which was 206.7 TWh in actual and it is estimated to reach 316.7 TWh in 2023 and to 474.4 TWh in 2035 which is the last year of the estimation in this study.(Öztürk, Kumbaroğlu, Avcı, & Küçük, 2015)

Besides, Table 4.7. demonstrates the studies in addition to Öztürk et al. on Turkey's electricity demand forecast.

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Table 4.7. *Comparison of Electricity Demand Projections*

	Authors& Year Name of Publication	Indicators&Variables	Period of Data	Estimation Techniques	Outcomes
1	(Günay, 2016) Forecasting annual gross electricity demand by artificial neural networks using predicted values of socio-economic indicators and climatic conditions: Case of Turkey	GDP per capita, inflation percentage, unemployment percentage, average summer temperature, average winter temperature	1975-2013	Time series Artificial Neural Networks	460 TWh in 2028
	(Öztürk et al., 2015) Electricity Demand Projection for Turkey: Bottom-Up Modeling Approach, and Comparison with EU and Asia	official demographic projections, energy efficiency improvement expectations, sectorial growth and development expectations		Long-range Energy Alternatives Planning System (LEAP) Benchmarking	316.7 TWh in 2023 474.4 TWh in 2035
2	(Özer, Görgün, & Incecik, 2013) The scenario analysis on CO_2 emission mitigation potential in the Turkish electricity sector: 2006-2030	Historical electricity consumption, GDP, value added per activity sector, the energy intensity of the different sectors with sectoral growth rates, ratio of each sector in total electricity demand, population growth	1990-2009	Long-range Energy Alternatives Planning System (LEAP)	341 TWh in 2020 696 TWh in 2030
3	(Dilaver & Hunt, 2011) Turkish aggregate electricity demand: An outlook to 2020	GDP, average real electricity prices, Underlying Energy Demand Trend	1960-2008	Structural time series	Between 259 TWh – 368 TWh in 2020.
4	(Erdogdu, 2007) Electricity demand analysis using cointegration and ARIMA modelling: A case study of Turkey	GDP per capita, net electricity consumption per capita	1984-2004	Cointegration ARIMA Modelling	2005-2014 160 TWh in 2014

5	(Akay, Diyar. Atak, 2007) Grey prediction with rolling mechanism for electricity demand forecasting of Turkey	Electricity consumption	1970-2004	Grey prediction with rolling mechanism (GPRM)	2006-2015 265,7 TWh in 2015
6	(H. K. Ozturk & Ceylan, 2005) Forecasting total and industrial sector electricity demand based on genetic algorithm approach: Turkey case study	GNP, population, import and export	1980-2003	Genetic Algorithm (GA)	2004-2020 462 TWh- 492 TWh in 2020 (low growth scenario) 492TWh – 500 TWh in 2020 (high growth scenario)

4.1.2.1. Data Description and The Econometric Model

In this thesis, the data used for the cross country panel data analysis is taken from the World Development Indicators of the World Bank for the period of 1960-2014. The data of OECD countries except the data of Iceland are included in the model. Iceland is excluded due to being world's largest electricity consuming country per capita. For the reason that Iceland has abundance of natural resources mainly from renewables which makes the cost of electricity low and low population mostly living in the urban areas having higher life standards relative to other countries using more electricity than any other countries.

In addition, Argentina, Brazil from Latin America, China, India, Indonesia from Asia and South Africa from sub-Saharan countries are included in the analysis, taking high populated countries into considerations with the developed ones since developed countries' past data are substantive for the prediction of future consumption of developing ones. The analysis of data belonging to the period of 1980-2015 with 5 years' intervals assuming that the magnitude of annual changes considering electricity consumption is negligible. 2015 data does not exist therefore instead of 2015 data; 2014 data is substituted as a last year of the analysis. Before presenting the results of econometric models, some scatter plots are created. In order to increase the visibility of the graphs countries are grouped as per their population; i.e: group 1 composed of countries with population less than 11 million, group 2 composed of countries with population above 11 million less than 90 million and group 3 composed of countries more than 90 million. List of the countries is given in Table 4.8. The graphs present the relation between electricity power consumption and the real GDP by country through years; additionally, electricity power consumption and corresponding populations are through years presented. Instead of GDP per capita and electricity power consumption per capita, GDP and electricity power consumption are used considering that the short term fluctuations in GDP per capita does not have outstanding changes on electricity power consumption per capita, for instance personal preferences or personal use at home does not affect hastily by the increase in GDP per capita.

Although the overall interpretation of the relation can be summed up that there is an increasing trend between electricity consumption and GDP, this relation differs from one country to another. For instance, Turkey, Italy and Spain show similarities in terms of the slope. In addition, some countries have a larger slope, such as Korea. China experienced an exponential growth in the electricity power consumption. The countries having high elasticity of income with respect to electricity, as per capita income increase citizens prefer their needs of electricity met, similar to what the developed countries did before. United States’ electricity power consumption shows an increasing trend in response to the growth in GDP. However last years’ electricity power consumption seems stable even the GDP has increased. Moreover, countries like Australia, France and the United Kingdom had an increasing trend previously but after certain GDP, a decreasing trend is observed. The reason for this could be a decrease in their energy intensity due to the increase of energy efficiency or concerns of GHGs emissions and increase of environmental awareness.

The relation between electricity power consumption and GHGs emissions explicitly indicate that although electricity power consumption continues to increase, GHGs emissions are stable. This is one of the important finding that electricity consumption continues to increase whilst GHGs emissions are under control. Finland, Luxembourg, Norway and some other countries keep their GHGs emissions at the same level while electricity power consumption continues to increase. Brazil and India show similar trend, although there is a little increase in the electricity consumption, the increase in GHGs emissions became high.

Table 4.8. *Classification of Countries based on Population*

	Group-1 **<11 million**	**Group-2** **>11 mil <90 mil**	**Group-3** **>90 mil**
Name of Countries	Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, Greece, Hungary, Ireland, Israel, Latvia, Lithuania, Luxemburg, New Zealand, Norway, Portugal, Slovak Republic, Slovenia, Sweeden, Switzerland	Argentina, Australia, Canada, Chile, France, Germany, Italy, Korea Republic, Netherlands, Poland, South Africa, Spain, Turkey, United Kingdom	Brazil, China, India, Indonesia, Japan, Mexico, United States

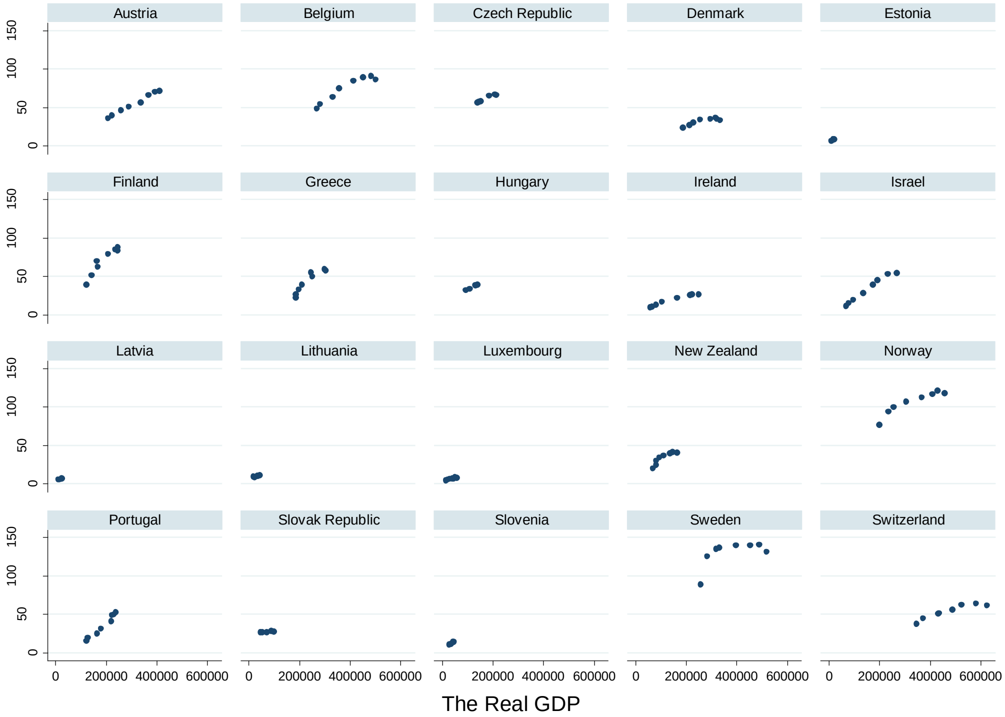

Figure 4.4. The relation between Electricity Power Consumption (TWh) and real GDP across group 1 countries

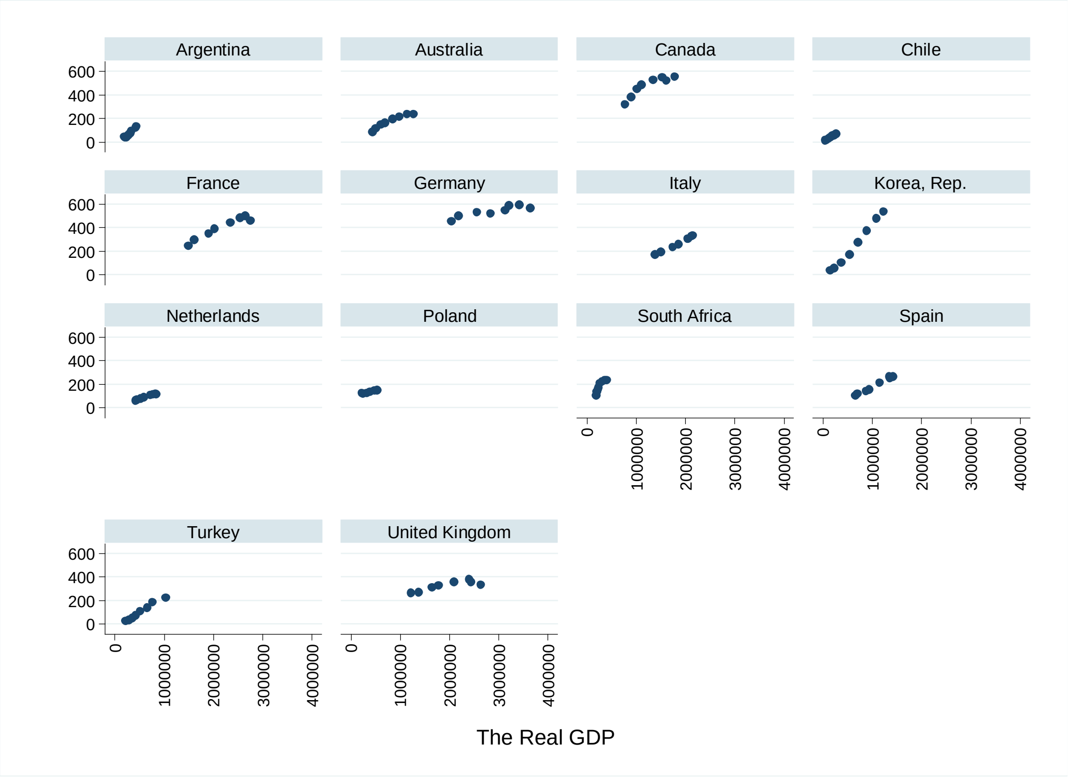

Figure 4.5. The relation between Electricity Power Consumption (TWh) and real GDP across group 2 countries

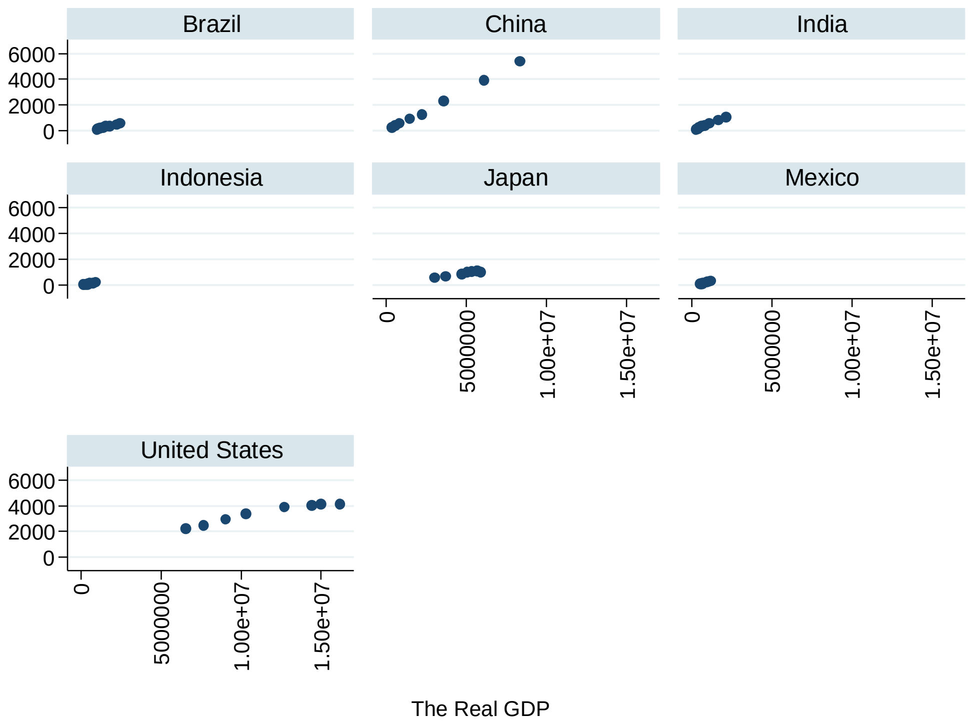

Figure 4.6. The relation between Electricity Power Consumption (TWh) and real GDP across group 3 countries

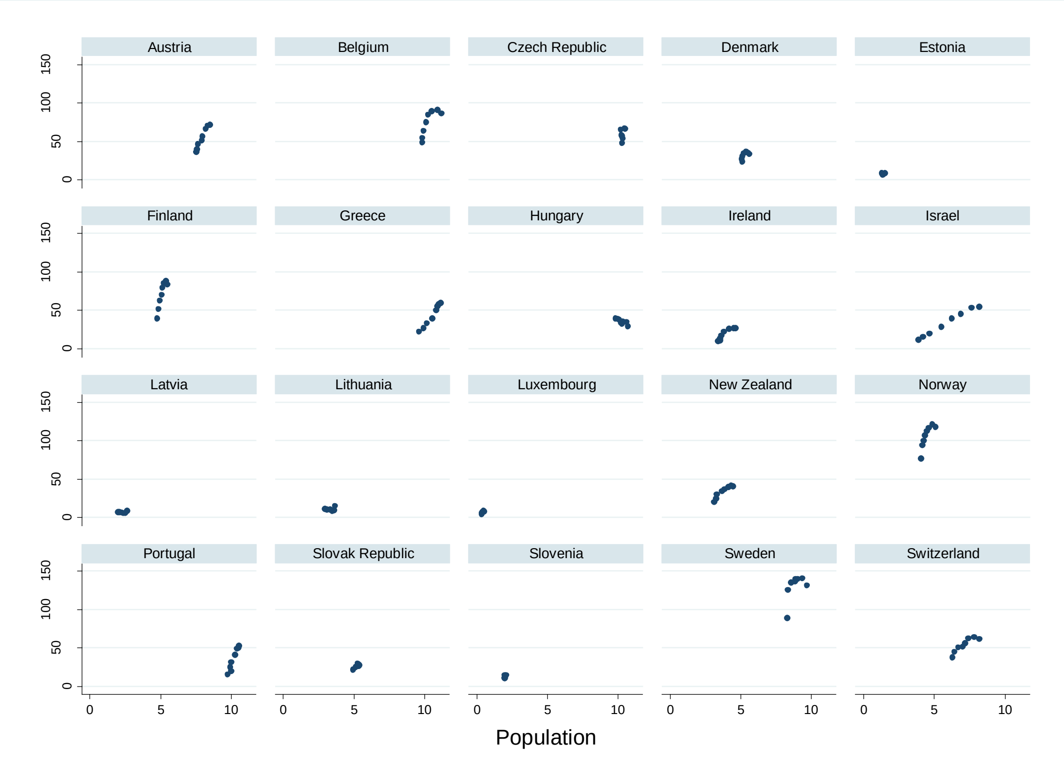

Figure 4.7. The relation between Electricity Power Consumption (TWh) and Population (million) across group 1 countries

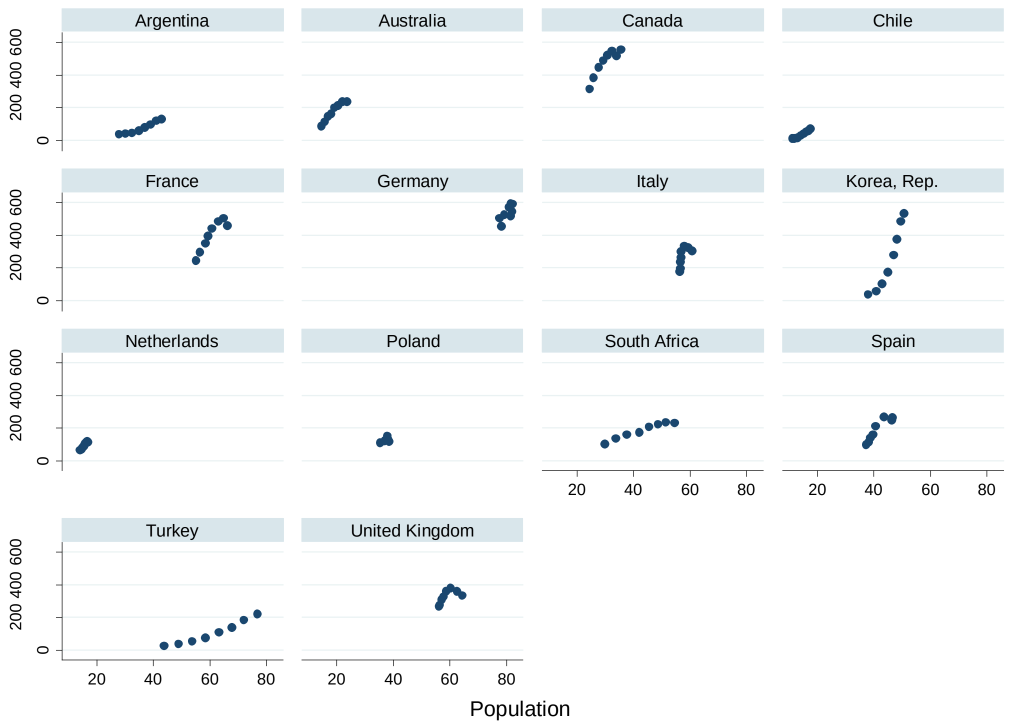

Figure 4.8. The relation between Electricity Power Consumption (TWh) and Population (million) across group 2 countries)

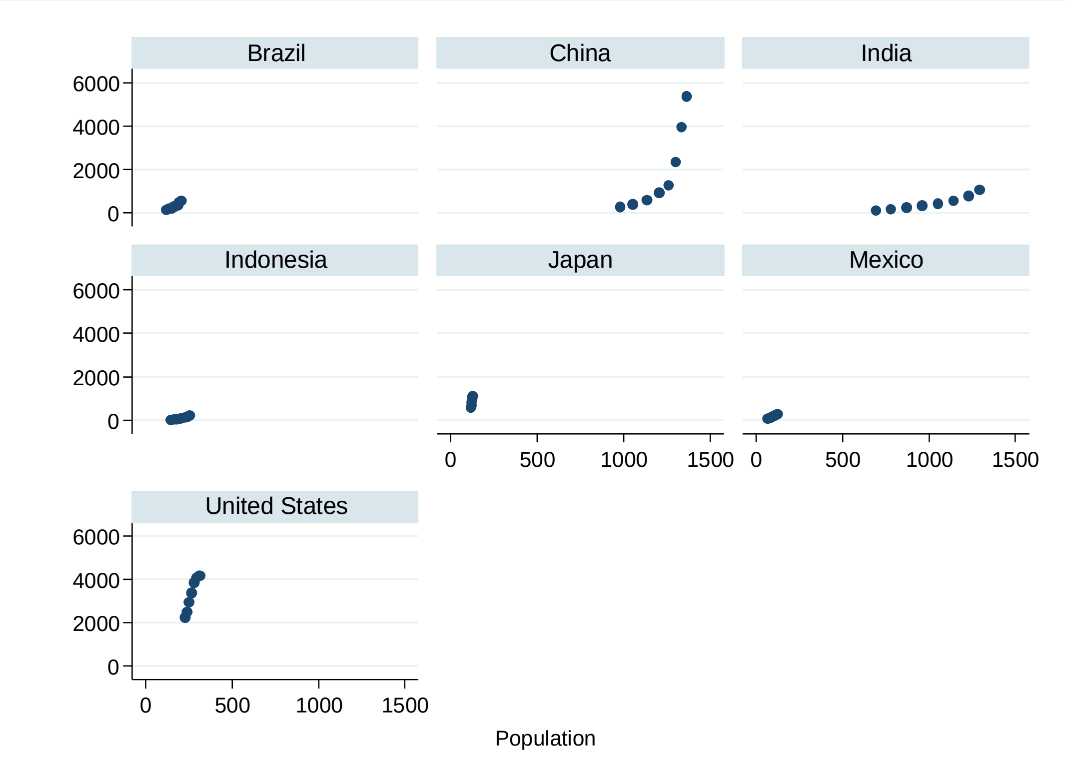

Figure 4.9. The relation between Electricity Power Consumption (TWh) and Population (million) across group 3countries)

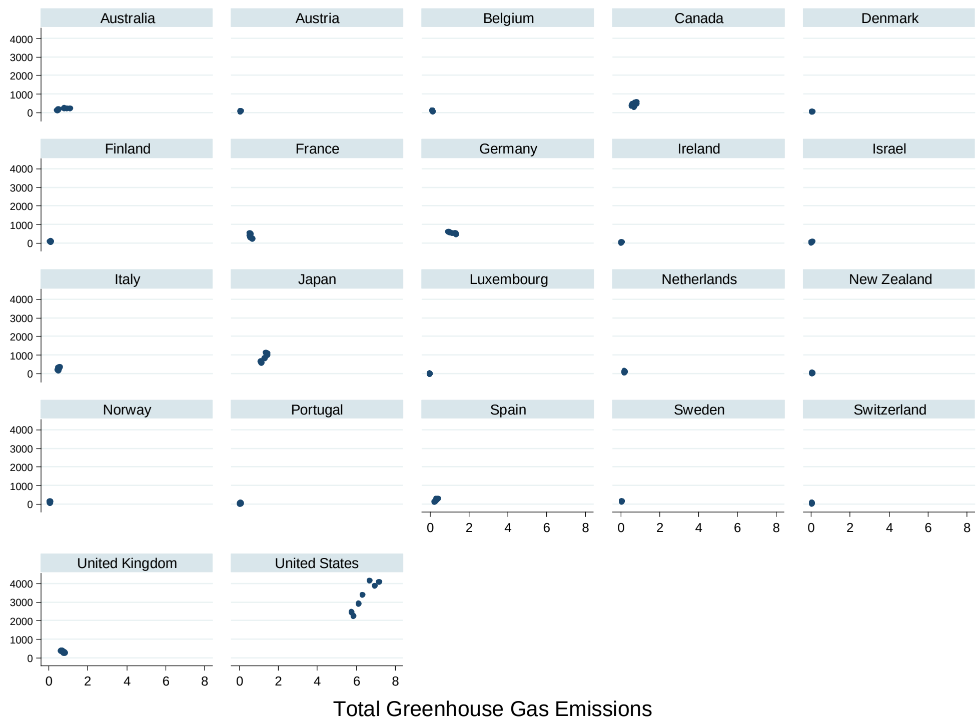

Figure 4.8. The relation between Electricity Power Consumption and GHGs Emission across group 1 countries

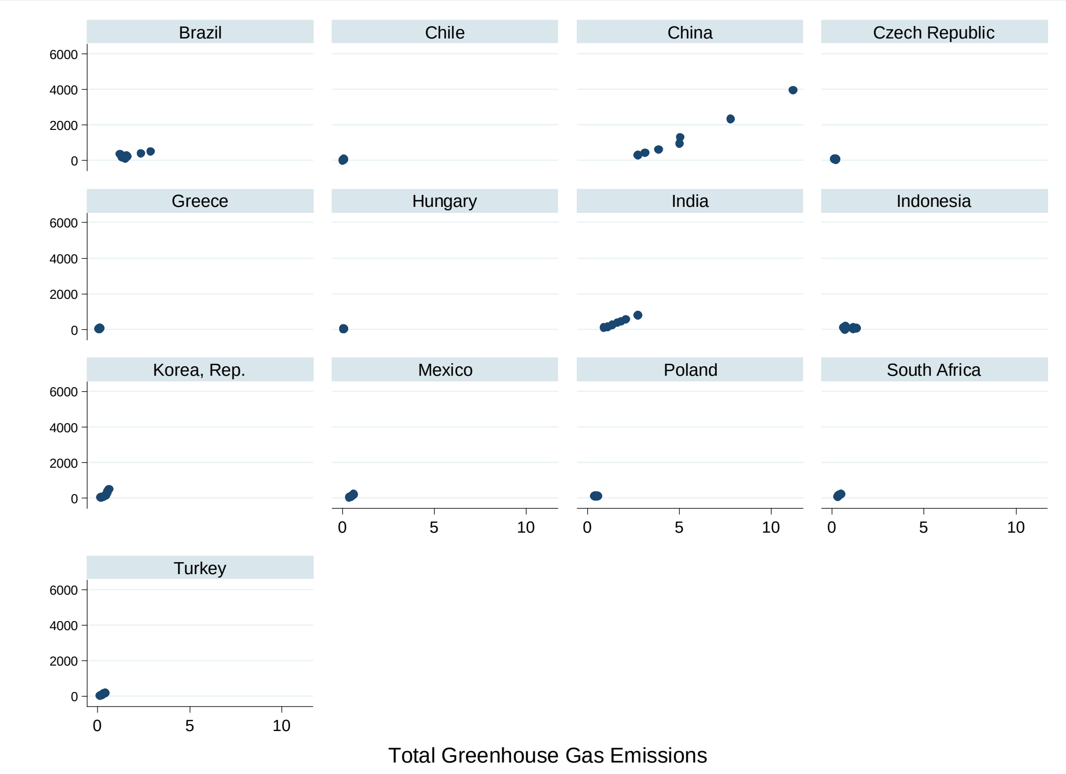

Figure 4.9. The relation between Electricity Power Consumption and GHGs Emission across group 2 countries)

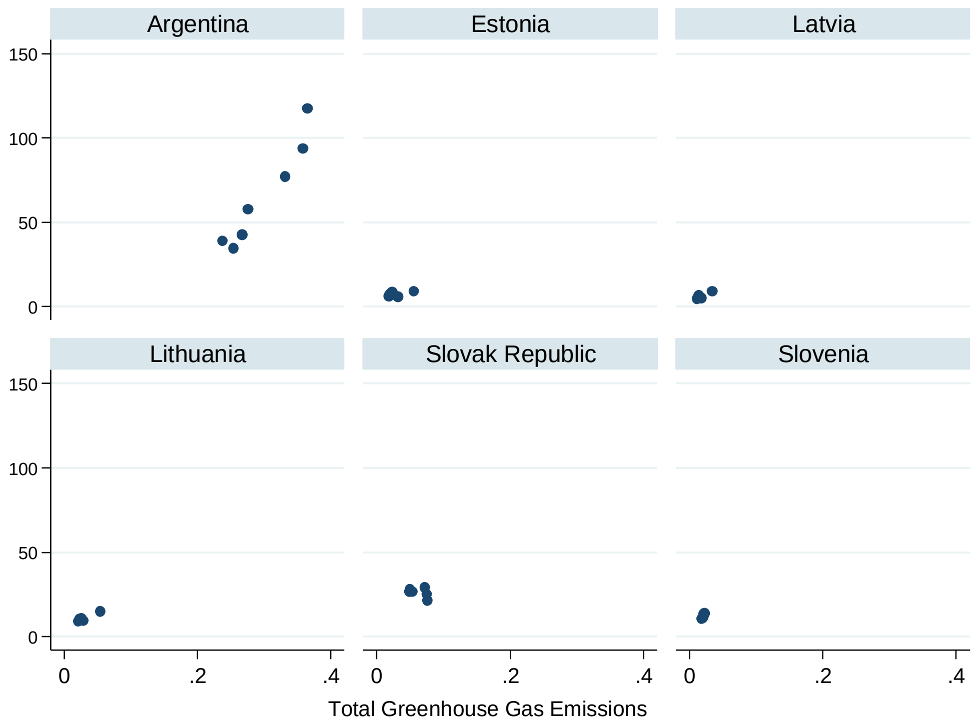

Figure 4.10. The relation between Electricity Power Consumption and GHGs Emission across group 3 countries

The relation between real GDP and total energy consumption for Turkey is given in the below Figure 4.11. to demonstrate the reason why panel data method is preferred instead of time series method. Subsequently, time series forecasting is the use of a model to predict values based on previously observed values. The gap between electricity consumption and GDP is high and the electricity consumption is far below the GDP. It is interesting to observe how GDP increase without any substantial change in the electricity power consumption as GDP could increase via the increase in the production side and there has been strong correlation between productivity growth and electricity. Also, if GDP increases in non-negligible amount it is expected to observe some changes in the consumer behavior side which lead to increase in the electricity consumption especially in the emerging countries like Turkey, considering the low-middle income households having limited purchasing power will increase their accessibility to the new products or higher standards.

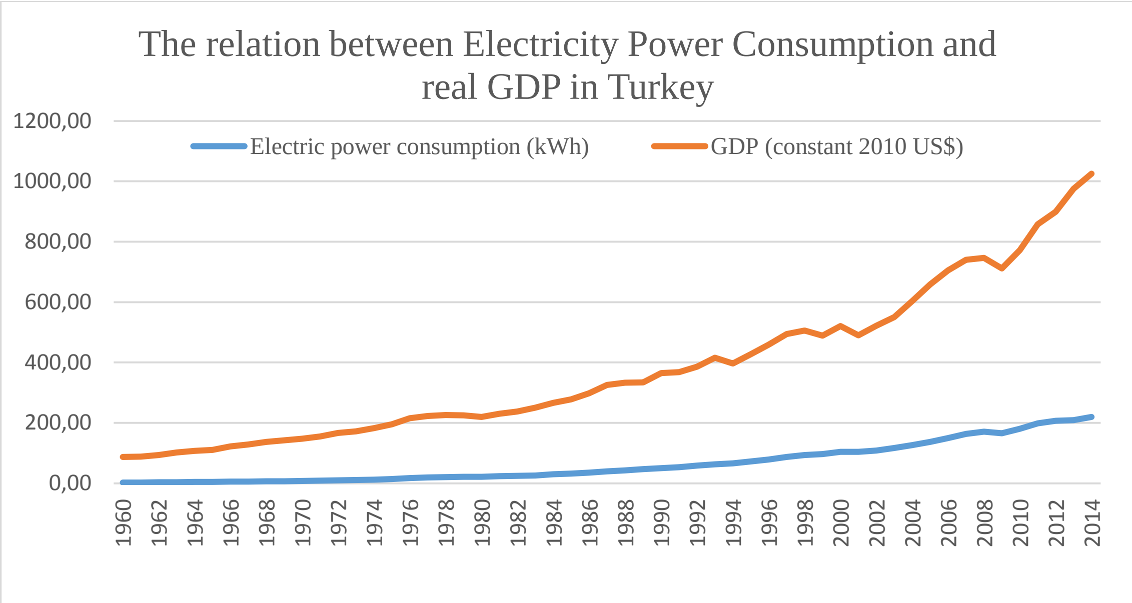

Figure 4.11. The relation between Electricity Power Consumption and real GDP in Turkey

Median values of electricity power consumption across countries through years shows heterogeneity across countries which are presented in the following Figure 4.12. Data are sorted by electricity power consumption from the smallest values to the highest values by countries. x-axis shows the numbers assigned to the countries in the sample. List of countries is given in Appendix A. The smallest electricity power consumption belongs to Luxemburg (#1). The highest electricity power consumptions are recorded by Japan (#39), China (#40) and the United States (#41), respectively.

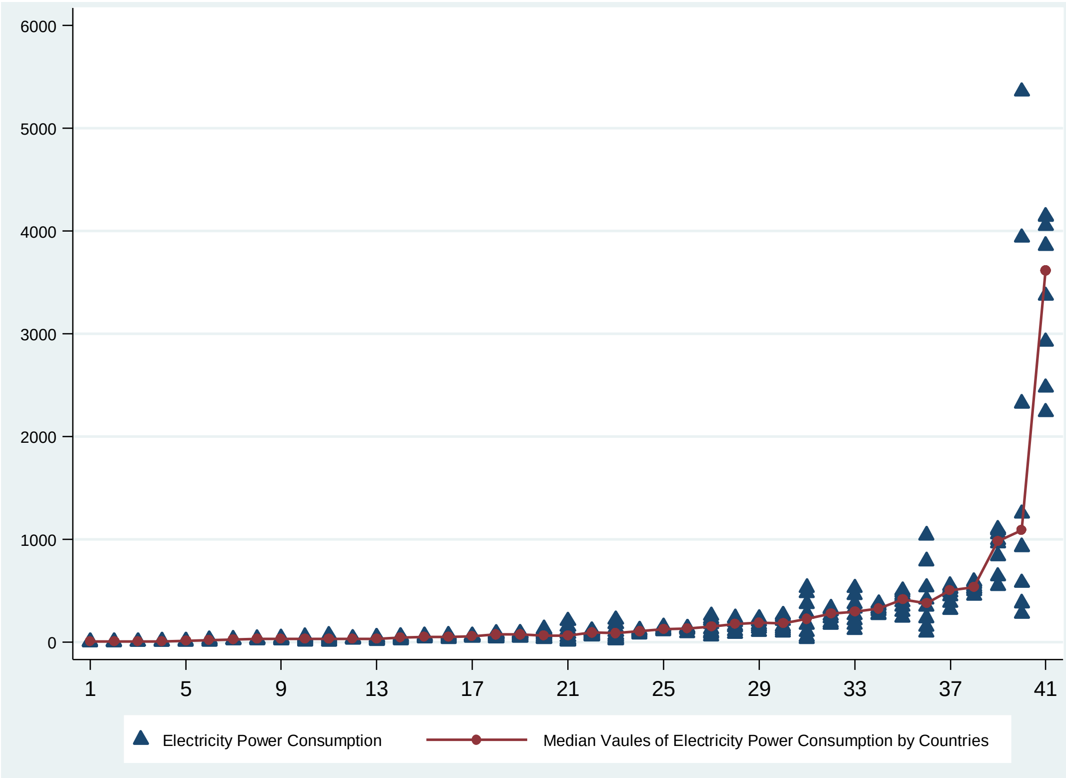

Figure 4.12. Median Values of Electricity Consumption Across Countries

Mean values of electricity consumption of countries across years show heterogeneity across year is presented in Figure 4.13.

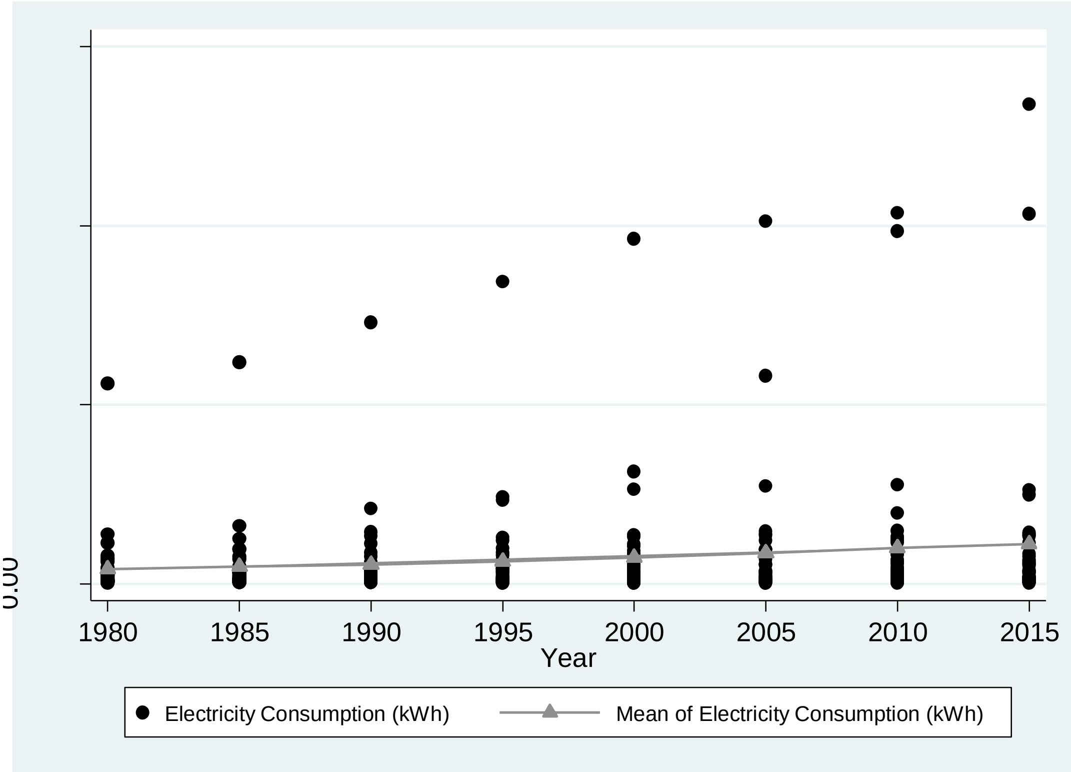

Figure 4.13. Mean Values of Electricity Consumption Across Years

A heterogeneous panel data presents the electricity demand equation as follows.

The basic panel data methods are fixed effects (FE) model and random effects (RE) model which are explained in detailed below. Following the related empirical literature, electricity demand is explained by the real GDP and population which is shown in general form below. Fixed effect models performed better than random effects model as per the preliminary tests which is Hausman test. Therefore, FE model is used for Turkey's electricity demand forecast. The results of the RE Model is given in the Appendix B.

The demand equation's functional form is linear as presented below in 4.1.

$$E_{it} = f(EC_{it}, GDP_{\mathrm{it}}, Pop_{it}) + error\ term \tag{4.1}$$

4.1.2.2. Fixed Effects Model

Fixed Effects Model is preferred if the aim is to analyze the impact of time-variant variables on the outcome variable. Analyzes with FE model control the effect of time-invariant characteristics of an entity which may affect the predictor or/and outcome variable. There are three equivalent approaches used in estimation; within group estimator, least squares dummy variable (LSDV) estimator and first difference estimator. These approaches deal with describing binary variables for each entity in panel data set. In FE models, time-invariant features of the entities are hidden behind allowing correlation between observed variables which are the real GDP and population in our case and entity-specific coefficients which are shown by β_0, it is in Equation (4.2), the expression of FE model. The potential endogeneity problem could be reduced by using fixed effects estimator.(Atkinson, 2018)

As per the FE models, each countries' error term and the constant variance differs and there is no correlation. If there is a correlation between individual error term and explanatory variable, then the null hypothesis is rejected and fixed-effects model is the appropriate one. The FE expression of the model is given in Equation (4.2).

$$E_{it} = \beta_{0,it} + \beta_1 Y_{it} + \beta_2 P_{it} + u_{it} \tag{4.2}$$

where E is the total consumption of electricity in country *i* at time *t*, Y_{it} is the real GDP (constant 2010 US$) of country *i* in time *t*, P_{it} is the total population of country *i* in time *t*.

4.1.2.3. Random Effects Model

Another popular method used in panel data estimation is random effects (RE) model that assumes the individual-specific effect which is a random variable that is uncorrelated with the explanatory variables. Other assumptions of RE model are constant variance of the individual specific effect and identifiability which is the regressors including a constant are not perfectly collinear, that all regressors (except the constant) have a non-zero variance and not too many extreme values. The RE expression of the model is given in Equation (4.3) is estimated by generalized least squares (GLS). Variance across countries are random. If there is no correlation between individual error term and explanatory variable the null hypothesis is valid and random-effects model is the appropriate one. Time-invariant variables can be included in RE models.

$$E_{it} = \beta_{0,it}+\beta_1 Y_{it} + \beta_2 P_{it} + w_{it} \tag{4.3}$$

---

where *E* is the total consumption of electricity in country *i* at time *t*, Y_{it} is the real GDP (constant 2010 US$) of country *i* in time *t*, P_{it} is the total population of country *i* in time *t*.

$$EC_i = \beta_{0,it}+\beta_1 GDP_{it} + \beta_2 Pop_{it} + u_{it} \tag{4.4}$$

The detailed definitions of dependent and independent (explanatory) variables are given in Table 4.8.

Total electricity power consumption is taken as a dependent variable to present the relationship between economic growth and electricity consumption. The explanatory (independent) variables are chosen depending on theoretical priors.

Total electricity power consumption is calculated by multiplying electricity power consumption per capita and total population.

Table 4.9. *Variable definitions and their expected relationship with the electricity demand*

Variable	Unit	Description	Type of Variable	Expected Sign
Electric power consumption	kWh/per capita	"*Electric power consumption measures the production of power plants and combined heat and power plants less transmission, distribution, and transformation losses and own use by heat and power plants".*	Dependent	
Population		*"Total population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship. The values shown are midyear estimates"*	Independent (explanatory)	Positive
GDP	constant 2010 US$	*"GDP at purchaser's prices is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant 2010 U.S. dollars. Dollar figures for GDP are converted from domestic currencies using 2010 official exchange rates. For a few countries where the official exchange rate does not reflect the rate effectively applied to actual foreign exchange transactions, an alternative conversion factor is used."*	Independent (explanatory)	Positive

The total electricity demand is explained by the real GDP (constant 2010 US$) and population in addition including time series corresponds to technological progress and booming of energy related activities due to population growth, urbanization and industrialization.

Since the size of the population is one of the determinants on electricity consumption, inclusion of population series of countries controls this variable.

Total electricity demand of Turkey for ex-ante forecasting period is calculated by using projected GDP and population.

Table 4.9 represents the FE estimates. Hausman test result (*F*-stat is 14.89 with 0.000 *p*-value) showed that the FE model is more suitable than RE model. We also expected that the FE model is more appropriate because our sample is not considered a random sample withdrawn from a large population referring to large geographical unit. As it is noted by Wooldridge (Wooldridge, 2012)this does make sense each β_0, it is a separate intercept to estimate for each country. The results of the FE Models are given in the table below.

Table 4.10. *FE Models Estimation Results*

VARIABLES	(1) Electricity Consumption	(2) Electricity Consumption	(3) Electricity Consumption
Gross Domestic Product	0.315***	0.333***	0.330***
	(0.014)	(0.015)	(0.015)
Population	1,702.725***	1,845.682***	1,800.726***
	(268.149)	(269.426)	(267.800)
d85		-1.817×10^{10}	
		(4.039×10^{10})	
d90		-4.274×10^{10}	
		(4.013×10^{10})	
d95		-5.967×10^{10}	
		(3.942×10^{10})	
d00		-8.524×10^{10}**	-5.032e+10*
		(3.994×10^{10})	(2.977e+10)
d05		-9.693×10^{10}**	-6.130e+10**
		(4.054×10^{10})	(3.028e+10)
d10		-9.626×10^{10}**	-5.996e+10*
		(4.120×10^{10})	(3.088e+10)
d15		-1.118×10^{11}***	-7.490e+10**
		(4.194×10^{10})	(3.161e+10)
Constant	-2.229×10^{11}***	-1.900×10^{11}***	-2.162×10^{11}***
	(2.559×10^{10})	(3.426×10^{10})	(2.562×10^{10})
Observations	298	298	298
R-squared	0.776	0.786	0.784
Number of countries	40	40	40
F-stat.	444.4***	101.7***	152.3***
R^2_within	0.776	0.786	0.784
R^2_between	0.893	0.888	0.891
R^2_overall	0.852	0.845	0.848
R^2_adjusted	0.741	0.745	0.745
rmse	1.630×10^{11}	1.610×10^{11}	1.610×10^{11}
ρ	0.810	0.853	0.843
Corr(X, u)	-0.763	-0.812	-0.803
σ_U	3.360×10^{11}	3.880×10^{11}	3.740×10^{11}
$\chi^2(1)$	14.42***	191.78***	573.63***

(.) denotes standard errors.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Referring to Table 4.9. above, three models were used to make estimations and each column is presenting the estimation results of each model. The first model does not include year effects. The second model includes the year effects except for the year

1980 which is considered the base year, in order to avoid dummy variable trap. The effects of the year 1985, 1990 and 1995 are not statistically significant at the traditional significance levels. The exclusion of these years' effects is tested. *F*-statistics is 0.88 with 0.452 *p*-value, meaning that those years can be excluded from the model. Therefore, the third model controls only statistically significant years' effects.

The table also presents the determination coefficients (R^2), root mean square errors (rmse) of the models that show forecasting accuracy, the ρ statistics that indicates variance of error term in terms differences across panel entities. *F*-stat refers to the test statistics for overall significance of the models.

In these three models, the coefficients of the real GDP and population are positively significantly estimated as expected. Determination coefficients are high in these three models showing that those three models are overall significant. All three models estimated the marginal effects of the real GDP and population close to each other. With and without controlling the year effects the fixed effect models estimation shows that 1$ increase in the real GDP of a country will be accompanied by 0.315 kWh, 0.330 kWh 0.333 kWh respectively, on average increase in total electricity power consumption.

Even though the second and the third models have lower *rmse* values and higher adjusted determination coefficients, the first model forecasted electricity consumption accurately for the years 2015, 2016 and 2017 that can be clearly seen with the comparison of the observed values of those years.

We also estimated the model whether all countries have different electricity consumption functions. In other words, we assumed that all slope coefficients as well as the constant term are variable over countries. The both t and F statistics show that slope coefficients do not vary over countries.

Since the ex-ante forecasts for the period 2018-2040, which is considered as far future, the assumptions on real GDP and population are required. The assumption on the real GDP are based on the IMF and OECD (2012), GDP growth rate forecast for Turkey, in addition population forecast is taken from State Institute of Statistics (SIS) which are presented in the below Table 4.11.

Table 4.11. *Forecast of real GDP and Population*

Years	IMF Projections for GDP growth	IMF Projections Emerging market and developing economies	OECD Potential real GDP growth	Population Projections by TUIK
2012			0.052	
2013			0.052	
2014			0.052	
2015			0.052	
2016			0.052	
2017			0.052	
2018	0.035	0.047	0.041	81,867,223
2019	0.004	0.047	0.041	82,886,421
2020	0.026	0.049	0.041	83,900,373
2021	0.021	0.049	0.041	84,908,658
2022	0.022	0.048	0.041	85,911,035
2023	0.026	0.048	0.041	86,907,367
2024			0.041	87,885,571
2025			0.041	88,844,934
2026			0.041	89,784,584
2027			0.041	90,703,600
2028			0.041	91,601,117
2029			0.041	92,476,323
2030			0.041	93,328,574
2031			0.023	94,153,776
2032			0.023	94,951,512
2033			0.023	95,721,347
2034			0.023	96,463,090
2035			0.023	97,176,768
2036			0.023	97,862,549
2037			0.023	98,520,720
2038			0.023	99,151,467
2039			0.023	99,754,923
2040			0.023	100,331,233

4.1.2.4. Results and Comparison

Population projection of SIS, IMF and OECD projections for GDP growth are taken into consideration in order to forecast the total electricity demand in 2040. 2015, 2016 and 2017 are forecasted by using the observed values of both GDP and population. Forecast based on FE Model-1 is presented above, the results of the remaining two are given in Appendix A.

Electricity demand for 2015, 2016 and 2017 calculated with the above mentioned point estimates demonstrate the accuracy of our model estimating the years; 252.9 TWh, 265.9 TWh and, 294.2 TWh respectively, while the observed value of those years are 264 TWh, 275 TWh and 289.9 TWh respectively.

Table 4.12. *Electricity Demand Forecasts*

Years	Electricity Demand Projections in TWh with IMF Projections for GDP growth	Electricity Demand Projections in TWh OECD Potential real GDP growth
2018	309.4	311.7
2019	312.7	329.6
2020	324.7	348.2
2021	334.9	367.5
2022	345.7	387.5
2023	358.4	408.2
2024		429.7
2025		452.0
2026		475.0
2027		498.9
2028		523.7
2029		549.4
2030		576.1
2031		592.2
2032		608.7
2033		625.4
2034		642.4
2035		659. 8
2036		677.4
2037		695.4
2038		713.8
2039		732.4
2040		751.5

Table 4.11. presents the forecast of Turkey's electricity demand starting from 2018 until 2040 with IMF's GDP growth forecast and OECD's GDP growth forecast for emerging market and developing economies. The electricity demand in 2040 estimated as 751.5 TWh. Figure 4.10. shows the electricity demand trend through years. Figure 4.11. indicates that thesis forecast is in between reference and high scenarios of MENR. 2037 the last year of MENR's estimation is forecasted as 695.4 TWh which is in line with the MENR reference scenario. Besides, projection of thesis

for 2018 was 311.7 TWh which the actual value was 293[5] TWh as of 31st December 2018.

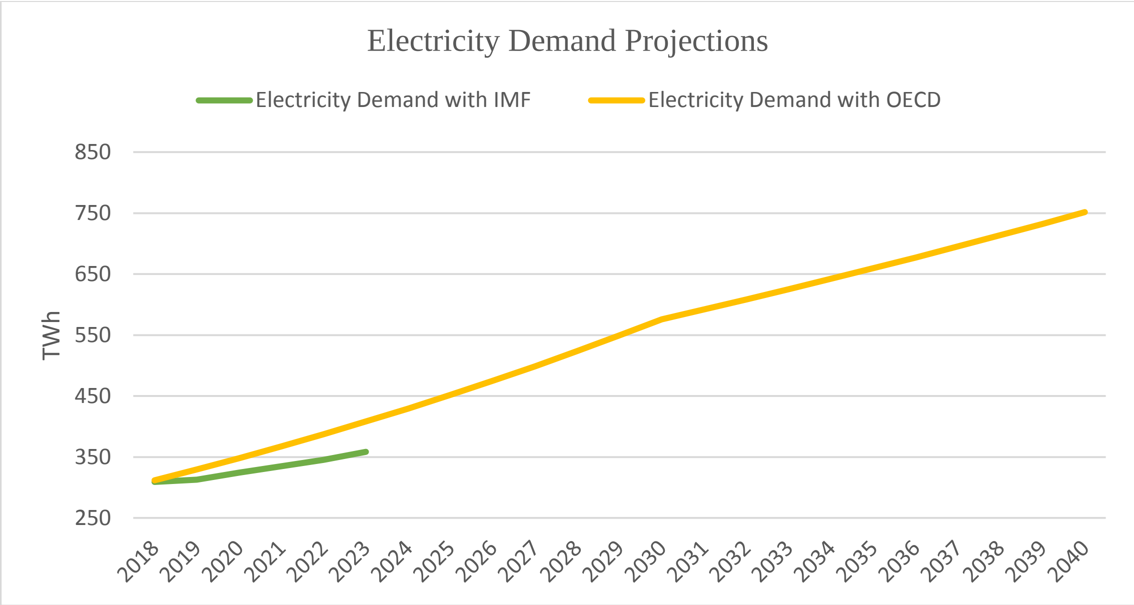

Figure 4.14. Turkey Electricity Power Consumption Forecast

5 https://www.haberturk.com/turkiye-nin-elektrik-tuketimi-gecen-yil-yuzde-0-75-artti-2286364-ekonomi

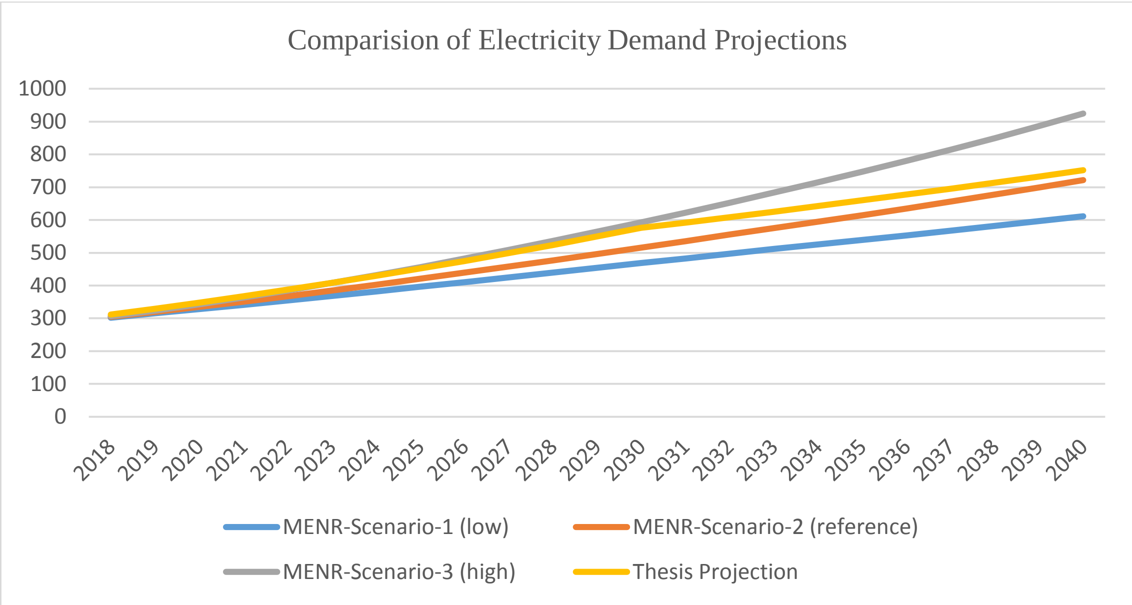

Figure 4.15. Comparison of Electricity Demand Projections

4.1.2.5. Electricity Demand of Turkey in 2040

Although electricity demand is estimated in line with MENR's reference scenario, it is expected to have lower electricity demand than the estimation due to the acceleration in the field of energy efficiency. First of all, all forecast run the calculations with GDP or GDP per capita or GDP growth and population forecasts, without taking into account energy efficiency, or improvement of distribution and transmission losses. Turkey has a target given in the INDC to decrease electricity transmission and distribution losses to 15 %.

There is a correlation between energy demand and GDP growth, however the unbounding of GDP growth from electricity demand started to be observed recently with the increase in the energy efficiency as "the first fuel" for electricity generation.

One of the recent study conducted by Carbon Brief [6] reveals that 35 countries continue their economic growth while reducing their emissions and consequently decoupling of GDP from GHGs emissions based on the World Bank GDP data for 216 countries and CO_2 emissions data from Carbon Dioxide Information Analysis Center (CDIAC). There are several studies that try to explain the root causes of slatted electricity growth. Though economic stagnation is considered one of the main reason of this stagnation, implementation of wide variety of energy efficiency programs have non negligible impacts on the decreasing trend of electricity consumption in the United States. The research indicates that there are two different patterns for two different periods. Considering 1993-2012 period; GDP, commodity price changes, long term trends, warmer weather and energy efficiency implementations were the main drivers that affect electricity use, alternatively for 2007-2012 period warmer winter and energy efficiency programs and plans are the main drivers behind the drop in electricity consumption. It is emphasized that the impact of energy efficiency for residential and commercial sectors is statistically significant but this was not the case for industrial sector. It is concluded that further research is required to differentiate the impacts of energy efficiency towards the use of electricity in comparison with economic and other dynamics especially for the industrial sector. Not only that, repetition of studies to observe whether this trend is continuing or not, is necessary to conclude the relation between energy efficiency and electricity consumption. (Nadel & Young, 2014)

In other respects, to substantiate above mentioned relationship between lower energy demand and increase energy efficiency is complex and unremarkably rebound effects are prominently.(Sorrell, 2015). Though there is an expectation of decreasing electricity demand due to increasing energy efficiency, clarifications on the above makes it tough to make a quantitative analysis to set forth the impact of increasing energy efficiency on the electricity demand forecast, especially for Turkey.

[6] https://www.carbonbrief.org/the-35-countries-cutting-the-link-between-economic-growth-and-emissions

In addition, in the short term there is low expectations of industrial growth in Turkey. Hence, we are expecting that realized electricity demand will be presumably lower than our forecast results in this Chapter.

CHAPTER 5

DESIGN OF SCENARIOS

In this section, four different scenarios are proposed and the outcomes of each scenario regarding two constraints mentioned in the first chapter of the thesis; which are to supply the increasing electricity demand of Turkey and to keep the emission targets on track are evaluated. In order to find the optimal solution of this problem, linear programming is used. The proposed models are first formulated in Microsoft Excel by using Solver Add-in. However, the models are then formulated and solved in General Algebraic Modeling System (GAMS) due to the variable and constraint limitations in Excel Solver as well as for the flexibility aspects. GAMS can solve large-scale problems with a licensed version, it is flexible compared to Excel Solver and also easy to understand and code.

5.1. Main Assumptions

Main assumptions of each scenario are summarized as follows:

- Cross country panel data coefficients, GDP and population projections are used to forecast the annual demand between 2020 and 2040. The electricity demand is estimated as 715.5 TWh for 2040.
- Capacity factor projections presented in the Turkey Electricity Power 5-Year Generation Capacity Projection prepared by Head of TEIAS Planning and Investment Management Department (TEIAS Planlama ve Yatırım Yönetimi Dairesi Başkanlığı Türkiye Elektrik Enerjisinin 5 Yıllık Üretim Kapasite Projeksiyonu) is used for all the scenarios. Solar photovoltaic capacity factor is taken from the U.S. Energy Information Administration-Capacity Factors

for Utility Scale Generators Not Primarily Using Fossil Fuels, since TEIAS does not present capacity factor for solar photovoltaic.

- Turkey's commitments presented in the INDC are considered as benchmark in order to establish the ranges of minimums and maximums for the assumptions of each scenario. For that reason, 10 GW solar installed capacity, 16 GW wind installed capacity and full potential of hydroelectric is regarded as benchmark until 2030.
- Total technical potential of local coal is estimated to reach 23.5 GW in 2023.
- Total technical potential of hydro is estimated to reach 46 GW.
- While hydro is considered climate friendly due to not emitting GHGs, it has various environmental impacts especially on the landscape, flora and fauna. Thus, the technical potential of hydro is not maximized.
- Total technical potential for wind is assumed as 48 GW.
- Total technical potential for solar photovoltaic was not elaborated exhaustively. Nonetheless, a recent study covers solely the technical potential of RTSPV whose details are presented in Section 3.1.3.2.2 of Chapter 3. The technical potential of RTSPV is estimated as 46.8 GW.
- New scenarios are set to start from 2025 considering the time required for the implementation of new policies, in addition the investment and construction durations.

Specific assumptions for each scenario is presented in Table 5.1.

Table 5.1. *List of specific assumptions for each scenario*

Scenarios	Assumptions
1. Base Case	Energy generation mix corresponds share of the resources is considered the same as 2017.
2. Maximize Local	Maximize local coal potential which is additional 13,670 MW. Maximize hydro and wind potential, which are 46 GW and 48 GW, respectively. Share of solar installed capacity is considered equal to 20% benchmarking with Italy's solar capacity in 2017. Share of other renewables (geothermal, waste etc) is considered as ≥ 3% ≤ 5%.
3. Generation Mix	Akkuyu NPP with 4800 MW is considered to be fully operational in 2023. The share of solar installed capacity is assumed as >15% ≤ 20% of total installed capacity Other renewables is assumed =5% of total installed capacity.
4. Minimize GHGs	This scenario is considered as 100% renewables, without fossil fuels and nuclear power plants.

Table 5.2. Summary of specific assumption 5-year scenario

Milestones	Scenarios	Assumptions
2020	3	The share of other renewables installed capacity is ≥ 3% ≤ 5%
	4	32 GW hydro
2025	All	the installed capacity of a given technology in a year can be increased by 20% at most except solar and hydro for which this parameter is 25%, while the installed capacity of a given technology in a year can be decreased by 15% at most.
	2,3,4	10 GW solar power, 16 GW wind power, the share of solar is assumed to be 12.5%
	2,3	32 GW hydro
	3	4.8 GW of nuclear
2040	2,3,4	the share of solar installed capacity is assumed to reach 20%
	3	48 GW wind
	4	The upperbound of other renewables installed capacity is ≤ 10%

5.2. Capacity Factor

Power plants may not operate with 100% efficiency as their nameplates claims due to various reasons; such as maintenance, weather conditions for renewables, fuel availability etc. The ratio of actual electrical energy output to the potential electrical output over a period of time is defined as capacity factor. Capacity factor is a ratio that provides the total amount of electricity produced over a specific period of time, by taking into account actual output. It is the ratio to the installed capacity of the electricity generation resources. Capacity factor depends on maintenance, failure, fuel availability and weather conditions for renewables. TEIAS analyzes the capacity factor of the existed power plants in Turkey between the years 2007-2016, then determines the capacity factors by electricity generation resources. Since there could be improvements in terms of fuel, the highest capacity factor of the fossil fuels power plant considered for the projection from this section on. Hydraulic and wind depends on the weather conditions therefore the projection assumes the same trend line in the past. Below Table 5.1. presents the annual capacity factor of the fossil fuels, hydraulic and wind consisting of actual values until 2017 and projections from 2017-2021 prepared by TEIAS.

Table 5.3. *Annual Capacity Factors and Projections by TEIAS*

% capacity factor	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Fossil Fuels	62	69.5	65.4	62	65.2	63.7	60.8	67.1	62.2	62.9	64.2	65.5	66.9	68.2	69.5
Hydraulic	77	75.2	77.5	79	75.4	71	71.3	61	65.1	65.4	66.3	65.8	65.3	64.9	64.4
Wind	44.2	41.3	44.6	41.1	41.3	37.1	39.8	33.8	36.8	46.9	38.8	38.6	38.4	38.2	38.1
Turkey Total	67.3	71.5	69.3	67.2	68.1	65	63	63.1	61.3	63.2	62.9	62.6	62.3	62.1	61.8

U.S. Energy Information Administration data[7] for the capacity factor of solar and nuclear energy is used due to the lack of information in Turkey. EIA presented capacity factor of nuclear as 92.2% and capacity factor of solar photovoltaic as 27% in 2017.

5.3. CO_2 Emission Factors from Electricity Generation

Turkey presented its Intended Nationally Determined Contribution. In this document, plans and policies to be implemented to achieve the declared commitment is explained. It is stated that total emissions were 440 Mt CO_2e in 2012 and the energy sector is responsible for 70.2 % of the above mentioned total emissions. In 2016, total GHGs emissions have reached to 496.1[8] mt CO_2e and the energy sector is responsible for 72.8%. It is assumed that under Business-As-Usual Scenario the total emissions will reach 1,175 mt CO_2e in 2030. It is expected that the emissions will reach 929 mt CO_2e and will be 246 mt CO_2e lower which corresponds 21% reductions than the Business-As-Usual Scenario with the implementation of plans and policies presented, this scenario named as Mitigation Scenario.

In addition, the development of installed capacity which is presented in Table 5.2. summarized for certain years to point out the relation between electricity generation and CO_2 emission. It should be highlighted that CO_2 emission refers to the burning of fossil fuels and the manufacture of cement which is not the same parameter mentioned in the above paragraph.

[7] https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_6_07_b
[8] http://www.tuik.gov.tr/PreHaberBultenleri.do?id=27675

Table 5.4. *Installed Capacity and CO_2 Emissions*

		1990	2000	2010	2014
Installed Capacity	Fossil Fuel (MW)	9535.8	16052.5	32278.5	41801.8
	Hydrolic (MW)	6764.3	11175.2	15831.2	23643.2
	Renewables (MW)	17.5	36.4	1414.4	4074.8
	CO_2 (kt)	145858.6	216151.3	298002.4	345981.5

The first study for Turkey's specific CO_2 emissions caused by electricity generation was prepared by Arı by taking currently operating power plants emission factors into account. This study is developed under the framework of IPPC Guidelines methodology and consider the default emission factors in the Guideline. Due to different low heating values for different fossil fueled power plants, specific emission factor of technology i (SEF_i) in kg/MWh is calculated by dividing the total CO_2 emission (E_i) by the total electricity generation (EG_i) which is shown as follows. (Arı, İ., Koksal, M. A., 2011)

$$SEF_i = \frac{E_i}{EG_i} \quad (5.1)$$

One of the important finding of this study is to demonstrate that the lignite is producing highest CO_2 emissions among the other fossil fuel fired power plants.

In this thesis, emission coefficients (ECo_i) as Gg CO_2/TWh are calculated following the steps below. First of all, CO_2 emissions coefficients (CO_2Co_i) by fuel is taken from U.S. Energy Information Administration[9] estimates for natural gas, bituminous coal for import coal, lignite for local coal, for other which is referring to fossil fuels, thermal, multi fuels and fuel-oil is roughly estimated. Fuel inputs (FI_i) of these

[9] https://www.eia.gov/environment/emissions/co2_vol_mass.php

sources for 2017 are taken from energy balance tables[10]. Fuel inputs in ktoe for 2017 are multiplied by the CO_2 emissions coefficients in $GgCO_2$/ktoe , then this number is divided to actual generation (AG_i) for each sources in TWh which are taken from TEIAS website[11], thus emission coefficients in $GgCO_2$ per TWh is obtained and these coefficients for natural gas, import coal, local coal and others are multiplied by estimated generation in order to foresee the emissions for each scenario.

$$ECo_i = \frac{FI_i * CO_2Co_i}{AG_i} \quad (5.2)$$

Emission coefficients (ECo_i) as $GgCO_2$/TWh used for the estimation of future emissions for each scenario are given in Table below.

Table 5.5. *Comparison of Electricity Demand Projections*

Sources	**Emission Coefficients (CO_2/TWh)**
Natural gas	347.419
Import coal	819.790
Local coal	1016.425
Other (Fossil fuels; thermal, multi fuels, fuel-oil)	1838.048

5.4. Scenarios

The scenarios in the study are proposed in a way that they represent distinct pathways for power supply profile in Turkey and need simple procedures to be generated that is why the costs (overnight, fuel, maintenance, etc.) are not taken into account in scenario development. Moreover, seeking for a least cost power generation is another genre of studies in the literature, i.e., optimal generation expansion planning. Then, a simple

[10] https://www.eigm.gov.tr/tr-TR/Sayfalar/2017Yili-Ulusal-Enerji-Denge-Tablolari

[11] https://ytbs.teias.gov.tr/ytbs/frm_login.jsf

linear program has been formulated in order to generate the scenarios. The sets, parameters, equations and the objectives of the model are given below.

5.4.1. Sets, Parameters, Variables

Sets, parameters and variables are presented in the following tables.

Table 5.6. *Definition of Sets*

Set	Definition
i, j	Power technologies {Hydro, Wind, Solar, OthRen, NaturalGas, ImpCoal, DomCoal, OthFos, Nuclear}
t_0, t, tt	Years - t_0: 2017; t: 2017, 2020, 2025, … ,2040; tt: 2020, 2025, … ,2040
rnw	Renewable technologies {Hydro, Wind, Solar, OthRen}
$local$	Local technologies {Hydro, Wind, Solar, OthRen, DomCoal}
s	Scenarios {BaseCase, MaxLocal, GenMix, MinGHG }

Table 5.7. *Definition of Parameters*

Parameter	Definition
$CapFac(i)$	Capacity factor of technology i
$InsCap0(i)$	Installed capacity of technology i in t_0
$EleDem(t)$	Electricity demand in year t (TWh) – the projections from panel data analysis
$Life(i)$	Lifetime of technology i in years
$DepRate(i,t)$[12]	Depreciation rate of technology i in year t
$EmisFac(i)$	Emission factor (Gg CO_2 eq. per TWh) of technology i
$LB(i,tt)$	Lower bound on the installed capacity of technology i in year tt (as a ratio of total installed capacity)
$UB(i,tt)$	Upper bound on the installed capacity of technology i in year tt (as a ratio of total installed capacity)
$LB2(i,tt)$	Lower bound on the installed capacity of technology i in year tt (as a ratio of total installed capacity in year t-1)
$UB2(i,t)$	Upper bound on the installed capacity of technology i in year tt (as a ratio of total installed capacity in year t-1)

[12] 30 years remaining lifetime is assumed for coal, natural gas, and hydro power plants. 40 years lifetime is assumed for nuclear, and no depreciation rate is considered for wind and solar power plants.

$UBrnw(tt)$	Upper bound on generation by renewable technologies in total generation in year tt
M	Big M, which is used to calibrate the weight of idle capacity in the objective function
$ActGen_0(i)$	Actual generation of technology i in t_0
$ShrIC_0(i)$	Share of installed capacity in t_0

Table 5.8. *Definition of Variables*

Variable	**Definition**
$vEmis(i,t)$	Emission due to generation of technology i in year t (Mton CO_2 eq.)
$vAnnEmis(t)$	Total annual emissions in year t (Mton CO_2 eq.)
$vTotEmis$	Total emissions throughout 2020-2040 (Mton CO_2 eq.)
$vInsCap(i,t)$	Installed capacity of technology i in year t (GW)
$vInsCapAct(i,t)$	Actively used Installed capacity of technology i in year t (GW)
$vAnnInsCap(t)$	Total installed capacity in year t (GW)
$vNewInsCap(i,t)$	Newly installed capacity in year t (GW)
$vEleGen(i,t)$	Generation by technology i in year t (TWh)
$vTotEleGen(t)$	Total generation in year t (TWh)

5.4.2. Model Equations

The base year of the model, t_0, is 2017 and time indices go on with 2020, 2025 ,…, until 2040 with period length of five years.

Eqn. (5.3) says that the total electricity generated by all technologies in a period is equal to the electricity demand in the corresponding where the demand projections are obtained from the panel data analysis.

$$vTotEleGen(tt) = EleDem(tt) \qquad \forall\, tt \tag{5.3}$$

Eqn. (5.4) implies that the total installed capacity in year tt is equal to the installed capacity of the previous period $(tt-1)$ plus the newly installed capacity in year tt minus the depreciated capacity of the base year.

$$vInsCap(i,tt) = vInsCap(i,tt-1) - DepRate(i,tt) * vInsCap(i,t_0) + vNewInsCap(i,tt) \qquad \forall\, i,tt \quad (5.4)$$

In Eqn.(5.5) , it is seen that the total installed capacity in a period is equal to the sum of installed capacities of separate technologies.

$$vAnnInsCap(tt) = \sum_{\forall i} vInsCap(i,tt) \qquad \forall\, tt \quad (5.5)$$

Eqn. (5.6) represents the electricity generation of a given technology, i.e., generation amount is the product of number of hours in a year (8760), capacity factor of the corresponding technology and its installed capacity. Eqn. (5.7), on the other hand, indicates that the total electricity generation is the sum of generations from distinct technologies.

$$vEleGen(i,tt) = 8760 * CapFac(i) * vInsCapAct(i,tt)/1000 \qquad \forall\, i,tt \quad (5.6)$$

$$vTotEleGen(t) = \sum_{\forall i} vEleGen(i,t) \qquad \forall\, t \quad (5.7)$$

Eqn. (5.8) and (5.9) are the equations related to emissions. They represent the annual emissions for each technology, total annual emissions and cumulative emissions throughout the model horizon, respectively.

$$vEmis(i,t) = EmisFac(i) * vEleGen(i,t) \qquad \forall\, i, tt \quad (5.8)$$

$$vAnnEmis(t) = \sum_{\forall i} vEmis(i,t) \qquad \forall\, t \quad (5.9)$$

$$vTotEmis = \sum_{\forall tt} vAnnEmis(tt) \qquad (5.10)$$

Actual capacity (or the utilized capacity) of a technology in a year should be lower than the installed capacity for the corresponding technology which is formulized as seen in Eqn. (5.11)

$$vInsCapAct(i,tt) \le vInsCap(i,tt) \qquad \forall\, i, tt \quad (5.11)$$

Eqn. (5.12) ensures that the installed capacity of technology i in a year may have some lower and upper bounds set as a ratio of total installed capacity in the given year. Eqn. (5.13), on the other hand, sets lower and upper bounds as a ratio of the capacity in the previous period.

$$LB(i,tt) * vAnnInsCap(tt) \le vInsCap(i,tt) \le UB(i,tt) * vAnnInsCp(tt) \qquad \forall\, i, tt \quad (5.12)$$

$$(1 - LB2(i,t)) * vInsCap(i,t-1) \leq vInsCap(i,tt) \leq (1 + UB2(i,t)) * vInsCap(i,t-1) \qquad \forall\, i,t \quad (5.13)$$

Eqn. (5.14) guarantees that the share of electricity generation by renewable technologies is lower than pre-defined lower bounds (starting from 60% to 100% gradually) considering the intermittency and unpredictability of these resources. However, in line with expected advances in development of storage technology and strict targets of several countries such as Sweden, this constraint allows the model to assign 100% renewable generation by 2040.

$$\sum_{\forall i | rnw(i)} vEleGen(i,tt) \leq UBrnw(tt) * vTotEleGen(tt) \qquad \forall\, tt \quad (5.14)$$

5.4.3. Objectives of the Scenarios

Four scenarios are developed namely Base Case, Maximize Local (MaxLoc), Generation Mix with Nuclear (GenMix) and Minimize GHGs (MinGHGs).

Some of the scenarios require significant deviations from the current capacity mix. However, it is not realistic to retire current capacities immediately. Moreover, it is clear that the current power sector has an excess capacity and it is vital to utilize current capacity as much as possible in the near future. Note that "The Regulation on the Electricity Market Capacity Mechanism" published on 20.01.2018 is an attempt to provide this objective and increase the supply security in the market. Then, replicates of the variables related to installed capacity are proposed which represent the utilized portion of the installed capacity. Then, in all of the scenarios, objective functions include the difference terms (the installed capacity minus the amount that is actively utilized) to be minimized. This approach ensures that the current capacity of the plants would be utilized as much as possible as a secondary concern in the scenarios where they have stronger primary concerns, e.g., minimizing GHGs in MinGHG scenario.

5.4.3.1. Scenario 1 - Base Case Scenario

The objective of the BaseCase scenario can be seen in Eqn. (5.15). As summarized above, the only aim of this function is to minimize the idle capacity. However, since this scenario assumes that the power generation will be in line with the base year generation profile, the objective has a minor effect on the development pathway. In other words, it helps the user select the path in which the idle capacity is minimized among many alternatives with the same generation mix as the base year.

$$obj(BaseCase) = Min \left\{ M * \sum_{\forall i,tt} [vInsCap(i,tt) - vInsCapAct(i,tt)] \right\} \tag{5.15}$$

This scenario indicates us where we will be in terms of CO_2 emissions and required additional installed capacity in order to satisfy the forecasted demand highlighted in the previous chapter.

As per the TEIAS' latest report, whose details and breakdown are presented in Figure 3.9. The percentages of 85.2 GW installed capacity is for 2017 as follows; hydraulic 32.01%, natural gas 27.07%, coal in total 21.91% (import coal as 10.32%, local coal (lignite) 11.59%), wind 7.65%, solar 4.01%, other fossil fuels (thermal, multi fuels, fuel oil) 5.42%, other renewables (geothermal, waste etc.) 1.92%.

This installed capacity corresponds 289.9 TWh electricity consumption in 2017.

The installed capacity in 2017 can correspond to 453 TWh potential electricity generation as per the above formulas (5.6) and (5.7). This is an important finding to be considered while designing future energy policies. This indicates that today's total installed capacity actually exceeds today's electricity demand by 56.4 %. As per the MENR's projection given in Table 4.2, today's installed capacity might correspond the electricity demand in 2029 as per low scenario and the demand in 2027 as per reference scenario. Considering the results of cross-country panel data analysis, the capacity can correspond the forecasted demand in 2026. Today's excess capacity installed in current technology will be outdated in the near future, which will become a barrier to implement new energy efficient technologies on time. In order to supply the forecasted electricity demand in 2040 with keeping the same share of the allocation of resources in the electricity generation mix, an additional capacity of 29.7 GW is required. More than half of this additional capacity needs to be supplied from the fossil based fuels which implies an increase of GHGs emissions. Total installed capacity is estimated to be approximately 141 GW. Additional 13.4 GW natural gas and import coal power plants imply expensive electricity cost due to dependency on import and therefore supply of security is not attained. In addition, GHGs emissions from electricity will increase by 138% and reach to 314,832.5 Gg CO_2e from 132,192.1 Gg CO_2e in 2017. The growth of GHGs emissions continues gradually in this generation mix, as a result, it is vital to modify today's electricity generation mix.

5.4.3.1. Scenario 2 - Maximize Local Resources

This scenario relies on the policy to promote local lignite in the electricity generation mix in order to secure the supply due to living in a very difficult geography. Therefore, this scenario is designed to promote local fossil resources and renewables, in order to be self-sufficient and not to be subjected to the effects of the FX volatility.

Eqn. (5.16) represents the objective of the MaxLocal scenario in which the electricity generated by the local resources are maximized while the idle capacity is minimized at the same time.

$$obj(MaxLocal) = Max\left\{\sum_{\forall i,tt|local(i)} vEleGen(i,tt) - M * \sum_{\forall i,tt}[vInsCap(i,tt) - vInsCapAct(i,tt)]\right\} \tag{5.16}$$

In this scenario, additional 13,670 MW potential local coal power plants are taken into account whose details are presented in Table 3.1. Government's recent regulation for capacity mechanism for security of supply and availability of power plants rely on lignite fired power plants and imported coal fired power plants. In addition to local lignite and hard coal, this scenario is built on the assumption that maximizing full hydro potential which is 46 GW full wind potential which is 48 GW.

In 2040, an additional installed capacity of 53.9 GW is needed to meet the demand forecasted in Chapter 4. Thus, the total installed capacity will reach to 185.9 GW. 83% of this installed capacity denotes renewables, namely, hydro, wind, solar and other renewables and in this way renewables correspond to 76% of the electricity generation. As a consequence, GHGs emissions have its source in electricity generation will increase 25 % and will reach to 165,699.8 GgCO_2e from 132,192.1 GgCO_2e in 2017. It should be highlighted that GHGs emissions will be 90% less than Scenario-1 base case.

5.4.3.1. Scenario 3 – Generation Mix with Nuclear

Government of Turkey is planning to deploy two nuclear power plants; Akkuyu Nuclear Power Plant (NPP) and Sinop Nuclear Power Plant will be put into operation by 2023, and intends to start the construction of the 3rd one at the same time. Akkuyu NPP is located in Mersin that has 4 reactors each 1,200 MW, corresponding to 4,800 MW total installed capacity. Sinop NPP is located in Sinop that has 4 reactors, each 1,120 MW, corresponding to 4,480 MW total installed capacity. In total, nuclear capacity is summed as 9,280 MW. Considering the project progress and the delays as of today, it is assumed that only one of these nuclear power plants would be in operation uttermost in 2040. In this scenario, Akkuyu NPP is considered active, where Sinop is considered as non-operational. The share of wind and solar is considered minimum 16 GW for wind and 10 GW for solar in 2030, because of the commitments declared in INDC. Full hydroelectric capacity of Turkey is included in this scenario. The full potential of wind is considered to be exploited, where at least 20% share of installed capacity is assumed to be solar. The amount of local coal is maximized.

Eqn. (5.17) again minimizes the idle capacity where the generation mix is mainly determined by the assumptions for the final period as well as the intertemporal targets exogenously given to the model.

$$obj(GenMix) = Min\left\{M * \sum_{\forall i,tt}[vInsCap(i,tt) - vInsCapAct(i,tt)]\right\} \qquad (5.17)$$

In 2040, 36GW additional installed capacity is needed to correspond the demand forecast in Chapter 4. Thus, the total installed capacity will reach up 174.3GW. 79 % of this installed capacity denotes renewables which are hydro, wind, solar and other renewables and in this way renewables correspond to 71 % of electricity generation. As a consequence, GHGs emissions caused by electricity generation will increase 25% and will reach to 165,699.8 GgCO_2e from 132,192.1 GgCO_2e in 2017. It should be highlighted that GHGs emissions will be same as Scenario-2 Max Loc.

5.4.3.2. Scenario 4 - Minimize CO_2 Emissions

This scenario is an ideal case in terms of its environmental impact. The aim of this scenario is satisfying the increasing demand while keeping the emissions minimum. In this scenario, Turkey's current complience to the ideal case is evaluated while defining the initial conditions to reach these ideal numbers in 2040.

Eqn. (5.18) shows the objective function of the MinGHG scenario where the total cumulative emissions are minimized while the idle capacity is minimized at the same time.

$$obj(MinGHG) = Min \left\{ \sum_{\forall i,tt} [EmisFac(i) * vEleGen(i,tt)] + M * \sum_{\forall i,tt} [vInsCap(i,tt) - vInsCapAct(i,tt)] \right\} \tag{5.18}$$

In 2040, 71.5 GW additional installed capacity is needed to meet the demand forecasted in Chapter 4 thus the total installed capacity will reach to 248.2 GW. 100% of this installed capacity denotes renewables which are hydro, wind, solar and other renewables and in this way renewables correspond 100% of electricity generation. As a consequence of these, GHGs emissions caused by electricity generation will decrease to zero from 132,192.1 $GgCO_2e$ in 2017.

Scenario-4 Min GHG reach zero emissions in 2040 while minimizing the idle capacity as well. In this scenario, solar installed capacity has to reach 128.7 GW in 2040 from 3,421 MW in 2017. Table 3.1. shows the development of installed solar capacity, where China gas become the global driving power in the last six years and touch to 130,250 MW in 2017 from 3,300 MW in 2011. In addition, the solar generating capacity will reach to 304 TWh. General Directorate of Electric Power Resources Survey and Development Administration, EIEI, (predecessor of General Directorate of Renewable Energy) forecasted the solar potential as 380 TWh which is in consistency with our findings. In this potential forecast, EIEI assumes annual average solar irradiation as 1,311 kWh/m2 although it is declared that as 1,527 kWh/m^2 by the MENR. This indicates that the solar potential is higher than the EIEI estimation. Last but not least the acceleration in the solar technology, yield increase of solar panels and reduce cost of technology lead to solar boom starting from 2010. As a result, the solar potential of Turkey is expected far greater than the current potential forecast. So, one of the crucial findings of this scenario is to deploy the feasible solar potential until 2040. Even though the RTSPV's technical potential is estimated, the cumulative solar potential of Turkey needs to be investigated and Turkey has to ensure robust and encouraging policies that will accelerate the solar investment. It is both technically and economically possible to reach the projected installed capacity by 2040.

CHAPTER 6

RESULTS OF SCENARIOS

In this chapter of the thesis, the results of the scenarios of the precedent chapter are evaluated.

6.1. Outcome of Scenarios

Four scenarios are evaluated in the previous chapters show that the electricity demand for 2040 can be supplied by using a variety or primary sources with different ranges while utilizing a large potential of primarily hydro and wind. Within this frame, two constraints which are highlighted at the beginning of the thesis as to supply the increasing electricity demand and to keep the emission targets on track are satisfied.

Scenario-2 Maximize Local and Scenario-4 Minimize GHGs Emissions indicate that nuclear is not the only remedy in order to satisfy the increasing electricity demand of Turkey. Due to the fact that the share of the nuclear in the total installed capacity does not have an essential effect. Nonetheless, Scenario-2 Maximize Local and Scenario-3 Generation Mix with Nuclear reach same GHGs emissions level. Today's GHGs emissions resulting from electricity generation corresponds to 27 % of total emissions declared by SIS. Emissions by 2030 designates that total emissions will reach to 893,891 Gg CO2e based on the assumption that it would be have the same proportion as it has in 2017. This amount is below the governmental projections given in the INDC as 1,175 $MtCO_2e$ due to overestimated GDP growth. Our findings is in consistency with Kat el al. (2018) and Yeldan & Voyvoda (2015) estimating base case projections 836 Mt CO2e, 787 Mt CO2e respectively.

6.1.1. Overview from 2020 to 2040

In this sub-section, all the scenarios are evaluated for 5-year intervals and a timeline is created. Table 6.1 presents the additional installed capacity needed to supply increasing demand and level of GHGs emissions as per each scenario.

Table 6.1. *Timeline from 2020 to 2040*

	2020	**2025**	**2030**	**2035**	**2040**
Demand (TWh)	348.2	452	576.1	659.8	751.5
	Additional Installed Capacity Needed (MW)				
Base-Case	7,526	12,544	35,678	28,284	29,788
Max. Local	473.7	29,473.8	35,583.5	39,056.8	53,903.8
Generation-Mix with Nuclear	786.4	36,794.9	32,177.3	41,078.7	36,063.3
Min GHGs	13,932	33,645	44,411	57,196	71,485
	Level of GHGs Emissions (Gg CO_2e)				
Base-Case	189,811	189,811	241,350.6	276,415.82	314,832.506
Max. Local	170,829.9	139,194.8	171,611.6	187,929.23	165,699.834
Generation-Mix with Nuclear	170,829.9	139,194.8	107,559.6	107,434.7	165,699.834
Min GHGs	48,389	47,110	40,614	22,923	0

Today's generating capacity is larger than the forecasted demand until 2026. This overcapacity could create a barrier for the deployment of renewables. Implementing a policy for accelerating deployment of renewables could result in improvement in order to substitute fossil-fuel-based generating capacity. The figures below, Figures 6.1, 6.2, 6.3 and 6.4indicate the additional installed capacity and GHGs emissions development of each scenario for 5-year time intervals.

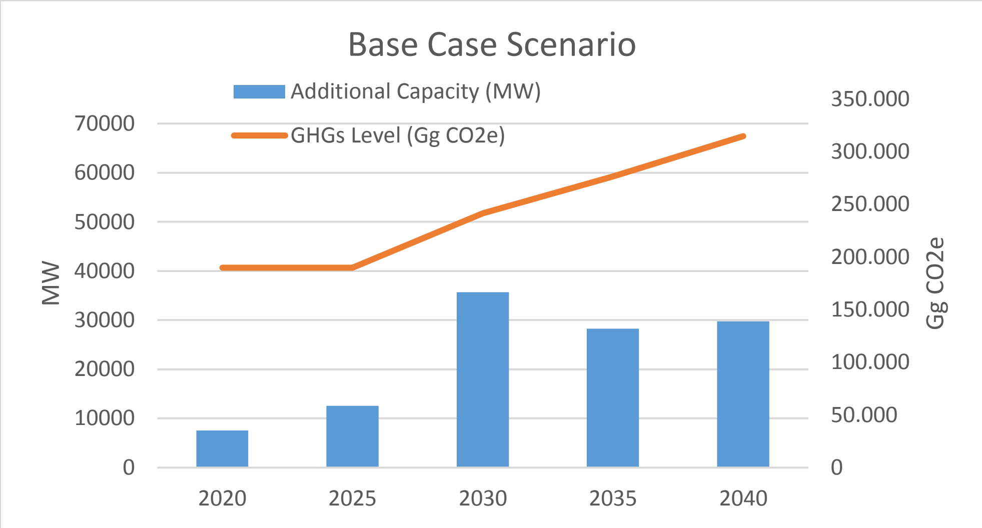

Figure 6.1. Development of Additional Installed Capacity and GHGs Emissions for Base Case Scenario

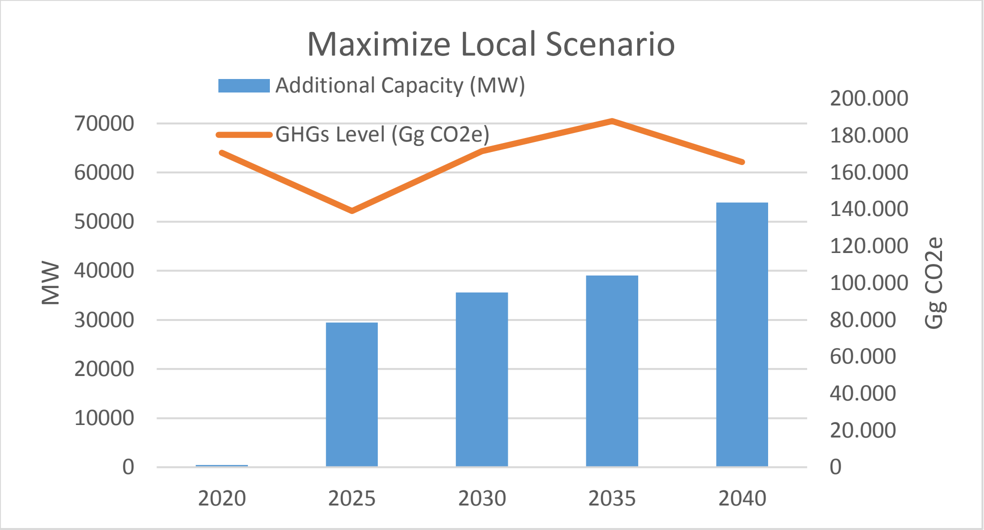

Figure 6.2. Development of Additional Installed Capacity and GHGs Emissions for Maximize Local Scenario

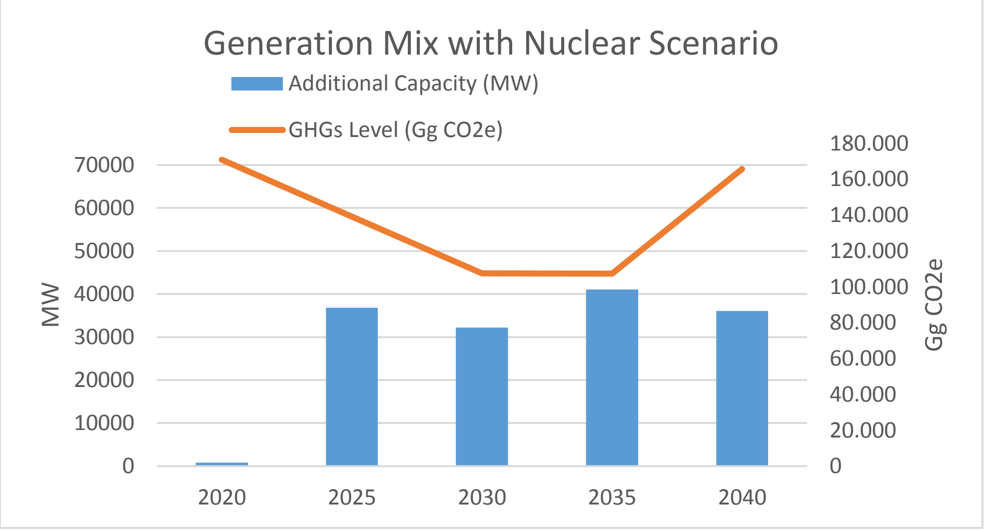

Figure 6.3. Development of Additional Installed Capacity and GHGs Emissions for Generation Mix with Nuclear Scenario

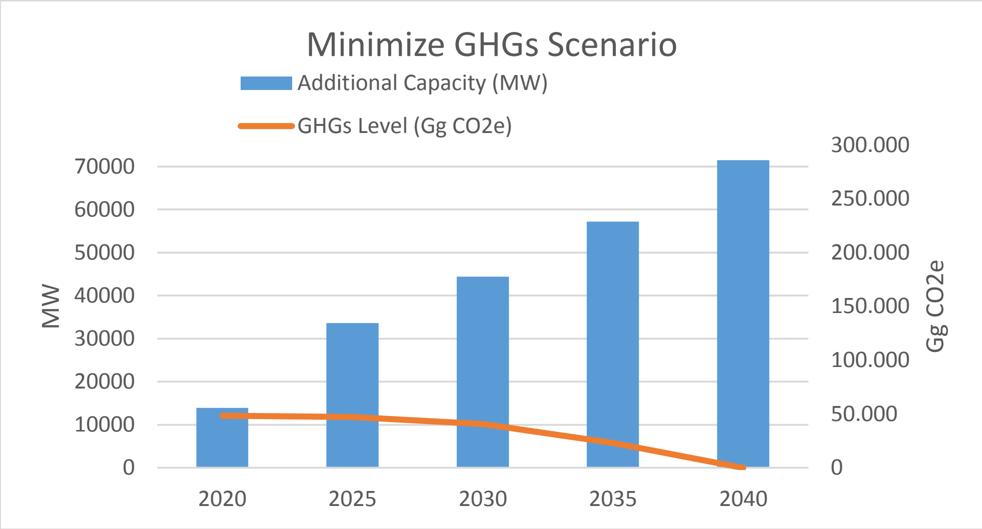

Figure 6.4. Development of Additional Installed Capacity and GHGs Emissions for Minimize GHGs Emissions Scenario

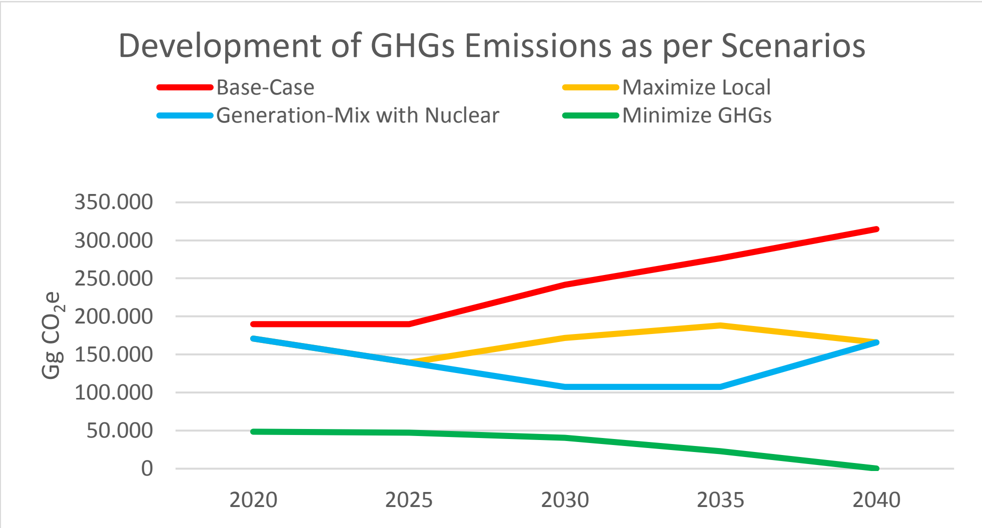

Figure 6.5. Development of GHGs Emissions as per Scenarios

Figure 6.5 reveals that the current generation mix , the base-case, has the highest emission level in 2040. For this reason, Turkey must focus on changing its generation mix to meet the GHGs emissions target. Scenario-2

Maximize Local reaches the highest emission level in 2035 but after this peak it falls sharply due to the increase of renewables' share in generation. Scenario-3 Generation Mix with Nuclear reaches the highest emission level in 2040. Scenario-2 Maximize Local and Scenario-3 Generation Mix with Nuclear reach the same emission level in 2040. It is still possible to reduce emission while keeping local coal in the generation mix. To include local coal in the generation mix is also a political decision. Scenario-4 Min GHGs indicates that 100% renewable is possible in 2040 with robust policies and with expected advances in development of storage technology.

6.2. Paradigm Shift

Electricity generation facilities tend to create natural monopolies because of economies of scale. All plants were specially designed and built on site, creating economies of scale. The unit cost per unit electricity generation is lower for large plants in comparison to smaller plants. These conditions prevailed from 1910 through 1960, and companies in the power industry and governments have met on a common ground that remote, central generation was optimal, that it would deliver power at the lowest cost versus other alternatives (central generation paradigm).

In this thesis, I have studied how these patterns shall be modified over time and the reason why energy transition is a need to be happen. Fundamentally it is an energy transition of this sort that is required for a carbon-intensive production style to become a carbon free production style. Strong and reliable energy infrastructure and robust energy policies are key parts of what happened in these other developed countries, combining optimum resource diversity and making use of its energy in the most efficient way integrating energy efficiency polices and solutions.

The future of electricity production, in 10 years the way of electricity generation will radically change. Electricity generation is no longer just about fossil fuels, nuclear or hydro. Decentralization is focused on the best way to produce electricity from the available local resources and consume it locally, a huge diversification of ways to supply electricity. Decentralization and energy efficiency offer part of the solution as long as they are well aligned with governmental policy and planning, and adapted to the particular needs of each consumers. So what will electricity production look like toward 2040? While its effects will vary from country to country depending on the level of the development and many other parameters, the potential benefits of the decentralization and energy efficiency are huge.

6.3. Conclusion

The global environmental challenge which also applies to Turkey is how to allocate resources to secure the electricity supply which is vital for the development and while mitigating GHGs emissions. This thesis deals with these two queries; first, to supply the increasing electricity demand of Turkey and second, to mitigate GHGs emissions committed in the INDC. A cross country panel data analysis is carried out for the period of 1980-2015 by using GDP, electricity power consumption and population data from 41 countries.

Firstly, the available local resources potential of Turkey is scrutinized.

Secondly, electricity demand forecast of Turkey for 2018-2040 period is performed by utilizing cross country panel data coefficients, IMF projections for GDP and SSI projections for population. Notwithstanding that there is much lower anticipation than the study result itself considering the fact that the previous models overestimated the electricity demand of Turkey and recent developments in the field of energy efficiency is expected to result proportional reduced electricity demand, the results of our analysis is in line with the official projection. We believe that the impact of energy efficiency on the demand side needs to be more diligently inquired.

Thirdly, four scenarios are designed to put forth impacts of different energy generation mix on GHGs emissions; i.e. base case which is considered as business as usual and hence keeping the existing generation mix, maximize local is concentrating to use local resources both renewables and local coal which are lignite and hard coal, generation mix with nuclear accommodates 4800 MW fully operational nuclear power plant by 2023 and last but not least minimize GHGs emissions scenario which is considered as ideal scenario that carries onward in terms of achieving not only emissions targets but reaching zero GHGs emissions. The allocation of the resources for each scenario firstly corresponding to the electricity demand in 2040 and then for each 5-year is studied as an optimization problem by taking capacity factor as a variable of the optimization equation. Regardless of the success of each scenario to combat with climate change, each scenario creates different generation mix to supply the forecasted electricity demand. Base case scenario puts down to the fact that current overcapacity by 2026 could create barriers for the transition of low carbon generation and today's generation mix will result 138% increase in the GHGs emissions for that reason it is critically important to modify today's generation mix. Maximize local scenario has reached its peak in terms of GHGs emissions in 2035 because of maximization of all local coal potential between 2025 and 2035 afterwards, the demand is supplied by increasing the share of renewables. Scenario-3 Generation Mix with Nuclear is having the lowest GHGs emissions until 2040 among first three scenarios, because of the fact that Akkuyu NPP will fully into operation in 2023 and this allows to increase renewable capacity gradually and minimize the share of fossil fuels until 2030. After 2035, due to the nature of this scenario all resources share will increase in the generation mix to supply the electricity demand. In 2040, generation mix with nuclear and maximize local will lead 43.7% less GHGs emissions than base case scenarios. Though nuclear can be considered as a panacea to mitigate GHGs emissions, this thesis did not evaluate its tremendous risks. On the other hand, it has an importance from the view point of diversification of the generation mix. Minimize GHGs emissions scenario disclose the available renewable potential to supply the increasing electricity demand in a carbon freeway at the same time the bottlenecks to get up to this level indicating how far we are especially in terms of existing installed capacity, policy point of view and infrastructure.

As a conclusion, the forecasted electricity demand of Turkey can be supplied with different energy generation mix. Scenario-2 Maximize Local and Scenario-3 Generation Mix with Nuclear both have contributed to decreasing GHGs emissions at certain level. Scenario-4 Minimize GHGs Emissions achieves zero emissions and presents our ideal scenario. These three scenarios shall be scrutinized carefully considering other energy policy dynamics. Over and above, it is concluded that nuclear power is more a political decision than economic or environmental.

6.4. Further Studies

Further studies on cost associated low CO_2 energy transition, distributed electricity generation solutions, other renewables' potentials such as off-shore wind, biogas, geothermal etc., energy efficiency, behavioral studies supporting energy-efficient choices, planning of energy investments on a platform including urban planning dynamics with marking potentials and best suitable areas, improvements on regulation, storage technologies, effective policies for the acceleration of renewable energy, studies on sociotechnical systems that lead large-scale transformations are needed in order to shed light on two main concerns of this thesis.

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APPENDICES

A. LIST OF COUNTRIES

Table A.1. *List of Countries as per their Electricity Power Consumption*

No	Name of Countries
1	Luxembourg
2	Latvia
3	Estonia
4	Lithuania
5	Slovenia
6	Ireland
7	Slovak Republic
8	Denmark
9	New Zealand
10	Israel
11	Chile
12	Hungary
13	Portugal
14	Greece
15	Switzerland
16	Austria
17	Czech Republic
18	Finland
19	Belgium
20	Argentina
21	Indonesia
22	Netherlands
23	Turkey
24	Norway
25	Poland
26	Sweden
27	Mexico
28	Australia
29	South Africa
30	Spain
31	Korea, Rep.
32	Italy
33	Brazil
34	United Kingdom
35	France
36	India
37	Canada
38	Germany
39	Japan
40	China
41	United States

B. RE MODELS RESULT

The baseline model is estimated by using random effects estimator. RE estimator is also used to allow unit specific intercepts. The main assumption of this estimator is zero correlation between explanatory variables and error term. RE estimator or RE models are estimated by the feasible generalized least squares estimator. FE model already allows country dummies and RE model treats the country effects or dummies as part of the error term. Country effects are under control in this RE model unlike FE model. For that reason, RE model with country dummies given in Table B.1. complies with the FE model coefficients. Table B.1. below presents the RE model estimates with year and country effects.

Table B.1. Comparison of Electricity Demand Projections

VARIABLES	(1) Electricity Consumption	(2) Electricity Consumption	(3) Electricity Consumption
Gross Domestic Product	0.299***	0.301***	0.315***
	(0.010)	(0.010)	(0.014)
Population	759.893***	764.805***	1,702.725***
	(101.342)	(103.563)	(268.149)
			(1.607e+11)
d85		-7.013e+09	
		(4.330e+10)	
d90		-1.478e+10	
		(4.282e+10)	
d95		-1.221e+10	
		(4.161e+10)	
d00		-2.624e+10	
		(4.181e+10)	
d05		-2.736e+10	
		(4.206e+10)	
d10		-1.674e+10	
		(4.234e+10)	
d15		-2.354e+10	
		(4.267e+10)	
Country effects			Yes
Constant	-1.036e+11***	-8.964e+10**	-8.102e+10
	(2.763e+10)	(3.976e+10)	(5.814e+10)
Observations	298	298	298
Number of countries	40	40	40
rmse	1.720e+11	1.730e+11	1.630e+11
ρ	0.418	0.426	0
χ^2	1304***	1267***	5117***
R^2_within	0.768	0.771	0.776
R^2_between	0.941	0.941	1
R^2_overall	0.896	0.896	0.952

(.) denotes standard errors.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$
The third column includes country dummies that are time-invariant. The significant effects are found to be for Brazil, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Spain and United Kingdom at the traditional significance levels.

In addition, model 1 coefficients are used to forecast electricity demand of Turkey with the same projections of population and the real GDP. The electricity demand is forecasted as 366,3 TWh for 2020, 460,5 TWh for 2025, 574,4 TWh for 2030, 650,6 TWh for 2035 and 735.0 TWh for 2040.

C. GAMS MODEL RESULTS

Table C.1. *Results of Scenario-1 Base Case*

			Installed Capacity			
	2017	**2020**	**2025**	**2030**	**2035**	**2040**
Hydro	27.2731	27.2731	27.2731	34.67859625	39.71695505	45.23687742
Wind	6.5162	6.5162	6.5162	8.28555129	9.489336471	10.80817878
Solar	3.4207	3.4207	3.4207	4.34952661	4.981457485	5.673787966
OthRen	1.6388	1.6388	1.6388	2.083785251	2.386532735	2.718216657
NaturalGas	23.0637	23.0637	23.0637	29.32621302	33.58693864	38.25490207
ImpCoal	8.7939	8.7939	8.7939	11.18171779	12.80627912	14.58611512
DomCoal	9.8726	9.8726	9.8726	12.55331845	14.3771559	16.37531472
OthFos	4.6212	4.6212	4.6212	5.875999757	6.729707759	7.665012702
Total	**85.2002**	**85.2002**	**85.2002**	**108.3347084**	**124.0743632**	**141.3184054**
			Active Capacity			
		2020	**2025**	**2030**	**2035**	**2040**
Hydro		9.21559796	27.08786805	34.67859625	39.71695505	45.23687742
Wind		6.5162	6.5162	8.28555129	9.489336471	10.80817878
Solar		3.4207	3.4207	4.34952661	4.981457485	5.673787966
OthRen		1.6388	1.6388	2.083785251	2.386532735	2.718216657
NaturalGas		23.0637	23.0637	29.32621302	33.58693864	38.25490207
ImpCoal		8.7939	8.7939	11.18171779	12.80627912	14.58611512
DomCoal		9.8726	9.8726	12.55331845	14.3771559	16.37531472
OthFos		4.6212	4.6212	5.875999757	6.729707759	7.665012702
Total		**67.14269796**	**85.01496805**	**108.3347084**	**124.0743632**	**141.3184054**
			Genaration			
	2017	**2020**	**2025**	**2030**	**2035**	**2040**
Hydro	57.961	53.52308708	157.3230871	201.4091256	230.6713089	262.7303556
Wind	17.668	22.03361803	22.03361803	28.01643171	32.08686277	36.54634339
Solar	0.022	8.09063964	8.09063964	10.28750034	11.78214324	13.4196433
OthRen	7.823	3.87608976	3.87608976	4.928568876	5.644627225	6.429126038
NaturalGas	109.377	129.7084037	129.7084037	164.9282759	188.890256	215.1425089
ImpCoal	50.279	49.45619009	49.45619009	62.88508633	72.02148926	82.03114456
DomCoal	39.879	55.52271259	55.52271259	70.59885868	80.85597458	92.09345998
OthFos	6.768	25.9892591	25.9892591	33.04615256	37.84733806	43.10741824
Total	**289.777**	**348.2**	**452**	**576.1**	**659.8**	**751.5**
			Emissions			
	2017	**2020**	**2025**	**2030**	**2035**	**2040**
Hydro						
Wind						
Solar						
OthRen						
NaturalGas	37999.64796	45063.16391	45063.16391	57299.21669	65624.06383	74744.59529
ImpCoal	41218.22141	40543.69007	40543.69007	51552.56493	59042.49668	67248.312
DomCoal	40534.01258	56434.67315	56434.67315	71758.44493	82184.03396	93606.09506
OthFos	12439.90886	47769.50572	47769.50572	60740.41461	69565.22403	79233.50387
Total	**132191.7908**	**189811.0328**	**189811.0328**	**241350.6412**	**276415.8185**	**314832.5062**
			Newly Installed Capacity			
		2020	2025	2030	2035	2040
Hydro		2.72731	4.545516667	11.95101292	9.583875469	10.06543903
Wind				1.76935129	1.203785181	1.318842307
Solar				0.92882661	0.631930875	0.692330481
OthRen		0.16388	0.273133333	0.718118584	0.575880817	0.604817255
NaturalGas		2.30637	3.84395	10.10646302	8.10467562	8.511913433

ImpCoal	0.87939	1.46565	3.853467794	3.090211325	3.245486004
DomCoal	0.98726	1.645433333	4.32615178	3.469270782	3.643592163
OthFos	0.46212	0.7702	2.024999757	1.623908002	1.705504943
Total	**7.52633**	**12.54388333**	**35.67839175**	**28.28353807**	**29.78792562**

The installed capacity of 2017 is ample to respond the forecasted electricity demand in 2025.

Table C.1. designates GHGs emissions have its source in electricity generation will increase 82,6 % and will reach to 241,350.6 in 2030 from 132,192.1 $GgCO_2e$ in 2017. Today's GHGs emissions results from electricity generation corresponds to 27% of total emissions declared by SIS. Emissions by 2030 designates that total emissions will reach to 893,891 $GgCO_2e$ in direct proportion to 2017. This amount is below the governmental projections given in the INDC as 1,175 $MtCO_2e$ due to overestimated GDP growth. Our finding is in consistency with Kat and Yeldan & Voyvoda estimating base case projections as 836 $MtCO_2e$, 787 $MtCO_2e$ respectively.(Kat et al., 2018)(Yeldan & Voyvoda, 2015)

Table C.2. *Results of Scenario-2 Maximize Local*

Installed Capacity						
	2017	**2020**	**2025**	**2030**	**2035**	**2040**
Hydro	27.2731	24.54579	32	46	46	46
Wind	6.5162	6.5162	16	16	34.52981581	48
Solar	3.4207	3.894374439	11.88468762	17.71757913	25.31027244	59.55295034
OthRen	1.6388	1.47492	1.201786667	0.928653333	0.65552	0.382386667
NaturalGas	23.0637	20.75733	16.91338	13.06943	9.22548	5.38153
ImpCoal	8.7939	7.91451	6.44886	4.98321	3.51756	2.05191
DomCoal	9.8726	8.88534	7.239906667	16.79964171	23.543	23.543
OthFos	4.6212	4.15908	3.38888	2.61868	1.84848	1.07828
Total	85.2002	78.14754444	95.07750095	118.1171942	144.6301283	185.990057

Active Capacity					
	2020	**2025**	**2030**	**2035**	**2040**
Hydro	13.57776294	30.2663444	46	46	46
Wind	6.5162	16	16	34.52981581	48
Solar	3.894374439	11.88468762	17.71757913	25.31027244	59.55295034
OthRen	1.47492	1.201786667	0.928653333	0.65552	0.382386667
NaturalGas	20.75733	16.91338	13.06943	9.22548	5.38153
ImpCoal	7.91451	6.44886	4.98321	3.51756	2.05191
DomCoal	8.88534	7.239906667	16.79964171	23.543	23.543
OthFos	4.15908	3.38888	2.61868	1.84848	1.07828
Total	67.17951738	93.34384535	118.1171942	144.6301283	185.990057

Genaration						
	2017	**2020**	**2025**	**2030**	**2035**	**2040**
Hydro	57.961	78.85801782	175.7832963	267.16248	267.16248	267.16248
Wind	17.668	22.03361803	54.10176	54.10176	116.757738	162.30528
Solar	0.022	9.210974423	28.10966316	41.90561815	59.86385639	140.8546382
OthRen	7.823	3.488480784	2.842465824	2.196450864	1.550435904	0.904420944
NaturalGas	109.377	116.7375633	95.11949605	73.50142877	51.88336148	30.2652942
ImpCoal	50.279	44.51057108	36.26787273	28.02517438	19.78247604	11.53977769
DomCoal	39.879	49.97044133	40.7166559	94.47984101	132.4039486	132.4039486
OthFos	6.768	23.39033319	19.05879001	14.72724683	10.39570364	6.064160458
Total	**289.777**	**348.2**	**452**	**576.1**	**659.8**	**751.5**

Emissions						
	2017	**2020**	**2025**	**2030**	**2035**	**2040**
Hydro						
Wind						
Solar						
OthRen						
NaturalGas	37999.64796	40556.84752	33046.3202	25535.79288	18025.26556	10514.73824
ImpCoal	41218.22141	36489.32107	29732.03939	22974.75771	16217.47603	9460.19435
DomCoal	40534.01258	50791.20583	41385.42697	96031.6724	134578.6834	134578.6834
OthFos	12439.90886	42992.55515	35030.97086	27069.38657	19107.80229	11146.218
Total	**132191.7908**	**170829.9296**	**139194.7574**	**171611.6096**	**187929.2273**	**165699.834**

Newly Installed Capacity					
	2020	**2025**	**2030**	**2035**	**2040**
Hydro		11.99972667	18.54551667	4.545516667	4.545516667
Wind		9.4838		18.52981581	13.47018419

Solar	0.473674439	7.99031318	5.832891507	7.592693319	34.2426779
OthRen					
NaturalGas					
ImpCoal					
DomCoal			11.20516838	8.388791622	1.645433333
OthFos					
Total	**0.473674439**	**29.47383985**	**35.58357655**	**39.05681742**	**53.90381209**

In 2025, 29,473 MW additional installed capacity is needed to correspond the demand forecasted in Chapter 4 thus the total installed capacity will reach to 95,077 MW. It should be highlighted that GHGs emissions will be 28.9% less than scenario-1 base case in 2030.

Table C.3. Scenario-3 Generation Mix with Nuclear

Installed Capacity						
	2017	**2020**	**2025**	**2030**	**2035**	**2040**
Hydro	27.2731	24.54579	32	42.59021683	43.09633959	46
Wind	6.5162	6.5162	16	26.66666667	48	48
Solar	3.4207	4.20705379	12.83890927	18.35170918	26.40392588	38.31225752
OthRen	1.6388	1.47492	3.081338225	3.670341835	4.526387293	5.231968377
NaturalGas	23.0637	20.75733	16.91338	13.06943	9.22548	5.38153
ImpCoal	8.7939	7.91451	6.44886	4.98321	3.51756	2.05191
DomCoal	9.8726	8.88534	7.239906667	5.594473333	9.461403678	23.543
OthFos	4.6212	4.15908	3.38888	2.61868	1.84848	1.07828
			4.8	4.8	4.8	4.8
Total	**85.2002**	**78.46022379**	**102.7112742**	**122.3447278**	**150.8795764**	**174.3989459**
Active Capacity						
		2020	**2025**	**2030**	**2035**	**2040**
Hydro		13.45042746	29.11231911	42.59021683	43.09633959	46
Wind		6.5162	16	26.66666667	48	48
Solar		4.20705379	12.83890927	18.35170918	26.40392588	38.31225752
OthRen		1.47492	3.081338225	3.670341835	4.526387293	5.231968377
NaturalGas		20.75733	16.91338	13.06943	9.22548	5.38153
ImpCoal		7.91451	6.44886	4.98321	3.51756	2.05191
DomCoal		8.88534	7.239906667	5.594473333	9.461403678	23.543
OthFos		4.15908	3.38888	2.61868	1.84848	1.07828
				4.8	4.8	4.8
Total		**67.36486125**	**95.02359328**	**122.3447278**	**150.8795764**	**174.3989459**
Genaration						
	2017	**2020**	**2025**	**2030**	**2035**	**2040**
Hydro	57.961	78.11846862	169.0808559	247.3588685	250.2983688	267.16248
Wind	17.668	22.03361803	54.10176	90.1696	162.30528	162.30528
Solar	0.022	9.950523623	30.36658821	43.40546254	62.45056548	90.61615149
OthRen	7.823	3.488480784	7.287981169	8.681092508	10.70581123	12.37465161
NaturalGas	109.377	116.7375633	95.11949605	73.50142877	51.88336148	30.2652942
ImpCoal	50.279	44.51057108	36.26787273	28.02517438	19.78247604	11.53977769
DomCoal	39.879	49.97044133	40.7166559	31.46287047	53.21017737	132.4039486

OthFos	6.768	23.39033319	19.05879001	14.72724683	10.39570364	6.064160458
				38.768256	38.768256	38.768256
Total	**289.777**	**348.2**	**452**	**576.1**	**659.8**	**751.5**

Emissions						
	2017	**2020**	**2025**	**2030**	**2035**	**2040**
Hydro						
Wind						
Solar						
OthRen						
NaturalGas	37999.64796	40556.84752	33046.3202	25535.79288	18025.26556	10514.73824
ImpCoal	41218.22141	36489.32107	29732.03939	22974.75771	16217.47603	9460.19435
DomCoal	40534.01258	50791.20583	41385.42697	31979.64812	54084.15454	134578.6834
OthFos	12439.90886	42992.55515	35030.97086	27069.38657	19107.80229	11146.218
Total	**132191.7908**	**170829.9296**	**139194.7574**	**107559.5853**	**107434.6984**	**165699.834**

Newly Installed Capacity					
	2020	**2025**	**2030**	**2035**	**2040**
Hydro		11.99972667	15.13573349	5.051639427	7.449177079
Wind		9.4838	10.66666667	21.33333333	
Solar	0.78635379	8.631855481	5.512799905	8.0522167	11.90833165
OthRen		1.879551558	0.862136944	1.129178791	0.978714417
NaturalGas					
ImpCoal					
DomCoal				5.512363678	15.72702966
OthFos					
		4.8			
Total	**0.78635379**	**36.79493371**	**32.17733701**	**41.07873193**	**36.0632528**

Table C.4. Scenario-4 Minimize GHGs

Installed Capacity						
	2017	**2020**	**2025**	**2030**	**2035**	**2040**
Hydro	27.2731	32	38.04818652	46	46	46
Wind	6.5162	6.5162	16	39.08698205	48	48
Solar	3.4207	4.616464868	14.08833273	21.68610209	63.81088681	128.7093105
OthRen	1.6388	2.748162024	3.381199854	4.337220418	5.676784418	7.445027418
NaturalGas	23.0637	24.76564389	24.11129604	20.26734604	16.42339604	12.57944604
ImpCoal	8.7939	7.91451	6.44886	4.98321	3.51756	2.05191
DomCoal	9.8726	8.88534	7.239906667	5.594473333	3.94904	2.303606667
OthFos	4.6212	4.15908	3.38888	2.61868	1.84848	1.07828
Total	**85.2002**	**91.60540078**	**112.7066618**	**144.5740139**	**189.2261473**	**248.1675806**

Active Capacity					
	2020	**2025**	**2030**	**2035**	**2040**
Hydro	29.17890288	38.04818652	46	46	46
Wind	6.5162	16	39.08698205	48	48
Solar	4.616464868	14.08833273	21.68610209	63.81088681	128.7093105
OthRen	2.748162024	3.381199854	4.337220418	5.676784418	7.445027418
NaturalGas	24.76564389	24.11129604	20.26734604	11.73203033	
ImpCoal			0.220143118		
DomCoal					
OthFos					
Total	**67.82537366**	**95.62901514**	**131.5977937**	**175.2197016**	**230.1543379**

Genaration						
	2017	**2020**	**2025**	**2030**	**2035**	**2040**
Hydro	57.961	169.4675664	220.9793015	267.16248	267.16248	267.16248
Wind	17.668	22.03361803	54.10176	132.1671576	162.30528	162.30528
Solar	0.022	10.9188627	33.32172456	51.29196866	150.9255095	304.4232612
OthRen	7.823	6.499952818	7.997213895	10.25839373	13.42673051	17.60897885
NaturalGas	109.377	139.28	135.6	113.9819327	65.98	
ImpCoal	50.279			1.238067284		
DomCoal	39.879					
OthFos	6.768					
Total	**289.777**	**348.2**	**452**	**576.1**	**659.8**	**751.5**

Emissions						
	2017	**2020**	**2025**	**2030**	**2035**	**2040**
Hydro						
Wind						
Solar						
OthRen						
NaturalGas	37999.64796	48388.51832	47110.0164	39599.48908	22922.70562	
ImpCoal	41218.22141			1014.955179		
DomCoal	40534.01258					
OthFos	12439.90886					
Total	**132191.7908**	**48389**	**47110**	**40614**	**22923**	

Newly Installed Capacity					
	2020	**2025**	**2030**	**2035**	**2040**
Hydro	7.45421	10.59370319	12.49733014	4.545516667	4.545516667
Wind		9.4838	23.08698205	8.913017954	
Solar	1.195764868	9.471867858	7.597769362	42.12478473	64.89842367
OthRen	1.273242024	0.906171164	1.229153897	1.612697334	2.041376333
NaturalGas	4.008313893	3.189602143			
ImpCoal					
DomCoal					
OthFos					
Total	**13.93153078**	**33.64514435**	**44.41123545**	**57.19601668**	**71.48531667**

In 2040, 100 % of this installed capacity denotes renewables which are hydro, wind, solar and other renewables and in this way renewables corresponds 100 % of electricity generation. As a consequence of these, GHGs emissions have its source in electricity generation will be zero from 132,192.1 GgCO_2e in 2017.

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WORK EXPERIENCE

Year	Place	Enrollment
2017-Present	ENGIE TURKEY	BtoT Coordinator
2014-2017	ENGIE NDD – Sinop NPP Project	Business Developer
2013-2014	AKENERJİ ELEKTRİK ÜRETİM A.Ş	Project Manager
2010-2013	AKENERJİ ELEKTRİK ÜRETİM A.Ş Erzin CCGT Power Plant (900MW)	Permit and Approval Specialist
2010-2008	Armada Consultancy	Project Manager
2008-2007	Politecnico di Milano Urban Simulation Lab in Garibaldi Repubblica Project	Intern

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