A MULTIDIMENSIONAL ANALYSIS OF TURKISH GERMAN LOW CARBON ENERGY TRANSITIONS

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submitted by **ALPARSLAN BAYRAKTAR** in partial fulfillment of the requirements for the degree of **Doctor of Philosophy** i**n Earth System Science, Middle East Technical University** by,

Prof. Dr. Halil Kalıpçılar
Dean, Graduate School of **Natural and Applied Sciences**

Prof. Dr. Bülent Gültekin Akınoğlu
Head of the Department, **Physics**

Prof. Dr. Oktay Fırat Tanrısever
Supervisor, **Department of International Relations, METU**

Prof. Dr. Özlem Özdemir
Co-Supervisor, **Business Administration, METU**

Examining Committee Members:

Prof. Dr. Alp Erinç Yeldan
Department of Economics, Kadir Has University

Prof. Dr. Oktay Fırat Tanrısever
Department of International Relations, METU

Prof. Dr. Hakan Berument
Department of Economics, Bilkent University

Prof. Dr. Alper Ünal
Department of Eurasia Institute of Earth Sciences, ITU

Prof. Dr. Matthias Finger
Department of Economics, ITU

Date: 10.12.2020

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name : Alparslan Bayraktar

Signature :

ABSTRACT

A MULTIDIMENSIONAL ANALYSIS OF TURKISH GERMAN LOW CARBON ENERGY TRANSITIONS

Bayraktar, Alparslan
Doctor of Philosophy, Earth System Science
Supervisor: Prof. Dr. Oktay Fırat Tanrısever
Co-Supervisor: Prof. Dr. Özlem Özdemir

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Long-term structural changes in energy systems, commonly referred as "energy transition", have occurred in the past and still occur worldwide. This global energy transition is being observed in multiple fields. Energy systems driven by fossil fuels is being gradually replaced by more decentralized, decarbonized, innovative and technologically smarter alternatives. This desired low-carbon system is mainly shaped by climate change mitigation and adaptation efforts. This inevitable transition to low-carbon economy has immense implications globally and indirectly force all countries to rethink their energy policies. In this regard, Germany is an important case study to observe the effects and management of this transition and a great example for other countries to learn from past experiences and prepare themselves for potential challenges.

This research highlights how energy transition in Turkey, a growing economy which started restructuring its energy sector since 2002 through a variety of interlinked measures, is shaped and moving forward. The process is compared to mature German experience, "Energiewende" which is often regarded as the front runner in the global energy transition. The proposed multidimensional analysis focuses on energy security, economic and environmental motives of this transition. This analysis discusses whether Energiewende is a unique model towards low carbon or a model that can be extended to Turkey.

Keywords: Energy Transition, Germany, Turkey, Energiewende, Multidimensional Analysis

ÖZ

ALMANYA VE TÜRKİYE'DE DÜŞÜK KARBONLU ENERJİ DÖNÜŞÜMÜNÜN ANALİZİ

Bayraktar, Alparslan
Doktora, Yer Sistem Bilimleri
Tez Yöneticisi: Prof. Dr. Oktay Fırat Tanrısever
Ortak Tez Yöneticisi: Prof. Dr. Özlem Özdemir

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Enerji sistemlerinde, süregelmekte olan "enerji dönüşümü" olarak ifade edilen uzun dönemli yapısal değişimler tüm dünyada gerçekleşmektedir. Bahse konu küresel enerji dönüşümü, birçok alanda yaşanmaktadır. Bu zamana kadar fosil yakıtlar üzerinden gerçekleşen enerji dönüşümü tartışmalarının yerini dağıtık, karbonsuz, inovatif ve teknolojik olarak daha akıllı alternatifler almaktadır. İstenilen düşük karbonlu sistem temelde iklim değişikliği adaptasyon ve azaltım çabaları üzerinden şekillenmektedir. Düşük karbonlu ekonomiye kaçınılmaz dönüşümün büyük etkileri bulunmakla birlikte tüm ülkeleri enerji politikalarını yeniden düşünmeye sevk etmektedir. Bu anlamda, Almanya enerji dönüşümünün etkilerinin ve yönetiminin incelenmesi adına önemli bir vaka çalışmasıdır. Ayrıca, ülkelerin süreç içerisinde karşılaşabilecekleri potansiyel zorluklara kendilerini hazırlamaları için de önemli bir örnek teşkil etmektedir.

Bu çalışma, enerji sektörünü yeniden yapılandırmaya 2002 yılından beri devam eden Türkiye'nin enerji dönüşümünün nasıl başladığını, şekillendiğini ve devam etmekte olduğunu araştırmaktadır. Türkiye'nin dönüşüm süreci, küresel enerji dönüşümünde öncü kabul edilen "Energiewende" olarak adlandırılan Alman enerji dönüşümü ile kıyaslanmaktadır. Çok seviyeli analiz enerji güvenliği, ekonomik ve çevre motivasyonları olmak üzere üç temel ayakta toplanmıştır. Analiz, Energiewende'nin Türkiye için de uygulanabilir olup olmadığını değerlendirmektedir.

Anahtar Kelimeler: Enerji Dönüşümü, Almanya, Türkiye, Energiewende, Çok Seviyeli Analiz

To My Beloved Daughter,

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ABBREVIATIONS

%: Percent

°C: Degrees Celsius

$ / USD: United States Dollar

€ / EUR: Euro

ACEE: Advisory Committee on Energy Efficiency

AT: Austria

AtG: Atomgesetz / German Atomic Energy Act

BAU: Business as Usual

Bbl: Barrels

Bcf: Billion Cubic Feet

Bcm: Billion Cubic Meter

BDI: Federation of German Industries

BE: Belgium

BMU: Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety

BMWI: The Federal Ministry for Economic Affairs and Energy

BNEF: Bloomberg New Energy Finance

BO: Build-Operate

BOO: Build-Own-Operate

BOOT: Build-Own-Operate-Transfer

BOT: Build-Operate-Transfer

BOTAŞ: Petroleum Pipeline Company of Turkey

BRICS: Brazil, Russia, India, China and South Africa

CCS: Carbon Capture and Storage

CDM: Clean Development Mechanism

CDU: Christian Democratic Union

CHP: Combined Heat and Power

CNG: Compressed Natural Gas

CO_2: Carbon Dioxide

CO_2e: Carbon Dioxide Equivalent

COP: Conference of Parties

CPI: Consumer Price Index

CSU: Christian Social Union

CWE: Central Western Europe

DC: Direct current

DE: Germany

DistCos: Distribution Companies

DSI: State Hydraulic Works of Turkey

EBRD: European Bank for Reconstruction and Development

EC: European Commission

EDF: Électricité de France

EECB: Energy Efficiency Coordination Board

EEG: Erneuerbare-Energien-Gesetz / The Renewable Energy Sources Act

EIA: Energy Information Administration

EIEI: Electrical Power Resources Survey and Development Administration

EIT: Economies in Transition

EnBW: Energie Baden-Württemberg AG

Energiewende: German Energy Transition

ENTSO-E: European Network of Transmission System Operators for Electricity

EPDK / EMRA: Electricity Market Regulatory Authority of Turkey

EPR: Electron Paramagnetic Resonance

ES: Spain

ESCOs: Energy Service Companies

ETI: Energy Transition Index

EU ETS: European Union Emissions Trading System

EU: European Union

EÜAŞ: Electricity Generation Company of Turkey

EXIST/EPİAŞ: Energy Exchange Istanbul

FDP: Free Democratic Party

FFVs: Flexible-Fuel Vehicles

FiT: Feed-in-Tariff

FPC: Federal Power Commission

FR: France

FSRU: Floating Storage Regasification Unit

G20: Group of Twenty

GB: United Kingdom

GDP: Gross Domestic Product

GDRE: General Directorate of Renewable Energy

GEF: Global Environmental Facility

GHG: Greenhouse Gas

Gt: Gigatonnes

GW: Gigawatt

GWEC: Global Wind Energy Council

GWh: Gigawatt Hour

IEA: International Energy Agency

IECP: Integrated Energy and Climate Programme

IEEFA: Institute for Energy Economics and Financial Analysis

ILO: International Labor Organization

INDC: Intended Nationally Determined Contribution

IPCC: Intergovernmental Panel on Climate Change

IRENA: International Renewable Energy Agency

IT: Italy

Kcal/kg: Kilogram calories / kilogram

KEP/$: Kilogram of Oil Equivalent / Dollar

Kg: Kilogram

KWh: Kilowatt Hour

KWh/cap: Kilowatt Hour

LNG: Liquefied Natural Gas

LPG: Liquefied Petroleum Gas

Max: Maximum

Mcm: Million Cubic Meter

MENR: Ministry of Energy and Natural Resources

MFA: Ministry of Foreign Affairs

MMBtu: Million British Thermal Units

MMcf: Million Cubic Feet

MTA: Mineral Research and Exploration General Directorate of Turkey

$MTCO_2$ eq.: Metric Tons of Carbon Dioxide Equivalent

Mtoe: Millions of Tonnes of Oil Equivalent

Mtoe/yr: Millions of Tonnes of Oil Equivalent/Year

MW: Megawatt

MWe: Megawatts Electric

MWh: Megawatt Hour

NDK: Nuclear Regulation Authority of Turkey

NEA: National Environment Agency

NEEAP: National Energy Efficiency Action Plan

NEMP: National Energy and Mining Policy

NETL: National Energy Technology Laboratory

NGO: Non-Governmental Organization

NGPA: Natural Gas Policy Act

NPP: Nuclear Power Plant

OPEC: The Organization of the Petroleum Exporting Countries

PJ: Petajoule

PMUM: Market Financial Settlement Center of Turkey

PURPA: Public Utilities Regulatory Policy Act

PV: Photovoltaic

R&D: Research and Development

RE-ZONE: Regulation on Renewable Energy Resource Zones

RE: Renewable Energy

REN21: Renewable Energy Policy Network for the 21^{st} Century

RES: Renewable Energy Sources

RFS: Renewable Fuel Standard

RPS: Renewable Portfolio Standards

SME: Small and Medium Sized Enterprises

SPD: Social Democratic Party

StrEG: Stromeinspeisegesetz / Electricity Feed-in Act

SWOT: Strengths, Weaknesses, Opportunities and Threats

TAEK: Turkish Atomic Energy Authority

TANAP: Trans Anatolian Natural Gas Pipeline

TBMM: Grand National Assembly of Turkey

Tcm: Trillion Cubic Meter

TCO_2/cap: Total Carbon Dioxide / cap

TEAŞ: Turkish Electricity Generation and Transmission Company

TEDAŞ: Turkish Electricity Distribution Company

TEİAŞ: Turkish Electricity Transmission Company

TEK: Turkish Electricity Authority

TEPAV: The Economic Policy Research Foundation of Turkey

TETAŞ: Turkish Electricity Trading and Contracting Company

TFEC: The Foundation for Enhancing Communities

TKİ: Turkish Coal Enterprises

Toe: Tonnes of Oil Equivalent

Tonnes CO_2 e/GWh: Tonnes Carbon Dioxide Equivalent / Gigawatt Hour

TPES/GDP: Total Primary Energy Supply/Gross Domestic Product

TSO: Transmission System Operator

TTK: Turkish Hard Coal Enterprises

TÜİK: Turkish Statistical Institute

TWh: Terawatt Hour

TWh/y: Terawatt Hour/Year

UN: United Nations

UNCED: United Nations Conference on Environment and Development

UNEP: United National Environment Programme

UNFCCC: United Nations Framework Convention on Climate Change

US: The United States

W/m^2: Watt Per Square Meter

WCED: World Commission on Environment and Development

WEC: World Energy Council

WEF: World Economic Forum

WEO: World Energy Outlook

WHO: World Health Organization

WNA: World Nuclear Association

YEKA: Renewable Energy Resource Areas

YEKDEM: Renewable Energy Resources Support Mechanism

YoY: Year over Year

ZDF: Zweites Deutsches Fernsehen

CHAPTER 1

INTRODUCTION

1.1. Scope and Objective

There are numerous energy transition experiences across the world. These experiences differ in terms of their motivations and objectives, providing unique lessons for each other. Most of these transition experiences are sparked by energy security concerns supported by increasing overall competitiveness of the economy. In contrast, the German experience dissociates from other countries with its unique motivators. The energy transition in Germany, commonly referred as Energiewende, is mainly triggered by environmental concerns and public support. Therefore, while Germany is not the only country undergoing a transition, it sparks international attention with its fundamentally different motivators.

The thesis represents a branch of a political economy literature. The main focus of the thesis is energy transition policies of Germany and Turkey. The analysis includes several aspects ranging from energy security, environment to socioeconomics. All these aspects have been factored throughout the entire analyses and discussions included in the thesis. Despite Germany and Turkey are central to this research, this thesis explains the positions of other major players in energy transition, namely, France, the US, China and Brazil. Beyond these countries, the multidimensional analysis serves as a benchmark for rest of the countries, especially developing ones. Although the thesis spans a variety of aspects, it does not focus on geopolitical factors that play critical roles in energy transition decisions. This aspect was purposefully missed because geopolitical drivers are mostly unique to their region. The drivers with global impacts are indispensably reflected on socioeconomics, hence covered throughout the thesis. Moreover, the thesis does not include detailed technological discussions which would potentially shape the future of energy systems. In this regard, these aspects could be further included to complement the discussions.

The analysis spans a period of almost 20 years starting from 2000 up to 2019. The year 2000 marks an important year for both countries. Germany enacted the historic renewables law as well as agreed on full nuclear phaseout which are the setting stones of the Energiewende. Moreover, Turkey started its market liberalization process as of 2000s. Therefore, this coinciding time frame is essential for both energy transitions.

1.2. Research Problem

The focus of this thesis is on multidimensional analysis of energy transitions of Turkey and Germany, which is relatively a fertile area in the study of the political economy. Therefore, the analysis fills a missing portion of the political economy literature.

An important branch of energy transition focuses on multidimensional analysis. This branch of the literature consists mostly of cross-country analysis. As energy transition experiences draw attention to international cooperation and lesson drawing, the importance of multidimensional analyses increases. However, this type of analyses remains to be scare. In the literature, there are numerous papers on comparison of Energiewende with other economies, yet, the comparisons remain limited in terms of the countries they cover and mostly focus on developed countries. This thesis not only provides details of energy transition in Turkey but it also examines the Energiewende and energy transition of Turkey from a multidimensional perspective. Additionally, it suggests possible fields of cooperation areas for further progress in the transition of both countries. To my knowledge, there is no multidimensional research on the energy transition experiences of Germany and Turkey so far. Thus, this thesis fills a critical gap by providing a cross-country analysis of Energiewende with Turkey, a developing country.

Among many other countries energy transition literature extensively covers the German Energiewende. While most of the literature on Energiewende is cited throughout this thesis most of the literature is only in German. In this perspective, this thesis is crucial that it belongs to a scarce, yet, growing literature.

It is important to draw attention that Turkey's energy transition experience has a long history with many achievements regarding liberalization of the markets and integration of renewables. Hence, the experience itself can serve as an important example for developing countries. However, the transition of Turkey has not received the attention by neither the analysts nor the academics. There are only some reports by national and international organizations and a few government publications. To fill this missing element in the literature, this thesis delves into the energy transition experience of Turkey from various aspects and provides a detailed analysis through a concrete quantitative analysis.

This thesis focuses on Energiewende and analyzes the potential of its applicability for other countries. The thesis answers whether Energiewende is a fixed model or a dynamic policy tool that each country should adopt according to their unique circumstances. In this perspective, the thesis compares Turkish energy transition to German energy transition and asks whether Energiewende serves a direct pattern for developing countries or should be implemented depending on country specific priorities.

This thesis further examines the Energiewende and energy transition of Turkey and provides possible fields of cooperation areas for further progress in the transition of both countries. The main questions that are answered throughout the thesis are as follows:

Energy transition is a highly debated concept across the world. There are different understandings when it comes to defining this concept. This thesis aims to answer what is the definition of energy transition and how it evolves over time?

What are the motivations behind the energy transitions occurring globally? Given the unique circumstances of selected countries as case studies, what drives their energy transitions? The thesis also uncovers the specific policy targets as well as the tools for each of these case studies.

More specifically, what makes the prominent German experience "Energiewende" different from others? The thesis would like to explore the drivers of Energiewende. What are the roles of the government, other stakeholders as well as technological innovation? Moreover, the thesis aims to discover the decision-making process and the policy tools that the German government implements.

In tandem with the developments in energy transition, what is the position of Turkey? What motivates the energy transition of Turkey? How far the country has achieved so far? Among numerous policies, plans and implementations spanning a period of almost 20 years, what are the challenges the country is facing and what needs to be done to overcome these challenges?

Through a comprehensive multidimensional analysis of Energiewende and energy transition in Turkey, what are the possible takeaways from the German experience that Turkey can benefit? Beyond Turkey, what possible spillover effects can Energiewende have on other countries, especially developing ones?

Given all the answers to the questions above, is there a unique energy transition model applicable globally, such as Energiewende, or several models suitable for different countries?

1.3. Literature Review

Over time an extensive literature has developed on energy transition across time and countries. This section presents a review of recent literature on energy transition with a specific focus on Germany's energy transition and its relation with other countries. As this thesis is conducting a multidimensional analysis on Turkey's and Germany's energy transitions, this section also presents the scarce literature written on Turkey.

1.3.1. Energy Transition

There is ample literature on energy transition spanning a variety of aspects. These aspects can be categorized in two major strands. First strand analyzes energy transition pathways from a socio-technical perspective (Geels et al., 2016; Sovacool, 2016). The other strand takes a more quantitative approach and uses mathematical models to formulate energy transitions (Bale et al., 2015; Karlsson et al., 2016). The second strand has found more place in the literature especially in the last decade. Recently, combining these two approaches can also be found in the literature. This relatively new approach combines socioeconomical variables such as institutions, values and actors and formulates a model to provide future predictions.

There is also an alternative literature more relevant to where this thesis belongs. This approach is majorly led by Turnheim et al. (2015) and by Cherp et al. (2018), in his paper, highlights the importance of "learning". He claims that transition pathways of experimentation, learning by doing and stakeholder involvement are highly influential. Moreover, Cherp stresses the importance of the role of political economy including the institutions, governments and geopolitical relations. While these two papers form a baseline for the approach of this thesis, a detailed literature is included in Chapter 2. Chapter 2 identifies a comprehensive literature on the definition of energy transition as well as how it evolved over time.

This thesis belongs to the political economy literature. Energy transition forms an important element of the energy literature as well as the political economy literature.

A very recent book published in 2020, extensively covers the existing literature on energy transition from a geopolitical perspective (Hafner & Tagliapietra, 2020). First academic paper in this arena was published by Goldthau. Goldthau et al. (2019) analyzed the global energy transition for various geopolitical scenarios. Understanding the geopolitics is crucial as this thesis also touches upon different country specific elements. Therefore, literature on country analysis forms an integral part of this thesis. The literature on energy transition of specific countries mainly focuses on developed countries and lacks critical work on developing countries.

Bressand (2012) draws attention to the international impacts of the transition in Europe and the US. Moreover there are other papers analyzing the energy transition in the European context While Lombardi and Gruenig (2016) focuses more on the energy security perspective, Eyl-Mazzega and Mathieu (2019) points out the importance of economic elements as well as technological innovation. In addition to Europe, transition in the big resource rich countries such as the US, Russia and MENA is also critical in the energy transition literature (Pascual 2015 for the US; Makarov et al. 2017; Luomi 2015 and 2018 for the Gulf; Griffiths 2017 for MENA). Among many other transition experiences across the world, a large literature on energy transition covers Germany's energy transition towards low carbon, Energiewende, which is extensively covered in the next subchapter.

1.3.2. Energiewende

Energiewende has attracted a lot of attention in the literature as it plays a pioneering role in global energy transition. However, almost entire policy-oriented literature on Energiewende is only for German speakers. Some exceptions (Gawel et al., 2019; Moss & Gailing, 2016) exist providing useful analysis in English. There are several frontrunner books entirely covering the German energy transition (Fischer et al., 2016; Gawel et al., 2019; Gründinger, 2017; Hager & Stefes, 2016; Hake et al., 2015;

Krick, 2018; Morris & Jungjohann, 2016; Schlomann et al., 2014; Unnerstall, 2017) Each of these books highlights a different perspective on Energiewende.

Hake et al. (2015) analyze the drivers of Energiewende from a historical perspective. Moreover, their paper emphasizes the national as well as international political elements in the emergence of Energiewende. Unnerstall (2017) examines the Energiewende from various aspects to lay down the strengths and weaknesses of this unique transition model. It specifically takes an economic approach and assesses the cost factor of this transition model. Moreover, it formulates valuable lessons to be learned from an international perspective mainly emphasizing how to reduce the cost of an energy transition. Gründinger (2017) delves into the role of interest groups in shaping the energy policies of Germany. The book investigates the patterns of Germany's public policy and analyzes the success of some interest groups. The paper by Fischer et al. (2016) mentions 5 controversial elements of the Energiewende including energy security, electricity prices and employment. In their paper, the implications of the specified 5 issues is analyzed. Another important book is by Moss and Gailing (2016). Their book examines the institutional arrangements as well as power relations. Morris et al. (2016) in their book "Energy Democracy" turn the focus to transition towards low carbon and analyzes the renewable transition of Energiewende in detail.

While all these books and papers are entirely covering Energiewende, a branch of literature focuses on cross country analysis which is related to the multidimensional analysis of this thesis. The European dimension of the Energiewende has been studied since the formation of the EU (Gawel et al., 2019; Welsch et al., 2017). Gawel et al (2019) gathers papers related to both impacts of Energiewende on the EU as well as the EU's impact on Energiewende. The book discusses whether Germany is a frontrunner in the EU with respect to energy system transition. Moreover, it also emphasizes the importance of convergence in national energy policies for the overall success of Europe. There also exist more specific works focusing on individual countries. A commentary by Rhys (2013), compares the German experience with the UK within the context of EU. Geels et al. (2016) also compares the low carbon electricity transition of Germany and UK between the years 1990 and 2014. Besides the UK, there are studies analyzing the Netherlands, Denmark and Germany (Oteman et al., 2014) and the US, China and Germany (Zhu & Wang, 2020) as case studies.

Among the abovementioned comprehensive literature on Germany's energy transition and its potential applicability for other countries, 2 major books stand out related to this research. The book "Exporting the Energiewende" by Steinbacher (2019) conducts interviews with different stakeholders, decisionmakers as well as government officials on how Germany can export its policies on transition towards low carbon. The book primarily considers three case studies: Morocco, South Africa and California. The book concludes that the leadership of Germany in developing policies on renewable presents great benefits for other countries especially the three case studies included in the book. Another crucial book providing cross country analysis which is highly beneficial for this thesis is "Germany's Energy Transition: A Comparative Perspective" (Hager & Stefes, 2016) . This book is very comprehensive in a way that it starts with a historical overview of the Energiewende. Following the debates on Energiewende, it is analyzed in the European context, later followed by American, Chinese and Japanese experiences. The book is ended by potential lessons to be learned from the German experience. The book concludes that while going through an energy transition the challenges are not only limited to technological and financial but also political. Therefore, other countries undergoing a transition are advised to learn from the political confrontations that Germany went through. One last key message that this book presents is that finding and implementing the right institutions are critical which is the major lesson that must be drawn from the German case. In light of the discussions provided in these two books as well as the previous literature, this thesis considers the potential lessons that Turkey can learn from the Energiewende which can later be implemented in other developing countries.

1.3.3. Turkish Energy Transition

Energy transition in Turkey is an ongoing process and it can learn from other country experiences and accelerate its progress through better measures. In this regard, as a developing country, Turkey's energy transition is highly crucial for the developing countries as it would form an example for the development future transitions. Despite its importance transition in Turkey is missing in the literature. Although there are many studies on various countries, the research in Turkish energy transition remains limited.

As far as to my knowledge, there is only one comprehensive report written on Turkish energy transition published by the World Bank (2015). The report analyzes Turkish energy transition since the beginning of 2001 up until 2015. While the market liberalization process is extensively discussed in the report, the transition is covered source by source. The developments in the natural gas, electricity, renewables, coal and nuclear sectors are separately discussed. The report also presents the challenges that Turkish energy transition faces and potential solutions are provided.

A series of recent studies were conducted by SHURA energy transition center (Shura, 2018a, 2018b, 2019a). The report "Lessons from global experiences for accelerating energy transition in Turkey through solar and wind power" (2018), studies different scenarios for solar and wind development. Accordingly, doubling the wind and solar installed capacity by 2026 does not require any additional investment, yet, tripling requires additional integration strategies. This paper is one of its kind as it is the first to suggest a roadmap for renewable development required for a successful energy transition. Another report "Financing the Energy Transition in Turkey" (2019), points out the importance of financing for the development of new projects to fulfil the goals of energy transition. After discussing the previous methods used by Turkey until 2018, the report suggests the need for new financing mechanisms supported by diversified sources. Moreover, according to the report, new technologies as well as innovative financing models must be integrated.

In addition to the reports mentioned above, there exists very limited amount of academic work in the literature on energy transition in Turkey (Karbuz, 2014; Saygin et al., 2018). Both of these studies draw importance of the need for an energy transition to reduce the import dependency. Karbuz (2014) suggests that energy policies made today would shape the economic performance of Turkey. He formulates two scenarios, proactive and conservative, and calculates the cost of energy transition for Turkey. Saygın et al. (2018), focuses on the transition issue from several aspects ranging from energy security to environmental effects. The work also highlights useful lessons that Turkey can learn from the US and Germany.

All in all, the previous studies have shown the importance of energy transition spanning a variety of aspects. In this regard, seminal contributions have been made. Especially, the German experience is well documented from numerous perspectives. A closer look to the literature on Turkish energy transition, however, reveals a number of shortcomings. While only a very limited amount of reports was published, Turkish experience lacks a thorough analysis. Additional studies to understand the key tenets of the Turkish energy transition is necessary. Moreover, to my knowledge there is no academic work with a multidimensional analysis on Germany's and Turkey's energy transitions. In that sense, this thesis aims to fill a critical gap.

1.4. Argument

This thesis argues that there is no unique model applicable to all countries through the lens of Energiewende. In this regard, each country shapes their energy transition taking into account their country specific circumstances. To support this argument, the thesis analyzes Turkish energy transition experience. While Germany and Turkey are both committed to low carbon energy transition over the long-term they have different motivators. Overall, infrastructure, policy instruments and market reforms played major roles in the energy transitions of both Turkey and Germany. While Germany decided to phase-out nuclear and coal according to its ambitious Energiewende targets, Turkey has focused on reducing import dependency by increasing domestic production. However, there are numerous challenges each country faces. For Turkey, along with the increasing economic development, population growth is driving energy demand upwards leaving fossil fuels critical to meet energy demand requirements. Energiewende experience also comes with its own shades of grey when it comes to the implementation of the ambitious plans.

Although Germany and Turkey share similar and different characteristics in many aspects, lesson drawing and cooperation at international level is essential to reach energy transition both locally and globally. As a result of the multidimensional analysis, this thesis derives important conclusions on the lessons that Turkey can learn from the German experience which can further be extended for other countries undergoing a transition. In sum, Energiewende should not be considered as a unique model but rather an experience that must be continuously developed through international exchange of information. International partnerships not only provide an "exporting" opportunity for Energiewende but also provides opportunity for "importing" international practices.

1.5. Methodology

There are numerous methodologies used throughout the thesis with each chapter including some elements from each methodology.

The thesis used **Descriptive Analysis** for providing the background information on energy transition experiences. Within the scope of the analysis, academic articles, journals, books, national and international country reports and analysis were utilized. The analysis gathers information from various resources to provide different perspectives and give a whole picture with opposing views. Energy transition towards low carbon is an ongoing process for all countries. Since many discussions covered in the thesis are related to current issues, newspaper articles and reliable online sources were also utilized to provide the most accurate and up to date information.

Additionally, **Case Study** method is used to present detailed historical background information on the evolution of energy transition definitions across time and countries. The case studies reveal how energy transition experiences differ depending on national and international circumstances. Four case studies are analyzed in the thesis to reinforce the importance of how interlinked the global experiences are and can provide valuable lessons for each other.

Quantitative Method was also utilized throughout the thesis. Through a comprehensive quantitative analysis, the energy transitions in Germany and Turkey are compared with numbers laying out starking similarities, differences and potential cooperation areas. The analysis is also provided in a more visual form through graphs, pie charts, tables and figures for reader comfort. Official policy documents and reported statistics are used as key sources in the analysis of energy transitions of Germany and Turkey. The detailed analysis is further supported by historical and actual development plans, strategy papers and government announcements. The quantitative analysis is also supplemented by the statistics covered in the reports of well-known international organizations such as IEA, IRENA, REN21 and WEC.

Finally, the thesis includes a **Multidimensional Analysis.** From the comparison of Germany and Turkey, the thesis derives insights on different experiences of developed and developing countries with different national circumstances. Through the multidimensional analysis, the thesis draws conclusions with regard to lessons that Turkey can learn from the Germany experience. In a more general sense, the analysis enables the thesis to offer conclusions for the entire global transition debates.

Among many other sources, the primary source for data is EnerData, an internationally recognized independent information and consulting firm specialized in carbon and energy markets (Enerdata, 2019).

Data regarding Turkish energy markets are mainly obtained from their primary sources. The Ministry of Energy and Natural Resources announces balance tables annually. Moreover, the Energy Markets Regulatory Authority announces data related to tariffs. In addition, TurkStat has energy consumption data. For German data, official websites were also used. Governmental institutions as well as data released by Agora Energiewende were extensively utilized. In addition, for the multidimensional analysis, data obtained from international organizations such as IRENA and IEA were used to set the groundwork for the analysis. On top of the academic literature survey, for the discussion part, a detailed search was conducted on newspapers to make sure that the public discussions were included in the thesis. Therefore, the thesis includes official data related to energy sector, academic literature on energy transitions as well as ongoing discussions.

1.6. Chapters of the Thesis

The thesis is structured in 6 chapters. **Chapter 1** starts with introductory remarks. To give a gist of information on the entire thesis, the chapter sets the objectives first which is followed by the research problem. The academic discussions which this thesis is built upon is laid down in the literature review. After discussing the objectives, research problem and literature main arguments are stated in this chapter. The methodology used throughout the thesis is also discussed, followed by introductory overview of each chapter in the scope of the thesis.

Chapter 2 sets the baseline of this thesis and provides useful background information on energy transitions. The chapter starts with various definitions on energy transition and how these definitions evolved over time towards low carbon. The analysis is further supported by numerous energy transition examples from various regions and development levels. In this regard, four countries are selected as case studies based on their different understandings of energy transitions. France was selected because of its nuclear dominance. The US was chosen as a remarkable example investing in domestic production to transform its energy system. In addition, China was selected for its energy transition motivation and renewable equipment experience. China is an important example how environmental reasons like air pollution can cause an industrialized country like China to transition its economy. Lastly, Brazil was analyzed due to its entirely different experience with a sharp increase in bioethanol production replacing oil use. This chapter highlights that energy transitions share similar motivations across countries, yet, the methodologies used can differ based on country specifics. Moreover, the chapter mentions that energy transition is inseparable from transition towards low carbon and this transition towards low carbon economy is inevitable regardless of country circumstances.

Among many energy transition examples, Germany stands out with its unique experience. Germany has a first-mover advantage with its landmark Energiewende vision. Moreover, it could also become a leading actor in global climate talks and provide a credible model for other countries. In this perspective, **Chapter 3** elaborates on the origins of Energiewende and how it came into fruitation. First, the chapter provides basic indicators and figures in order to give a brief information on the country energy profile and socioeconomic position. Secondly, the historical background and legislative framework is covered in detail from a perspective of the energy transition related issues, namely, coal, nuclear, renewables and environmental policies. The policy documents enabling the energy transition was further analyzed chronologically. Thirdly, major motivators and challenges of Energiewende are discussed. The chapter ends with a discussion on where Energiewende currently stands and how far the targets are achieved.

Energy transition towards low-carbon has been among the long term strategies for Germany and Turkey. In tandem with the global trends, Turkey has also experienced energy transition over the last 20 years. In this regard, **Chapter 4** shifts its focus from Germany to Turkey. The chapter discusses the Turkish energy transition experience from a similar perspective as the previous chapter. As discussed for Germany, historical background, legislative framework, policy documents as well as challenges and motivations are provided for Turkey.

After reviewing and analyzing German and Turkish policies on energy transition separately, **Chapter 5**, the core chapter, compares Germany's and Turkey's energy transitions considering the following three aspects: energy security, economic impacts and environmental effects. The multidimensional analysis of Chapter 5 indicates that similarities and differences of the energy transition experiences of Turkey and Germany provide opportunities for further cooperation in these countries. The chapter then explores the potential gains that Turkey can get from Energiewende and future opportunities for the energy transition of both countries.

Chapter 6 concludes the thesis. Using the detailed analysis of Chapter 5, this chapter highlights the lessons that Turkey can learn both positively and negatively from Germany and concludes with a set of recommendations for future developments in the transition process.

CHAPTER 2

GLOBAL ENERGY TRANSITION

2.1. Introduction

Energy sector has entered a new era of energy transition globally. With technological enhancements, market and policy developments, energy systems are transforming all around the world. Fast transition is necessary to fulfil long-term climate goals. However, countries often hold back from innovation in the field of energy but rather prefer to follow other country experiences. Therefore, "lesson drawing" rises as an important concept in climate and transition policies. In this regard, this chapter provides a detailed literature review on global energy transition discussions supported by the analyses of major transition trends observed across the world, namely, France, the US, China and Brazil.

The chapter is organized as follows. It begins by a discussion on the definition of energy transition with an emphasis on historical developments. To fully grasp the background of energy transition, past legislative framework is elaborated which is followed by analyses of different factors that have laid the foundation for energy transitions. Supply security, economic implications, environmental impacts and social acceptance are considered to be among these factors and the major motivators of energy transitions. Second part of the chapter provides in depth review of four different countries, namely France, the United States, China and Brazil, each representing different transition patterns. The chapter ends with a brief comparison and review of these four case studies.

2.2. Definition & History

It is hard to define energy by drawing strict borders. Energy transition is even a more complicated concept with its various aspects and the reasoning lying behind (Smil, 2010). Without focusing on the reasons, “energy transition” can be described as “change in the composition of primary energy supply” (Bridge et al., 2013). To put it another way, it is a switch from a one or multiple energy source dependent system to another (Fouquet & Pearson, 2012). Throughout the history there have been multiple forms of transitions for various reasons. In the global energy arena today, we see prominent examples of energy transition evidences (Araújo, 2014). These transitions were mainly sparked by the international community in hopes of delivering a more sustainable environment for future generations.

2.2.1. Time Factor in Energy Transition

There are two opposing approaches in the literature on the definition of energy transition. Energy transition is defined to be “a particularly significant set of changes to the patterns of energy use in a society, potentially affecting resources, carriers, converters, and services” (O’Connor, 2010). Meaning that the transition is measured by the amount of time elapses during one energy source entering the market till it gets a significant share. According to this definition duration is the critical factor in defining energy transition. In this regard, one approach claims that global energy transitions take long durations to fully evolve, while the other side claiming the opposite. The idea of energy transition lies at the heart of these two opposing views.

According to the first approach “all energy transitions one thing in common: they are prolonged affairs that takes decades to accomplish” (Smil, 2010). Global Energy Assessment, a leading international group, defines energy transition as “long-term change processes in energy systems on a decade or century scale” (Banerjee et al., 2012). Some academics also claim “there is no quick fix: energy transitions are intrinsically slow” (Myhrvold & Caldeira, 2012). Peter Lund finds out in his paper that it takes at least 70 years for new energy systems to fully penetrate into the market (Lund, 2006). Roger Fouquet in his study shows that every transition has an innovation phase longer than 100 years followed by a penetration phase around 50 years (Fouquet & Pearson, 2012).

There are historical evidences supporting this literature. For example, in the US, it took coal more than a 100 years to reach 5% in the total energy consumption (Smil, 2012). Similarly for nuclear and natural gas it took more than 20 years to reach the 5% level as shown in Figure 2.1.

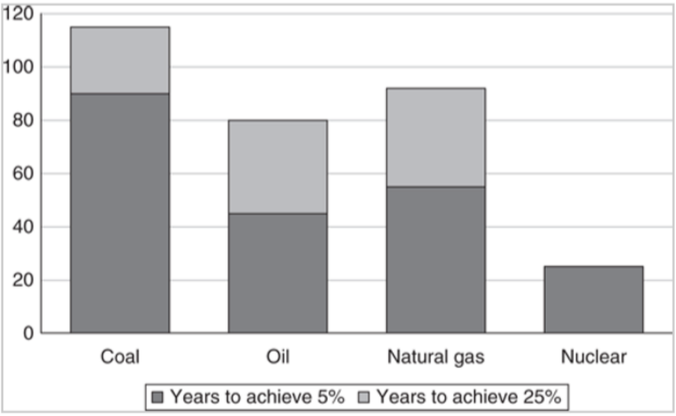

Figure 2.1 Major transitional shifts in global energy supply, 1750–2015

An earlier energy transition was encountered in the naval field, with the switch from coal to oil of the Royal Navy. Being a strong supporter of this change, in 1902 Fisher wrote "…a fleet with oil fuel will have an overwhelming strategic advantage over a coal fleet" (Hayes & Marder, 2006). There were numerous reasons that sparked this transition. The advantages of switching from coal to oil posed great importance to Britain, and also the US fleet as they both switched to oil around the same time (Dahl, 1999). An earlier profound example is steam engines. Steam engines were invented in 1770s but used during the beginning of 1800s for the first time and became widespread in 1920s (Smil, 2012).

The other side of the literature supports that transitions can occur in a short amount of time. There are numerous examples in history supportive of this side of the literature. Following the exploration of big natural gas reserves in the Netherlands, swift transition started in the country. Within 6 years, after the first gas delivery, share of natural gas in the primary energy consumption increased from 5% to 50% (Smil, 2010). In France, share of nuclear reached to 30% within 4 years (Araujo, 2012). A very rapid coal phase-out occurred in Canada due to a policy change. Following this change, in Canada, electricity generation from coal dropped from 25% in 2003 to 15% in 2008 and totally phased-out in 2014 (Office of the Premier, 2013). Moreover, in Kuwait oil didn't have a significant share in the energy supply in 1946. In just a one year the share increased to 25%, and within 4 years the share reached to 90% (Arent et al., n.d.). In Brazil, ethanol transformation in vehicle use reached to 90% in just 6 years. Table 2.1 shows several transition examples with the relevant accomplishment durations.

Table 2.1 *Overview of rapid energy transitions*

Country	*Technology/fuel*	*Period of transition*	*Number of years (from 1 to 25 per cent market share)*	*Approximate size (population affected in millions of people)*
Sweden	Energy-efficient ballasts	1991–2000	7	2.3
China	Improved cookstoves	1983–1998	8	592
Indonesia	Liquefied petroleum gas (LPG) stoves	2007–2010	3	216
Brazil	Flex-fuel vehicles (FFVs)	2004–2009	1	2

Table 2.1 (continued)

USA	Air conditioning	1947–1970	16	52.8
Kuwait	Crude oil	1946–1955	2	0.28
Netherlands	Natural gas	1959–1971	10	11.5
France	Nuclear electricity	1974–1982	11	72.8
Denmark	Combined heat and power (CHP)	1976–1981	3	5.1
Canada (Ontario)*	Coal	2003–2014	11	13

2.2.2. Innovation Factor in Energy Transition

To grasp the idea behind energy transitions further, one must also understand and identify the prominent ideas in the energy field. These ideas are listed as urgency, tradeoffs and innovation (Araújo, 2014). Ideas requiring "urgency" are usually shaped by pressures regarding sustainability and accessibility and security. "Tradeoffs" refer to switching to alternative fuels or forms of energy sources. And lastly, "innovation" which can be summarized as game-changers or breakthroughs in technology that has changed the way energy is utilized (Araújo, 2014). Technological innovations combined with innovations in the policy making together enhance the energy transition. Our previous discussion was over the duration of transitions. However, with today's knowledge and technology, future energy transitions could be expedited. According to Pearson and Fouquet, comparing past energy transitions with future's low carbon transition may not be a good analogy (Fouquet & Pearson, 2012). Thus, to analyze today's world, it is better to define energy transitions over innovations and focus on their role in shaping energy systems.

2.2.3. Energy Transition Today

Today, definition of energy transition is shifting from "transition" to "transformation". According to a joint report by International Renewable Energy Agency (IRENA), IEA and REN21, renewables are leading the global energy transition (IRENA et al., 2015). However, the ongoing transition cannot simply be described by shifting from fossil fuels to renewables, but rather a transformation with much broader implications.

Increase in renewables, mainly solar and wind, explains a big portion of today's energy transformation. This shift towards renewables has spillover effects on oil, gas and coal sectors. Figure 2.2 shows that, with continuing exponential growth in renewables, primary energy demand for renewables would pass fossil fuels by 2050s.

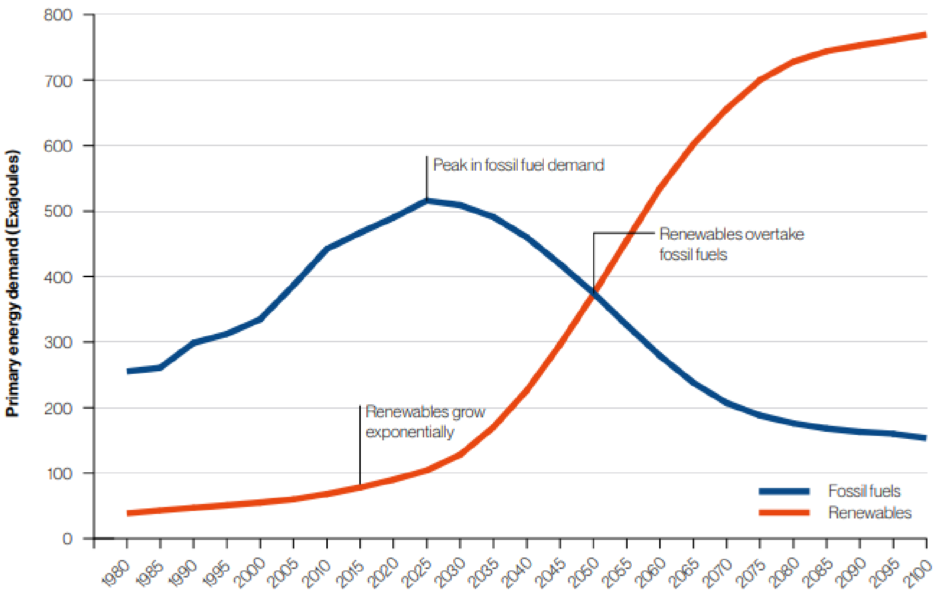

Figure 2.2 The Energy Transition Framework[1]

Just in 2017, additional installed capacity for renewables passed coal, oil and nuclear combined (International Renewable Energy Agency, 2018a). This shift is mainly triggered by declining costs and technological innovation. The cost of solar and wind have decreased by 73% and 22%, respectively, since 2010 (International Renewable Energy Agency, 2018b). During the same period, cost of lithium-ion batteries have declined by 80% (Bloomberg New Energy Finance, 2018). It is observed that increase in renewables mainly occurred in the power sector. Since 2016, power sector has attracted more investment than upstream oil and gas, indicating the growth in electrification (International Energy Agency, 2018a). However, with ongoing technological developments, renewable deployment is accelerating in transport, industry and building sectors as well. Therefore, for future energy transition discussions, digitalization, electrification, storage technologies led by innovation would play critical roles.

Renewables and technology led transformation will have significant implications. Firstly, it will change the trade patterns (International Renewable Energy Agency, 2018a). Moreover, it will reshape the relations between countries. Countries that heavily relay on fossil fuel exports will face risks of losing their economic power. The energy supply now will be dispersed over many countries rather than being controlled by a small amount of countries.

[1] This data is taken from the Shell Sky Scenario (2018), which has the merit of forecasting to 2100 and therefore projects the nature of the energy transformation over the course of the century. Other energy transition scenarios usually have shorter time horizons. The Sustainable Development Scenario (SDS) of the International Energy Agency (IEA), for example, only looks forward to 2040. IRENA's REmap scenario goes to 2050. Shell's forecast share of renewables and fossil fuels is similar to that of the IEA SDS scenario for 2040 as well as the DNV GL and Equinor Renewal scenarios for 2050. The IPCC 1.5 degree median scenario and IRENA REmap scenario anticipate a substantially larger share of renewables by 2050 with an earlier peak in fossil fuel demand.

Past studies clearly indicate that global energy markets have undergone a series of major events leading to transitions. Historical analysis of various energy transitions indicate that transitions have been characterized by an increase in energy consumption and demand (Grübler, 2004). These developments were laid forward mainly starting in 1850s with the transition from wood to coal. In 1910s, coal started to be replaced by oil followed by a transition towards natural gas in 1970s. After the global energy crises in 1970s and 1980s and the climate change concerns made energy transition the biggest energy challenge of history. In today's energy world, there is a search for a sustainable energy system that ensures energy security by taking into account it's all dimensions. In order to properly assess the development of global energy transition we are encountering today, we also need to understand the past legislative framework that put climate talks at the heart of energy transition discussions.

2.3. Past Legislation on Climate Change

In today's world, when we talk about energy transition most of us think about issues related to climate change mitigation right ahead. Energy transition refers almost always to transition to low-carbon energy. This transition towards low carbon energy sources was triggered mainly by raising environmental awareness which led to today's combatting climate change efforts, namely, emission reduction targets. In this regard, it is important to lay down the legal framework on climate change discussions.

One of the very first legislation that triggered the transition towards cleaner energy sources was announced in Stockholm in 1972 under the "United Nations Conference on the Human Environment." The declaration issued under this conference noted "the need for a common outlook and for common principles to inspire and guide the peoples of the world in the preservation and enhancement of the human environment" (United Nations, 1972). This declaration is accepted as the first document to define sustainable development. International environmental law got influenced from the outcomes of this conference; where 109 specific recommendations related to environmental issues were drafted by the "Framework for Environmental Action".

Furthermore, the World Commission on Environment and Development (WCED) published a report titled "Our Common Future, From One Earth to One World" in 1987, which came to be known as the Brundtland Report, named after the Commission's chairwomen, Gro Harlem Brundtland, the Prime Minister of Norway. In this report, it is noted that "there has been a growing realization in national governments and multilateral institutions that it is impossible to separate economic development issues from environment issues." (United Nations, 1987). The Brundtland Report stated major critical environmental problems that were the result of poverty in the South[2], while increased consumption and production strategies in the North[3] followed non-sustainable patterns. The report has a major section under sustainable development where multiple problems and ways to deal with this are stated. "Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without comprising the ability of future generations to meet their own needs." (United Nations, 1987). This was the first time the principle of "sustainable development" was laid forward. The phenomenal definition of sustainable development: "development which meets the needs of the present without compromising the ability of future generations to meet their own needs." (United Nations, 1987) has been widely used since the report was published.

In 1989, the Brundtland Report was debated in the UN General Assembly. Following the discussions over Brundtland Report, the Rio Summit was held in 1992, which came to be known as "The Earth Summit." During this conference the main goal was

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[2] Refers to the developing nations living mostly in the Southern Hemisphere.
[3] Refers to rich industrial countries in the North. North-South divide in Rio refers to a the conflict between a coalition of rich industrial nations with the developing countries led by 77 member countries.

to help governments rethink their economic development and find ways to halt the depletion of natural resources. The issues addressed during the summit included establishing alternative sources of energy to replace use of fossil fuels.

The Kyoto Protocol was introduced as an international treaty which evolved from the results of the Rio Summit held in 1992, by the UN Framework Convention on Climate Change (UNFCCC) in order to reduce greenhouse gas emissions. This treaty was adopted in December 1997 in Kyoto, Japan and entered into force in February 2005 with 193 parties. In order to promote sustainable development, the implementation of elaborate policies and measures were directed which ranged from enhancement of energy efficiency to progressive reduction of incentives or tax exemptions in all greenhouse gas emitting sectors to the promotion of sustainable forms or agriculture.

In 2015, a landmark agreement to combat climate change was achieved with a consensus of representatives from 196 governments at 21st Conference of Parties (COP21). The most recent and influential global climate agreement that led to major changes in the global energy transition is the Paris Agreement. Through this agreement each country plans, determines and reports its contributions regarding mitigation efforts of global warming. The aim of the agreement which is described as "holding the increase in the global average temperatures to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change." (UNFCCC, 2015). While the Paris Agreement provides orientation to tackle climate change, long-term plans by the governments are needed to achieve the limit the global temperature rise to 1.5°C. According to a recent report by International Panel on Climate Change (IPCC), the Special Report on Global Warming of 1.5°C, which was published during COP24 in 2018, two-thirds of greenhouse gas (GHG) emissions were energy-related. Hence, an immediate and large-scale energy transition is considered to be inevitable in order to meet Paris goals (IPCC, 2018).

As discussed in the previous subsections, energy transition has a range of complicated definitions. The only thing remains in common is that climate change mitigation efforts and polices in this respect, have major impacts for all transitions. Energy transitions cannot be summarized just by a single motivation. Instead, there are both exogenous and endogenous factors affecting the transitions of each country. For example, while global climate talks have impacts on the transitions of all countries, a potential natural gas discovery in a single country has regional impacts. A policy implementation, as in the Canada case, have direct effects on the country with spill-over affects to other countries. In this regard, each country has their own story and each story provides us a different perspective on energy transitions. Therefore, next section focuses on energy transition experiences of four unique countries.

2.4. Case Studies

In this section four countries namely, France, the United States, China and Brazil were selected as case studies based on several criteria. First of all, each of these countries have different energy mixes. While nuclear is very crucial in France's energy mix, shale gas is becoming more important in the US. In China, coal represents a significant share in the energy mix with renewables increasing its share. Brazil has a totally different story with increasingly high biomass power generation.

Secondly, all of these countries have high population and energy consumption rates representing a significant portion of the total global population and energy consumption. According to 2018 BP Energy Outlook – Country and Regional Insights for Brazil, a 60% growth in Brazil's energy consumption is expected until 2040 (BP, 2018). In the same report published for China, China is expected to reach 24% share of total global energy consumption in 2040 (BP, 2018).

Thirdly, France, as a member of the European Union, represents the potential impacts of EU-wide policies on energy transition of EU countries. Lastly, as discussed in the previous section, innovation plays a crucial role in energy transition. In this regard, transition of the US and China are elaborated further since they are the major players in this area.

Every country has their unique story mainly because they have different energy sources, different priorities in policymaking and different capabilities. In the following subsections, each country selected as a case study will be evaluated based on four factors that stimulate their energy transition: supply security, economic aspects, environmental issues and social acceptance. Before going into the case studies, these factors will be briefly discussed.

Energy supply security is defined as “the uninterrupted availability of energy sources at an affordable price” (IEA, 2016b). Supply security refers to the system’s ability to react to sudden changes in demand and supply. It has both social and economic impacts hence remains to be a major concern for policymakers. Throughout the chapter, supply security will be analyzed based on local, regional or global supply shifts leading to depletion or surplus of certain fuels (IEA, 2014). Each country tries to address supply security issues mainly by increasing domestic sources or energy efficiency. Supply security can also be ensured by technological advancements which enables the transfer of new technologies to switch between energy sources.

On the economical aspect, the changes in the cost structure of energy sources play a vital role in energy transition. Technological advancements and efficiency listed under supply security also play a critical role under economic issues (IEA, 2014). Through technological innovations, countries will have the ability to export certain technologies and also create more jobs, while transitioning to a more efficient energy market enables the market to be more economical (Liu & Goldstein, 2013).

Environmental impacts are also key elements in fueling global energy transitions. For example, severe air and water pollution, as in the case for China, makes alternative energy sources more attractive (Araújo, 2014). Moreover, as discussed in the past legislation on climate change, global climate agreements enforce strict restrictions on emissions which affect the major transition patterns.

Social acceptance is the last point that will be discussed. Public acceptance of policies is a critical factor that affects energy transition. For any government, above all, the utmost important issue is to have positive public opinion. Many energy transitions which will be discussed are directly shaped by public reactions.

All factors above can indeed be considered as factors that affect social acceptance. Shifting from fossil fuels to renewables for supply security creates more jobs which in turn has social impacts. Moreover, technological advancement brings economic benefits increasing social welfare and thus acceptance. Environmental aspects have direct effects on social welfare.

Each country puts different weights on the factors discussed above depending on their country-specific circumstances. That is why, it is crucial to examine different experiences. In the following subchapters, all these interconnected factors will be analyzed for the countries selected as case studies.

2.4.1. France

It is vital to lay down major historical developments to better comprehend the energy transition of France. In France, the first distribution network was built in 1884. However, the electricity system didn't evolve with a central planning resulting in over thousands of companies involved in all aspects of the energy system: distribution, generation, and transportation (EDF, 2017). Due to the resulting highly inefficient power system which created nearly 2,000 energy producers, transporters and distributors, in April 1946 the French government decided to establish a single nationalized electricity utility called Électricité de France (EDF, 2017).

By 1960s, EDF was mainly engaged in the establishment of hydro resources, mainly in the areas around the French Alps (Funding Universe, 2005). With rapid increases in demand and depletion in hydropower sources, EDF started to seek new alternative energy sources to meet the increasing demand (EDF, 2017).

During that time oil was seen as the best alternative for security of supply. By 1973, oil accounted for 70% of the country's total primary energy demand (Barth, 2008). Having limited amount of domestic oil resources, yet relying highly on oil was the main challenge that shaped the future of French power markets. With an oil dependent energy system where nearly, all of its oil supply was imported; with Middle Eastern countries contributing to over 71.6% of the total supply (Taylor et al., 1998). Major problems arose during the Arab-Israeli War. Oil dominated electricity generation mix of France was affected by the crisis led by oil embargo. Since then, supply security has been a critical issue for the French policymakers.

Nuclear

France was not subject to the oil embargo directly, however the indirect effects were still detrimental. To mitigate these effects, France looked other alternatives to replace oil as the primary source of electricity. As the oil reserves in the country were very scarce, the only liable option to decrease its dependency on foreign oil was introducing nuclear energy. This idea was first introduced by France's Prime Minister Pierre Messmer with a plan named the "Messmer Plan" and shaped the fundamentals of the French energy markets of today. In an interview made on March 6, 1974, Pierre Messmer stated:

> "(…) The energy question has been posed for a while. It has been posed in fact since last October, since that war which broke out in the Middle East once again (…) We hardly have any oil on our territory, we have much less coal than England or Germany, and we have much less natural gas than Holland (…)
>
> As far as oil is concerned, we don't have much hope, except of finding oil in the seas that surround us and perhaps abroad. And we will try, but this is undoubtedly not for tomorrow. But our great hope is in electrical energy of nuclear origin. We have made the decision to launch during 1974 and 1975

the construction of 13 nuclear power plants of a thousand megawatts each, which will cost about a billion francs each" (Sloan, 1979).

This plan set the foundations of today's energy mix of France. According to the World Nuclear Association (WNA) Information Library, in 2016 total gross electricity production in France was 556 TWh, while nuclear energy provided 75% of the total electricity demand from 58 nuclear reactors. The data alone shows how interwoven nuclear energy is into the French energy market (WNA, 2018).

The supply security issue that laid the pathway for nuclear development was turned into an economic advantage as well. This advantage can be divided into two parts: one is the technology export, the other regarding electricity trading activities. France has fully submerged itself in the European electricity grid. It has close to 15.000 MW of export capacity: 3.000 MW to Spain, Italy and Switzerland, 2.000 MW to Great Britain, and 4.000 MW to Central Western Europe (RTE, 2016). Although the interconnections amount to a huge sum, the EU is dedicated to increase the integration even more. The EU has provided 578 million euros of funding to link Spain and France, almost doubling its current power exchange capacity to 5.000 MW. As seen in Table 2.2, the net electricity exports after 2013 from France to her neighboring countries has been over 75.000 GWh. According to the IEA World Energy Balances 2017 Report, 74.000 GWh was exported in 2016, with Italy representing 22% of the total exported volume (IEA, 2017b).

Table 2.2 *Electricity Export of France*

Year	*Export (GWh)*
2006	71.863
2007	67.529
2008	58.736
2009	44.913

Table 2.2 (continued)

2010	50.206
2011	65.914
2012	56.933
2013	60.148
2014	75.063
2015	74.024

In 2015, France was a net exporter to all its border interconnected zones: Great Britain, Central Western Europe, Switzerland, Italy and Spain reaching to a total export volume of 91.3 TWh (RTE, 2016).

Figure 2.3 shows that electricity prices in France remain lower than its neighboring countries (RTE, 2016). Due to the low cost of power generation, France is the world's largest next exporter of electricity with profits reaching 3 million euros in 2017 (WNA, 2018).

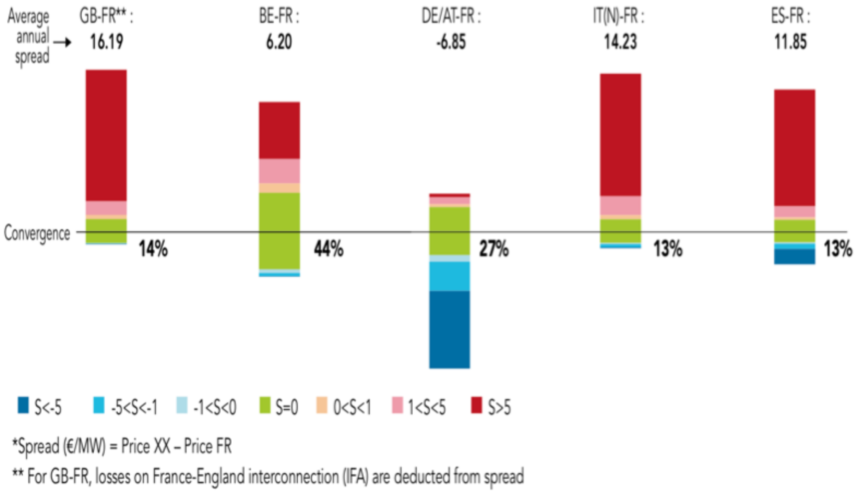


Figure 2.3 Distribution of Spreads

Another aspect that must be examined to understand the economic impact of nuclear is its technology exports. With the global low carbon transition that is already in effect, technological advancements in the nuclear reactor field has set France to be a global player in nuclear power operations. According to the WNA report, France is a net exporter of its nuclear reactor technology to many countries in various regions listed in Table 2.3. With the development of low-carbon energy markets, the possibilities of developing more reactors to phase out high carbon emitting power plants such as coal are increasing (Edenhofer et al., 2011).

Table 2.3 *Export sales and prospects for French nuclear power plants*

Country	*Plant*	*Type*	*Est. cost*	*Status, financing*
Iran	Darkhovin 1&2	M310	$2 billion	Cancelled in 1979
South Africa	Koeberg 1&2	M310		Commissioned 1984-85
South Korea	Hanul/ Ulchin 1&2	M310		Commercial operation 1988-89
China	Daya Bay	M310		Commercial operation 1994
China	Ling Ao	M310		Commercial operation 2002
Finland	Olkiluoto 3	EPR		Construction delayed/over budget
China	Taishan 1&2	EPR		Construction delayed/over budget
Turkey	Sinop 1-4	Atmea1	$22 billion	Planned
UK	Hinkley Point C 1&2	EPR	£19.6 billion	Planned, construction start 2019
UK	Sizewell C 1&2	EPR		Planned

Even though nuclear reactors still spark environmental concerns, the emissions produced from generating electricity as opposed to other fossil fuels is lower. In 2011, nuclear power plants supplied 2518 TWh of electricity. Table 2.4 presents the amount of emissions that would be emitted from other alternative fossil fuels equivalent to 2518 TWh of electricity. According to the Table, greenhouse gas emissions from nuclear power plants are 97% less than emissions from lignite.

Table 2.4 *Emissions from different fuel sources for power generation*

Fuel Source	Average lifecycle GHG emissions (tonnes/GWh)	Emissions produced from generating 2518 TWh of electricity	Additional emissions avoided through use of nuclear electricity in place of fossil fuel
Lignite	1054	2654 mt CO2	2581 mt CO2
Coal	888	2236 mt CO2	2163 mt CO2
Oil	733	1846 mt CO2	1773 mt CO2
Natural Gas	499	1256 mt CO2	1183 mt CO2
Nuclear	29	73 mt CO2	-

Renewables

France has long been regarded as a country with a nuclear energy dominating energy mix. Which is partially true. France is still generating over 70% of its electricity from nuclear (WNA, 2018). However, disputes over nuclear has been ongoing since late 1980s mainly over controversy on nuclear waste. Following this discussions over nuclear, also heated up by global trends, renewables has started to rise as an alternative energy source. France started to introduce renewable energy to its energy mix through feed-in system in 2000s. Although feed-in tariff program started to be implemented in 2000s, the actual development occurred in 2007. Until 2007, renewables in France consisted primarily of hydropower and biomass. In 2007, France implemented a new target of increasing renewable share of energy consumption to 20% until 2020 in line with the EU Directives (WNA, 2018). The target was further increased to 32% until 2030 as a part of the climate targets of the EU. During 2012-2015 a comprehensive national energy transition debate was sparked. According to the plan, power generation from nuclear would be reduced to 50% from 75% by 2025. Moreover, renewables share would be increased to 40% of electricity consumption and 32% of total energy use by 2030. The debate continued fiercely resulting in the adoption of "Energy Transition Law for Green Growth" in 2015. The law legitimized the existing targets and also included additional targets which is to reduce energy use by at least 50% until 2050 and reduce the share of fossil fuels in the energy mix by 30% compared to 2012 levels.

From a social perspective, French people are known for their support for nuclear energy. However, a recent study by Harris Interactive Research Institute, shows that French people are ready for a new model based on renewables. According to this survey, 91% of the respondents consider energy transition either a "priority issue" or "major issue". When they are asked what they understand from energy transition, according to 83% it refers to prioritizing renewable energy investments.

In France, it is observed that supply security and economic concerns triggered energy transition from oil towards nuclear. However, global climate talks have raised the awareness of the society forcing the country towards renewables.

2.4.2. The United States

To fully grasp the global energy transition in the United States we need begin by analyzing the historical developments in the coal and oil markets, separately. Based on these discussions, transition towards relatively cleaner sources, namely natural gas and renewables, will be discussed.

Coal

Native Americans have long been using coal to bake their potteries before the arrival of European settlers. During that time, Europeans were using wood instead of coal. Wood to coal transformation began with their first "encounter" with coal in mid-1060s. Since then, people have used coal to manufacture goods, power engines and make iron and steel. By the end of 1800s, coal was used primarily to generate electricity. Table 2.5 presents coal consumption between 1780-2010, which has increased 485 times in terms of per capita consumption.

Table 2.5 *Coal Consumption in the United States*

Year	*Thousand Tons Bituminous*	*Thousand Tons Anthracite*	*Tons per Capita*	*Energy Input (PJ)*
1780	19	0	0,007	1
1790	46	0	0,012	1
1800	108	0	0,020	3
1810	176	2	0,025	5
1820	330	4	0,035	9
1830	646	235	0,068	24
1840	1.345	1.129	0,145	67
1850	4.029	4.327	0,360	227
1860	9.057	10.984	0,637	545

Table 2.5 (continued)

1870	20.471	19.958	1,049	1.101
1880	50.757	28.650	1,583	2.171
1890	111.302	46.469	2,506	4.322
1900	207.275	55.515	3,458	7.217
1910	406.633	81.110	5,303	13.413
1920	508.595	85.786	5,583	16.357
1930	454.990	67.628	4,246	14.389
1940	430.910	49.000	3,632	13.224
1950	454.202	39.900	3,245	13.026
1960	380.835	17.247	2,203	10.379
1970	514.922	8.309	2,552	12.939
1980	697.600	5.129	3,093	16.271
1990	901.416	3.082	3,623	20.227
2000	1.079.478	4.617	3,842	23.821
2010	1.046.422	1.874	3,395	21.962

Oil

It is widely accepted that energy transition in the United States began after the OPEC oil crisis. According to the U. Energy Information Administration (EIA), before the OPEC oil crisis (around 1960-1965) the United States was importing over 60% of its oil from OPEC member countries. This imported amount equated to roughly about a quarter of its entire oil supply being shipped from OPEC as seen in the Table 2.6.

Table 2.6 *Historic Petroleum Trade Overview of the United States*

Years	*Imports from OPEC*	*Imports*	*Products Supplies*	*OPEC Imports as Share of Products Supplied*	*OPEC Imports as Share of Total Imported*
1950 Average	NA	850	6.458	NA	
1955 Average	NA	1.248	8.455	NA	
1960 Average	1.233	1.815	9.797	12,6%	67,9%
1965 Average	1.439	2.468	11.512	12,5%	58,3%
1970 Average	1.294	3.419	14.697	8,8%	37,8%
1975 Average	3.601	6.056	16.322	22,1%	59,5%
1980 Average	4.300	6.909	17.056	25,2%	62,2%

When we look at the consumption patterns of oil from 1860 to 2010, it is evident from Figure 2.4 below that consumption has grown exponentially until 2000s where it peaked.

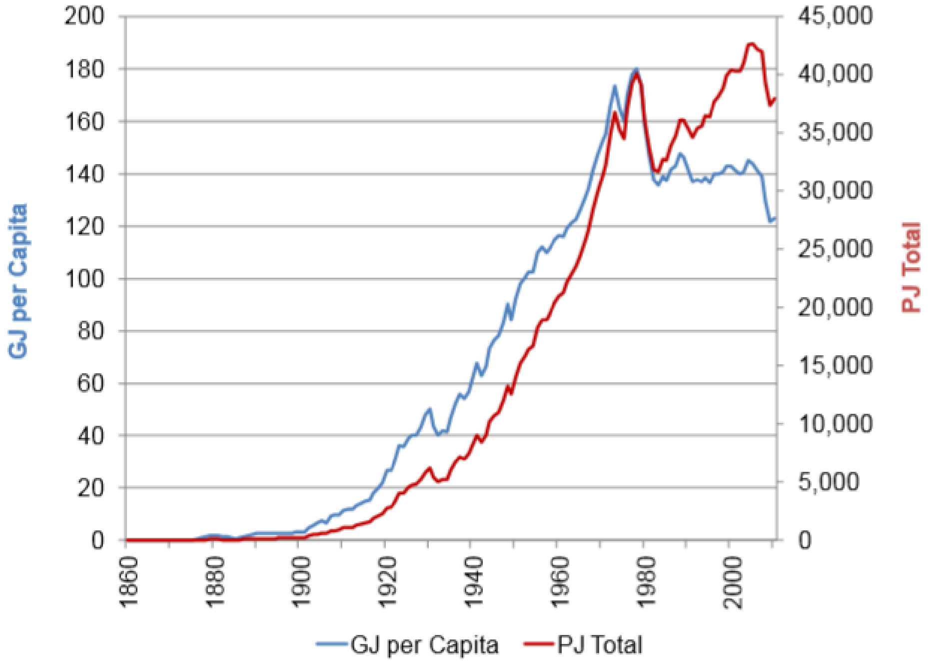


Figure 2.4 U.S. Petroleum Consumption, 1820-2010

From the production side, domestic production of oil dropped starting from 1970s. After 40 years of decline, domestic production increased in 2010s mainly due to developments in hydraulic fracturing technology.

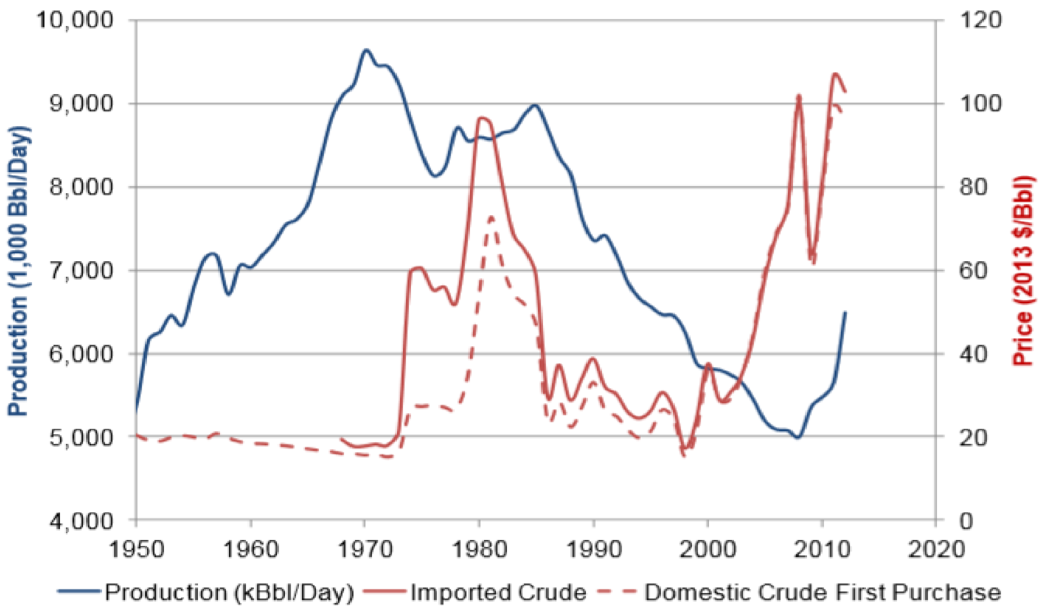


Figure 2.5 U.S. Oil Production and Price, 1950 - 2012

During post oil embargo period, the price of oil rose from nearly 3 dollars per barrel to around 12 dollars, quadrupling in only a year as presented in Table 2.7, leaving a massive impacts on the economy and security of supply. However, the adverse effects brought by this crisis set the road for long-term energy policies that would shape today's energy world.

Table 2.7 *Historic Crude Oil Prices*

Date	*Price in Contemporary Dollars*
31.12.1969	1,8
31.12.1970	1,8
31.12.1971	2,2
31.12.1972	2,5
31.12.1973	3,3
31.12.1974	11,6
31.12.1975	11,5
31.12.1976	12,8
31.12.1977	13,9
31.12.1978	14,0
31.12.1979	31,6
31.12.1980	36,8

Natural Gas

One month after the oil embargo was introduced, on November 7th, 1973 President Nixon stated:

> "Let us unite in committing the resources of this Nation to a major new endeavor, an endeavor that in this Bicentennial Era we can appropriately call "Project Independence." (…) Let us pledge that by 1980, under Project Independence, we shall be able to meet America's energy needs from America's own energy resources (…)" (Phillips, 2016)

President Nixon's plan with regards to Project Independence included the construction of many nuclear power plants by 1980 whether through federal funding, public-private partnerships or regulatory reforms which included exceptions to speed up the construction.

However, most of the plans were unsuccessful. Public support for nuclear was inadequate, leaving most of the nuclear power plants undeveloped. Following the Watergate scandal all plans were totally stagnated (Giberson & Kiesling, 2019).

Although these plans may seem to be outdated and forgotten, it laid out the milestones in the United States' energy market developments. These developments can be listed as follows:

- diversifying the energy portfolio and mix in order to absorb and future fluctuations in a certain fuel market,
- promoting energy independence by in order to be less effected by events such as the OPEC oil embargo,
- promoting environmental concerns regarding energy use,
- promoting more environmentally stable energy use (Solomon & Krishna, 2011).

Supply security concerns had pushed the United States to promote domestic production. Around 20 years before the OPEC oil embargo in 1973, the Federal

Power Commission (later to be known as Federal Energy Regulatory Commission) had implemented natural gas wellhead price regulation which caused significant gas supply shortages (Breyer & Macavoy, 1973). With many States experiencing major reductions to industrial customers the only way to overcome the shortages was by deregulating wellhead prices. In November of 1978, deregulation began with Congress passing the Natural Gas Policy Act. This legislation aimed at reducing shortages by gradually bringing wellhead gas prices up to the market levels.

For many years, extraction of gas from deep shale deposits were not commercially viable. However, with the advancements in deep vertical drilling technologies, hydraulic fracturing became economically feasible. George Mitchell, the "king of fracking", was known as the inventor of hydraulic fracturing. In 1997, one of Mitchel's shale gas wells proved that fracking could become commercially viable over the long term (Eells, 2013). Consistent R&D investments in horizontal drilling techniques led to a major increase in overall shale gas production in the US.

During the "shale gas revolution" era of the US demand didn't increase at the same rate. Therefore prices were kept at low levels causing recently developed unconventional natural gas wells to be underutilized. Later increase in demand increased market prices which led to an increase in production. The additional production was initially delivered to power sector causing coal fired power plants to be replaced by natural gas fired power plants.

A mature natural gas market was developed in the 1990s as liquid gas trading hubs were established such as the Henry Hub and the Dawn Hub. During this decade, production was increasing steadily at around 6% per year. However, the rise in consumption was faster resulting in an increase in imports, mainly from Canada (Joskow, 2016). To accommodate the shortages, large pipelines were built to bring in gas from both Canada and Alaska. In addition, Liquefied Natural Gas (LNG) terminals were expanded to increase imports from the rest of the world.

According to the EIA, US shale production has exponentially grown from 2007 to 2016. As seen in the Table 2.8 below, the U.S. natural gas demand has increased quiet steadily, around 2% on average between 2007 and 2016. On the other hand, shale gas production has dramatically increased by an average of 35%. In 2007, while shale gas production accounted only 5.5% of the domestic gas consumption, this number passed 62% within a decade.

Technological and economic advances in this field led to many major gas discoveries which further increased gas supply of the US. According to the BP Statistical Review of World Energy 2018, proven reserves in the United States went from 4.5 tcm in 1997 to 8.7 tcm in 2017.

Table 2.8 *United States Domestic Shale Gas Production and Total Consumption*

Year	*U.S. Shale Production (bcf)*	*Shale Production Increase (YoY)*	*U.S. Natural Gas Total Consumption (bcf)*	*Natural Gas Demand Increase (YoY)*	*Shale Gas Production Compared to Total Demand*
2016	17.032	12%	27.486	1%	62%
2015	15.213	13%	27.244	2%	56%
2014	13.447	18%	26.593	2%	51%
2013	11.415	10%	26.155	2%	44%
2012	10.371	30%	25.538	4%	41%
2011	7.994	50%	24.477	2%	33%
2010	5.336	72%	24.087	5%	22%
2009	3.110	47%	22.910	-2%	14%
2008	2.116	64%	23.277	1%	9%
2007	1.293	-	23.104	-	6%

New and efficient power gas power plants emit 50 to 60% less carbon dioxide compared to a new coal power plant (National Energy Technology Laboratory, 2013). That is why an increasing trend in global demand for cleaner energy translated into more US natural gas served to the market to phase out coal production (UNEP, 2017). Geographically, due to the long distances, LNG trading was considered to be the most feasible connection to supply gas to the rest of the world. As it can be seen from Table 2.9**,** in line with the increase in domestic production of shale gas, the United States LNG exports has grown exponentially.

Table 2.9 *Liquefied U.S. Natural Gas Exports*

Years	*Liquefied U.S. Natural Gas Exports (MMcf)*	*Percent Increase (YoY)*
2009	33.355	
2010	64.793	94%
2011	70.001	8%
2012	28.298	-60%
2013	2.924	-90%
2014	16.255	456%
2015	28.381	75%
2016	186.841	558%
2017	707.542	279%

From an economical point of view, the US has been able to maintain lower prices compared to other natural gas hubs presented in Figure 2.6. According to Figure 2.6, majority of the hub prices are 2 times the price of the US Henry Hub. Therefore, expanding LNG trade allowed US producers to gain access to markets with higher prices.

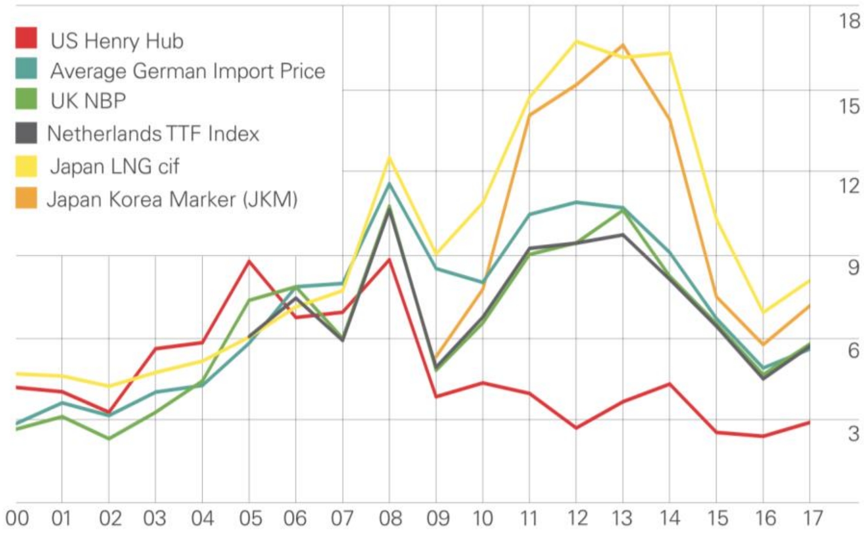


Figure 2.6 Regional Natural Gas Hub Prices ($/mmBtu)

Transition from coal to natural gas was caused by the shale gas revolution in the US. During the same period, climate change discussions gained momentum. The US has long been a leader in the climate talks and transition towards cleaner energy sources. In this regard, alongside natural gas, the US has increased the share of renewables substantially.

Renewables

The history of renewables in the US has started long before the climate change discussions In the 1980s, the US had the world's largest wind investments in California (Righter, 1996). There were major regulatory frameworks supporting the development of renewables, namely, state tax credits and especially the Public Utilities Regulatory Policy Act (PURPA). Shortly after the expiration of tax credits in 1982 the US started to fall behind the other competitors, mainly Germany and Denmark (Lewis & Wiser, 2007).

Renewable Portfolio Standards (RPS), which proliferated in 1990s, also supported the deployment of renewables in the US. RPS policies require a certain amount of a state’s electricity to come from renewable sources. Among the eligible technologies to be included in RPS are wind, geothermal, solar and biomass (Carley, 2011).

Additionally, net-metering policies enabled consumers to become prosumers. With net-metering, consumers are allowed to generate power using roof-top solar PV panels and sell the extra amount of generated power to the grid.

Transportation has been a target area in the energy transformation policies of the US. The US also has complementary regulations regarding the fuel standards. The Renewable Fuel Standard (RFS) Program requires blending of a certain percentage of biofuel into the petroleum. Additionally, there are more than 438 incentives for electric vehicles in the US. Sales tax exemptions, parking fee reductions and tax rebates are some of examples among many others. Above-mentioned regulations regarding renewables are only a couple among many others. There are other legislations supporting the transition towards cleaner energy.

When we look at the recent history of the country, the US has already become a net natural gas exporter in 2017 due to shale gas revolution and close to becoming a net oil exporter. Moreover, with its developing technology, the US is ahead of its competitors in the clean energy race. The US, being the world’s second highest greenhouse gas emitter, has long been at the forefront of clean energy transition. The Clean Power Plan, announced in 2015 during the Obama Administration, marks the first-ever carbon reduction plan of the US. However, in 2017, the Trump Administration announced to roll-back Clean Power Plan and their country’s intention to withdraw from the Paris Agreement. It is now important to follow and observe the spillover effects on the oil, natural gas and renewables markets both regionally and globally.

2.4.3. China

Energy transition in China is highly correlated with its rapid growing economy. Current energy mix that fuels the economy is dominated by coal, with a share of nearly two thirds of the total generation in 2016, accounting to 52 TWh of power generation (National Energy Administration, 2018a). Although projections indicate declining energy intensity in the region, energy consumption is expected to rise by 41% between 2016 and 2040 in China (BP, 2018).

According to the Table 2.10, which presents power generation by fuel source in 2015 and 2016, share of coal is in decline, compensated by increases in gas, nuclear, wind and solar production. The year-on-year developments in generation volumes mark the importance of these energy sources in the low-carbon energy transition.

Table 2.10 *2015 - 2016 Generation Mix of China (GWh)*

Indicator	*2015*	*2016*	*YoY*	*Share of Total Production*	
				2015	*2016*
Power Production	5.693.800	5.989.700	5%	-	-
Hydro Production	1.111.700	1.180.700	6%	20%	20%
Coal	3.853.900	3.905.800	1%	68%	65%
Gas	166.900	188.100	13%	3%	3%
Nuclear	171.400	213.200	24%	3%	4%
Wind	185.300	241.000	30%	3%	4%
Solar	38.500	66.200	72%	1%	1%

Renewables

Renewable energy sources are considered to be crucial to cope with increasing demand while maintaining low-carbon emission standards which is a major concern for China (IRENA, 2017). Rapid renewable deployment and gradual decrease in costs, provide great business opportunities. Renewables are estimated to be the fastest growing source of generation between 2015 and 2040, increasing steadily by an average of 2.8% per year; therefore, it is calculated that renewable energy sources will account for 31% of the electricity generation and match coals share in the electricity generation mix by 2040 globally (EIA, 2017).

Deployment of such a vast capacity in the global arena brings into questions on supplying the required equipment. In this regard, China has taken the lead in renewable energy adoption and production. This was initiated with the earliest PV production in China, which was small scale and intended for the small domestic market (Magazine, 2020). However, in the early 2000s, PV cells and modules surged dramatically, and Chinese exports quickly gained a dominant position in the global markets, where only less than 5% of the solar PV produced domestically was absorbed in the Chinese market (Liu & Goldstein, 2013). One of the main factors that made China a global leader in exports is largely due to the decreases in prices. Between 2008 and 2013 prices in solar panels dropped nearly 80% due to Chinese manufacturing (Fialka, 2016).

As it can be seen in Figure 2.7, exports of China's PV products accounted more than 13 billion USD since 2009 (Zhao et al., 2015). This production grew exponentially; however, in 2012 the US introduced a tariff of 30% ruling that Chinese exports were damaging the domestic PV markets (Reuters, 2012). Following the decision of the US, the EU introduced tariffs as well. However, a deal was made between the EU and China on allowing a certain amount of export capacity without any additional tariffs (Chaffin, 2013).

Figure 2.7 Export of China's PV Products

In 2014, China's total PV exports accounted for 14.41 billion USD, while its imports were 3.87 billion USD; which shows its export dominated the PV market (Cision PR Newswire, 2015). In 2017, despite global trade wars that introduced tariffs for Chinese PV creating a year-to-year downtrend, export market accounted in 9.45 billion USD in the first 11 months of 2017. However, the export amount in terms of capacity are still on the rise reaching 37.9 GW for the entire year, which marks an 80% increase compared to previous year (Liu & Goldstein, 2013).

Wind power also plays an important role in the energy market of China. As of 2000, the global market for wind turbines were dominated by European and American companies mainly due to their first-mover advantage (Lewis & Wiser, 2007). China's entrance to the market reversed the situation. However, unlike the PV market, the wind market was focused more on the domestic market (Liu & Goldstein, 2013). It is import to point out that, China's domestic market should not be disregarded. As seen in Table 2.11, cumulative installed wind capacity grew dramatically at an average rate of 79% annually between 2004 and 2017. Out of 539.123 GW of total global installed wind capacity in 2017, China currently holds over one third of the capacity by itself (GWEC, 2017).

Table 2.11 *Top 10 Countries with Cumulative Wind Capacity Development*

Rank	*As of December 2014*		*As of December 2017*	
	Country	*Cumulative Wind Capacity (MW)*	*Country*	*Cumulative Wind Capacity (MW)*
1	Germany	16.649	China	188.392
2	Spain	8.263	US	89.077
3	US	6.750	Germany	56.132
4	Denmark	3.083	India	32.848
5	India	3.000	Spain	23.170
6	Italy	1.261	UK	18.872
7	Netherlands	1.081	France	13.759
8	Japan	991	Brazil	12.763
9	UK	889	Canada	12.239
10	China	789	Italy	9.479

This rapid deployment of newly developed wind power capacity in China was initiated by foreign firms dominating the domestic market. However, as shown in Figure 2.8**,** there was a sharp increase in the development of Chinese brands, which eventually led the domestic supply surpassing the share of foreign firms and dominate the entire market with a share of almost 90% in 2009.

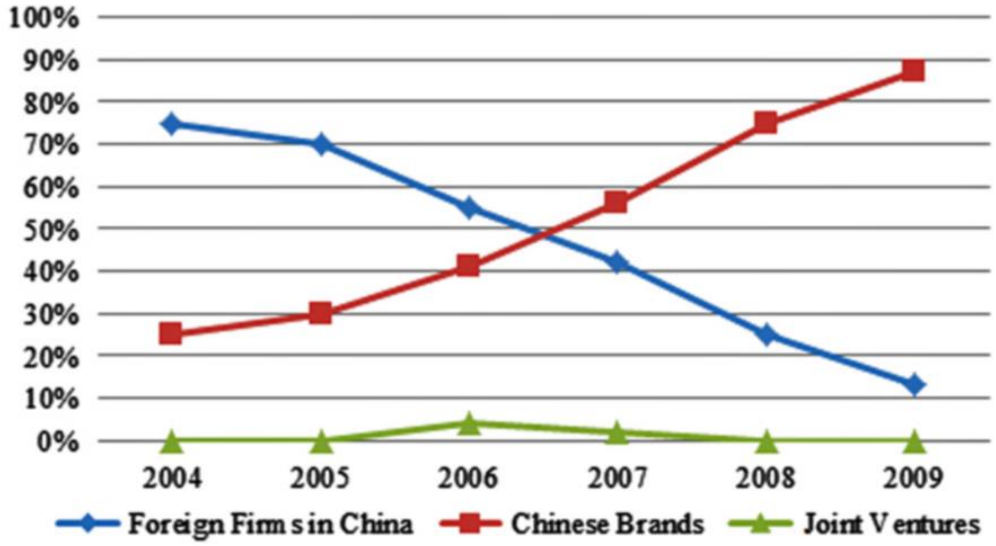


Figure 2.8 Suppliers of Newly Installed Chinese Wind Power Capacity

To get a clear glimpse of the global arena, the top 10 wind turbine suppliers in 2015 are shown in Figure 2.9; where it is evident that out of the 10 major companies of production, half are Chinese firms.

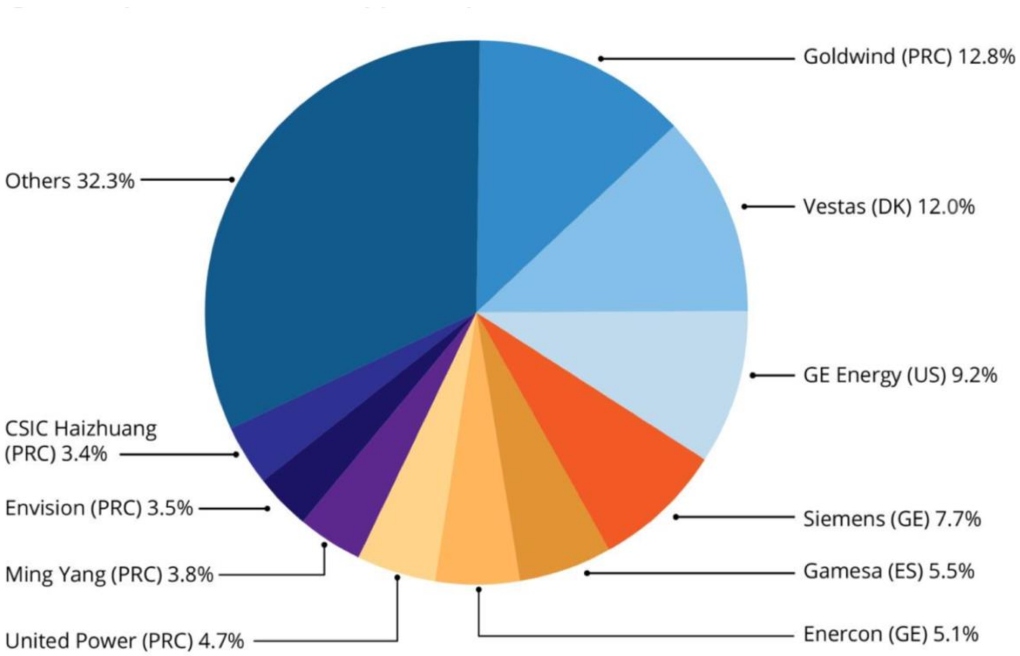


Figure 2.9 Top 10 Wind Turbine Suppliers by Market Share, 2015

A global innovation leading to more efficient renewable generation is utilization of storage in the field of energy. Battery costs have fallen sharply enabling economies of scale. Table 2.12 presents battery factories and production capacities worldwide. China again has taken the lead in battery production with capacities reaching up to 15 GWh/year, with its major manufacturer BYD's capacity more than doubling Panasonic's, its major competitor in Japan (International Energy Agency, 2018a).

Table 2.12 *Sample of Main Operation Li-ion Battery Factories*

Country	*Manufacturer*	*Production Capacity (GWh/year)*	*Year of Commissioning*	*Source*
China	BYD	8	2016	TL Ogan (2016)
United States	LG Chem	2,6	2013	BNEF (2018)
Japan	Panasonic	3,5	2017	BNEF (2018)
China	CATL	7	2016	BNEF (2018)

With these technological developments, China installed around 90 GW of renewable capacity in 3 years between 2010 and 2013. In the next 4 years from 2013, China was able to add over 100 GW of installed renewable capacity, leading to a total capacity of 293 GW in 2017 (National Energy Administration, 2018b) (The Pew Charitable Trusts, 2013).

Natural Gas

Another major development towards low-carbon transition occurred in the natural gas market. In China, shale gas production is expected to double in nearly 3 years from 2017 to 2020, with production reaching 17 bcm as more technological advances with drilling result in further cost cutting (Read, 2020). It is forecasted that by 2040, China will be the second largest shale gas producer after the US, growing its daily production capacity to nearly 623 mcm, 13-fold increase compared to 2017.

Utilization of shale gas plays a big role in solving the detrimental problems the high-carbon system (Helm, 2011). The air pollution index in areas around China reach up to 15 times the level that is considered safe by the World Health Organization; this issue is getting solved with the scrapping of coal plants in these regions under the plan "bring back the blue skies" (*Be ij Ing Pledges to 'Bring Back the Blue Skies,'* 2018). With air pollution levels reaching very high levels, studies estimate that the death tolls will reach 1.6 million people per year (Rohde & Muller, 2015). This leads to major concerns over pollution and in return policies to decrease fossil fuel use.

2.4.4. Brazil

Brazil's energy transition story is different from all other cases. Brazil became the first developing country to provide a concrete outline for emission reduction targets, whereas most other countries linked emission reduction targets to their potential growth (Pashley, 2015). Although this might be considered as major indication of Brazil's enthusiasm in low-carbon transition, the actual efforts portrayed, after the OPEC oil crisis, lies in bioethanol utilization (Solomon & Krishna, 2011).

Brazil, despite its great potential, has long disregarded bioethanol production. This was mainly due to petroleum-based fuels becoming inexpensive (Leite, 2009). Brazil encountered an economical shock during the OPEC oil crisis when oil prices increased. Even though, Brazil was not on the OPEC's embargo list (Rodriguez, 2018), the fluctuation in prices caused economic damages. At the time Brazil was importing 80% of its oil (Solomon & Krishna, 2011). Seeking for other alternatives National Alcohol Fuel Program (Proalcool) was developed in hopes of increasing domestic ethanol production and reducing oil dependency (Solomon & Krishna, 2011).

Three main government actions were taken in the Proalcool program:

- Purchasing a guaranteed amount of ethanol each year by the state-owned oil company, Petrobas,
- providing investment subsidies such as low interest loans through Banco do Brazil for ethanol producing agro-industries,
- providing subsidies and price cap set at 59% of gasoline price to make ethanol more attractive (Lehtonen, 2007).

This plan initiated an aggressive approach in pursuing domestic ethanol production and integrating it into the energy mix. As of 2000s, it is observed that price margins between gasoline prices and Brazil ethanol prices were getting closer, presented in Figure 2.10 below. This example clearly shows how supply security concerns can actually lead to long-term economic benefits.

Proalcool program, initiated by a military regime, was later adopted and accepted by all: civil society, agricultural sector and automobile manufactures (Glodemberg, 2007).

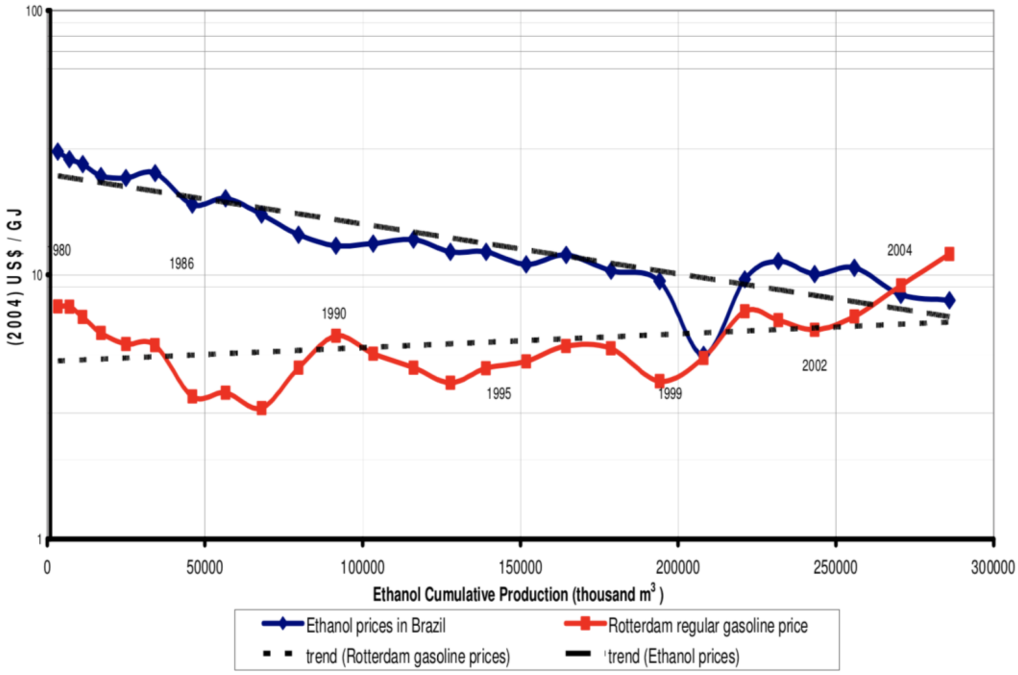


Figure 2.10 Brazil Ethanol and Rotterdam Gasoline Prices

During this time, automobile manufacturers showed strong interest in utilizing government incentives and in return stimulate alcohol-based car production (Solomon & Krishna, 2011). As an additional support, the government reclassified the automobiles as flexible-fuel vehicles (FFVs) which enabled them to be included in the same tax breaks with alcohol cars. In Figure 2.11, the different segments of automobiles are shown with the different shares of fuel types. Overall, the FFV share in the Brazilian automobile market reached almost 94% of total sales in 2013 (ICCT, 2015). The only close competitor here is Korea, with flex-LPG-CNG technology share of 10% (ICCT, 2015).

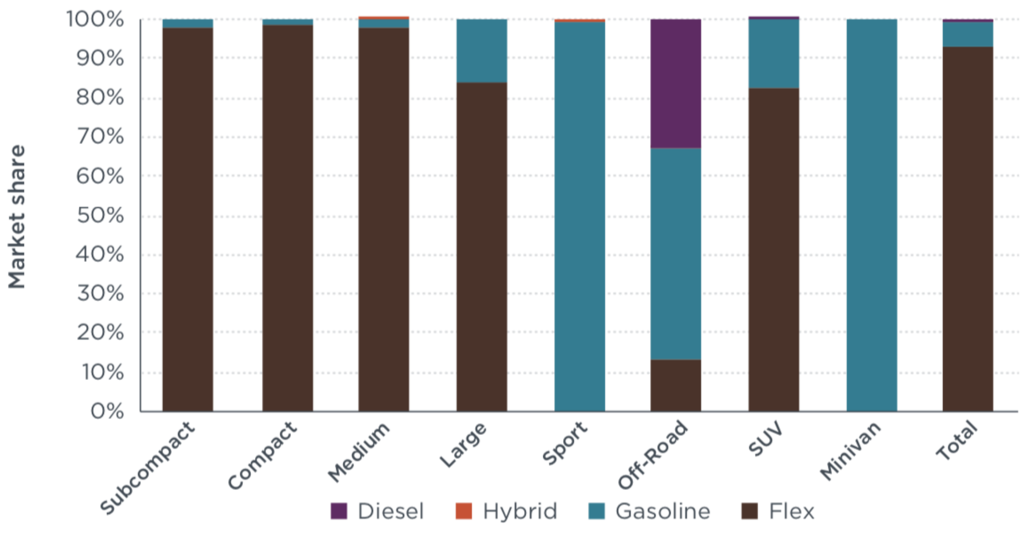


Figure 2.11 Fuel Type by Segment

In addition to the radical transformation that has undergone in the Brazilian transportation sector, the electricity market's fuel mix should also be examined as the energy matrix for Brazil is fairly different than most other countries.

Brazil is located in close proximity to major rivers allowing it to utilize vast quantity of waters. For example, Tucurui Hydro power plant in the Northern region itself has 8.370 MW of installed capacity (Dias et al., 2018). Brazil is considered to have the largest hydropower capacity in the South American region, with a total installed capacity of 100.273 MW. Hydraulic power makes up 64% of the country's total energy capacity, while meeting more than three-quarters of the total electricity demand (IHA, 2018). This is almost a seven-fold increase compared to the next highest installed capacity in the South American continent (IHA, 2018).

The energy transition of Brazil was considered to be a successful example for other countries. The transition was reducing greenhouse gas emissions by shifting away from fossil fuels mainly oil. However, there other concerns were raised. Unlike most other countries, Brazil's greenhouse gas emissions were mainly caused by deforestation, major environmental issue of the country. According to a report released in 2016 by Observatoria do Clima, which is a consortium of 40 environmental groups in Brazil, greenhouse gas emissions increased 3.5% in 2015 while its GDP fell 3.8% due to the economic recession (In, 2018).

Table 2.13 *Estimation of Greenhouse Gasses (Mt CO_2e GWP)*

Category	*Energy*	*Farming*	*Forestry and Land Use Change*	*Industrial Processes*	*Waste*	*Total*	*Share of Land Use*
2000	290	385	1.439	74	58	2.246	64%
2007	334	445	1.744	84	73	2.682	65%
2008	355	453	1.841	84	74	2.807	66%
2009	342	460	1.045	76	79	2.003	52%
2010	373	472	900	96	84	1.925	47%
2011	387	484	870	100	86	1.927	45%
2012	421	478	860	101	87	1.947	44%
2013	455	483	977	101	90	2.107	46%
2014	481	488	859	103	92	2.022	42%
2015	457	491	949	102	93	2.091	45%

Table 2.13 (continued)

2016	423	499	1.167	96	92	2.278	51%
2000	290	385	1.439	74	58	2.246	64%

Brazil accounts up to 5% of the current global greenhouse gas emissions and is forecasted to be responsible for 4% by 2030, releasing up to 2.800 MtCO2e (McKinsey & Company, 2009). As it can be seen from Table 2.13, the majority of carbon emissions are due to deforestation. Up until 2008, the share of forestry and other land use was over two thirds of the total greenhouse gas emissions, which in return was reduced to a minimum of 42% in 2014. A case study done by McKinsey & Company on GHG emission scenarios for 2030 portrays the differences between the global and Brazilian GHG emission profiles. In Figure 2.12, it can be seen that relative expected weight of GHG emissions in the power market is around 27%, whereas same number equals to 3% in Brazil. This is largely due to the fact that Brazil has a concentrated power generation from hydraulic power plants. Agriculture and forestry on the other hand show a global forecast of around 21%, while in Brazil this is expected to escalate up to 72%.

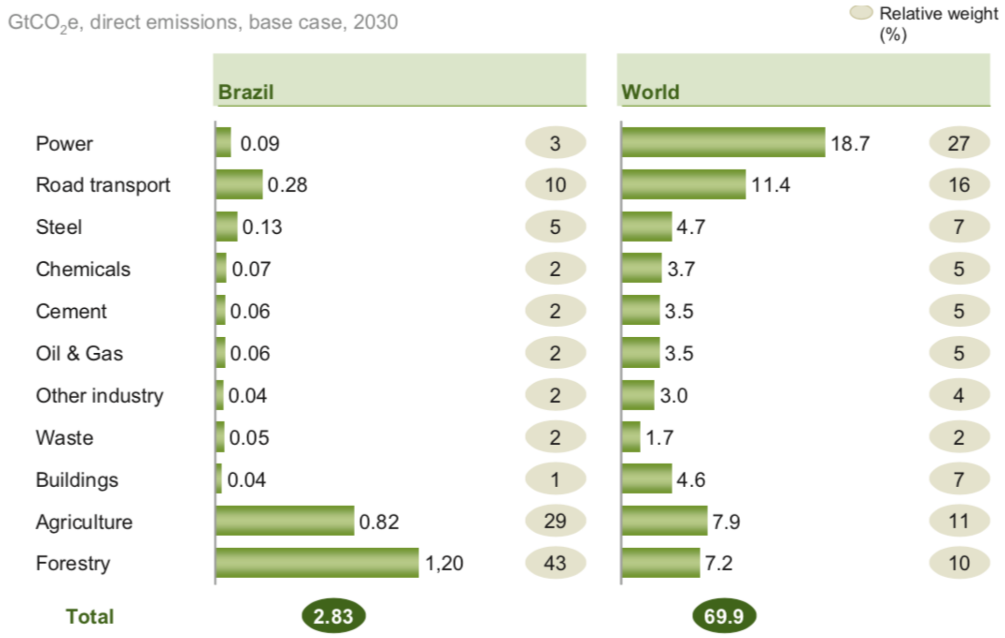


Figure 2.12 Comparison of Brazilian and Global GHG Emission Profiles

2.5. Review

In this chapter, different motivations behind energy transitions of various countries were discussed. The analysis has shown that each country has different incentives around the major stimulators of energy transitions: supply security, economic and environmental aspects and social acceptance. With changing trends in global energy markets, this transition has accelerated in the past decade. Whether it be supply security, economic or environmental factors energy transition is inevitable and this transition is far from being completed, but definitely is in full effect.

CHAPTER 3

THE GERMAN ENERGY TRANSITION: "ENERGIEWENDE"

3.1. Introduction

Chapter 2 provided a broad perspective on what is energy transition and how to approach energy transition from a global perspective with examples from various country experiences. After the detailed global energy transition analysis, Chapter 3 delves into the main focus of this thesis. To understand whether the German energy transition is a unique model applicable to each country or not, the chapter analyzes the German experience in detail to provide a benchmark for the multidimensional analysis of Chapter 5.

Before delving into an analysis, what is meant by German energy transition needs to be understood. Germany has set itself ambitious targets with its pioneering role in energy and climate policies. While Germany is among many countries striving for transition to a low carbon energy it has unique circumstances. Germany is aiming to phase out, a low-carbon energy source, nuclear while simultaneously moving away from fossil fuels and remaining to be a major industry with a growing economy. The combination of carbon emission reduction, renewable energy integration and nuclear phase-out policies of Germany are commonly referred as Energiewende, energy transition.

Energiewende remains to be at the forefront of global focus. Especially, the instruments being implemented to achieve Energiewende policies are under scrutiny. Energiewende has a strong international signaling effect. Energiewende is considered a pioneering example of how an industrialized economy can be committed to transform its power system into a low-carbon system while maintaining economic competitiveness and ensuring energy security. In this regard, German experience especially in renewables has been emulated by many countries. Political, technical and economic implementation of Energiewende policies have attracted the attention of the countries considering transition towards low carbon. In this regard, this chapter aims to highlight the formation and evolution of energy transition which have successively led to Energiewende.

The chapter is structured as follows. First, basic indicators and figures of Germany is presented. Following the brief descriptive statistics, the chapter focuses on specific political movements, exogenous events and social developments through a chronological and historical background. To reveal the drivers of the Energiewende, the energy polices since early 2000s were further elaborated. The chapter ends with a discussion over the current status of Energiewende.

3.2. Population

According to the Statistisches Bundesamt-DeStatis, the Federal Statistical Office of Germany, as of July 2018, Germany's population has reached to 82.793.800 which is equivalent to around 1% of the world population (Destatis, 2018). Two different projection studies were conducted by Destatis. These projections consist of high and low immigration and result in a population of 73.1 and 67.3 million respectively, which shows the gradual decrease in the population of Germany by 2060, shown in Figure 3.1.

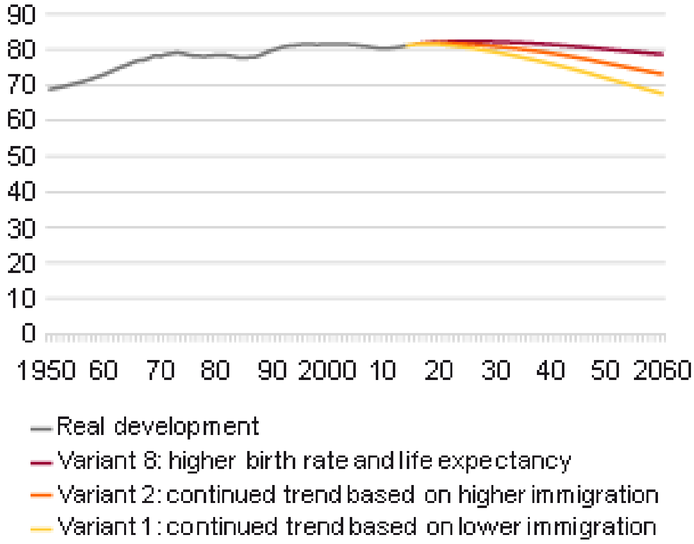


Figure 3.1 Population in Millions

3.3. GDP Growth Rate

According to World Bank statistics, Germany has 3.7 trillion USD GDP, ranking the 4th largest economy in the world (World Bank, 2018). In 2002, GDP of Germany was 2.0 trillion USD, resulting in an annual increase of 4.2%. The GDP development of Germany from 1970 to 2017 is displayed below in Figure 3.2.

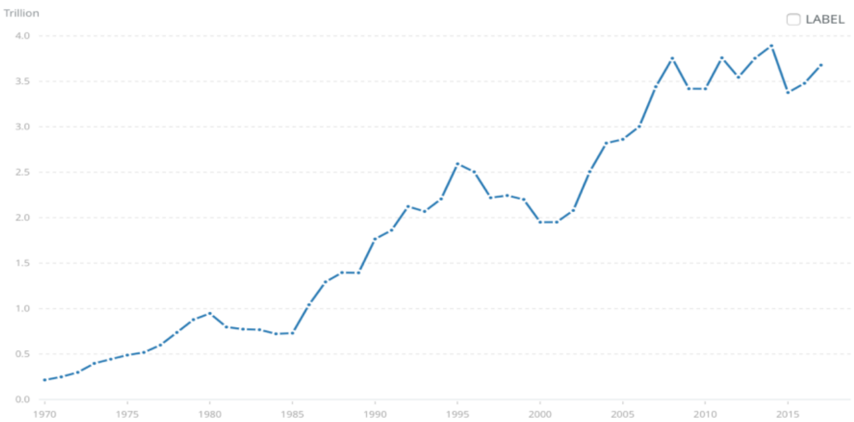


Figure 3.2 GDP in US Dollars

3.4. Primary Energy Supply

Table 1 presents the energy consumption of different fuel sources of Germany between 2013 and 2017. These numbers indicate that total energy consumption exceeded 4 billion GJ. Over 25% of this consumption is from natural gas, 15% from hard and brown coal usage and 20% from electricity generation.

3.5. Installed Capacity Development

Germany is the largest energy market in Europe with power demand reaching 522 TWh in 2017, 20% higher than its closest market, France with 445 TWh demand (Enerdata, 2019). Installed capacity development of Germany is presented in Figure 3.3. According to Figure 3.3, a major increase in the share of renewables is observed. While the share was 10% in 2005 with 63.1 TWh of generation, the number has reached to 16.6% in 2010. With staggering production after 2010, the share increased to 33% in 2017 with 218.3 TWh. From 2005 to 2017, in only twelve years, Germany was able to nearly quadruple its renewable energy gross production. This additional 113 TWh of renewable energy generation, was mainly fueled by 96 TWh of additional wind and photovoltaic generation. While a rapid increase in generation from renewables is observed, generation capacity from nuclear fell. While the share of nuclear generation capacity was 20.3% of total in 2005, it decreased to 10.8% in 2017 as shown in Figure 3.3.

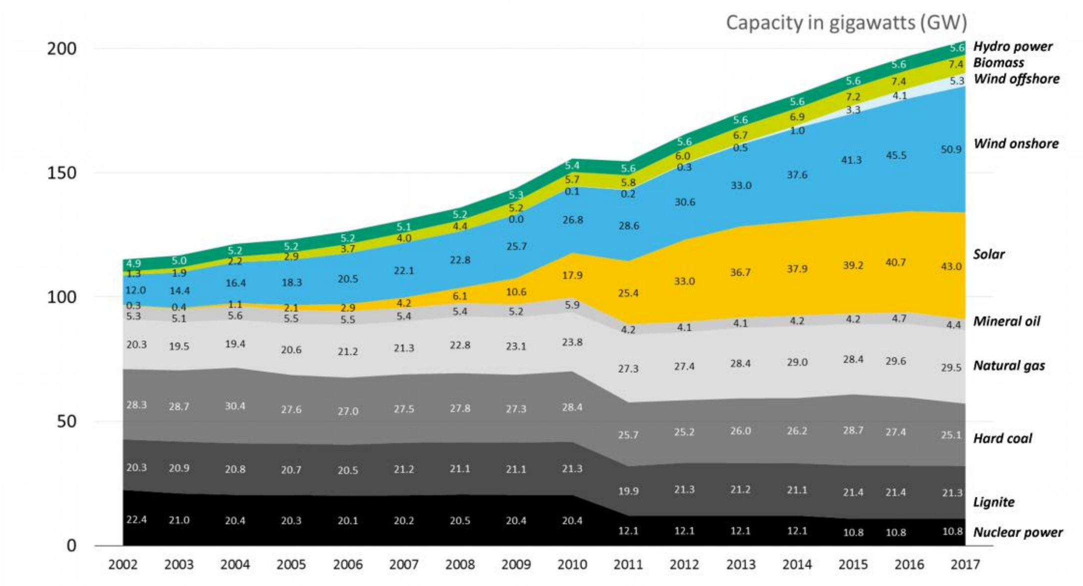


Figure 3.3 Installed Net Power Generation Capacity of Germany

3.6. Energy Imports

Figure 3.4 presents Germany's energy imports as a net percentage of energy use. According to the World Bank's most recent dataset, Germany's net imports in 2015 was around 61.4%, ranking Germany the14th highest energy import dependent country in the world (World Bank, 2018).

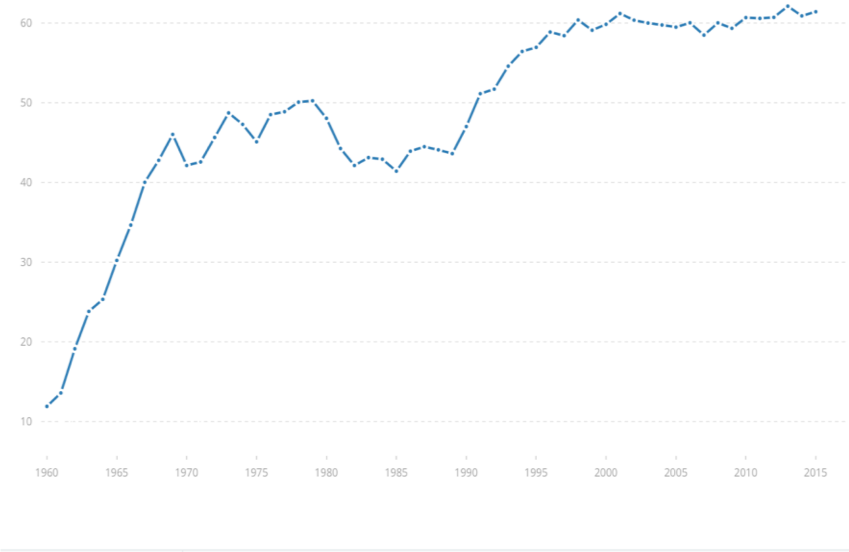


Figure 3.4 Energy Imports (Net % of Energy Use)

Focusing on import dependency by source, presented in Figure 3.5, Germany imported 98% of its mineral oil, 92% of natural gas and 93% of hard coal in 2017. It can be observed that, although the amount of imported volume decreased since 2006, the share of imports has increased.

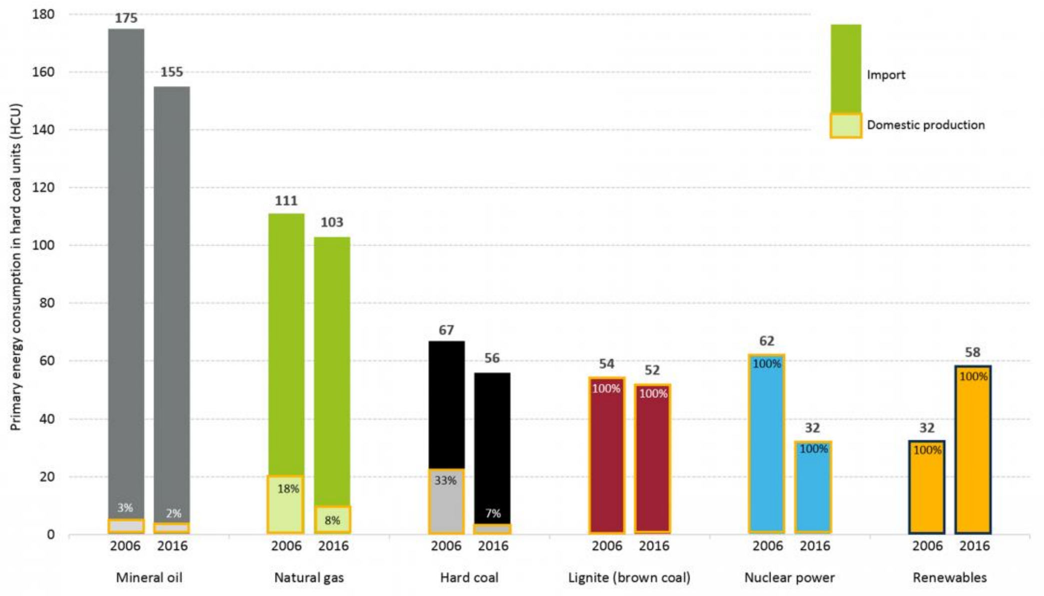


Figure 3.5 Import Dependency by Primary Energy Source for Germany, 2006 - 2012

Looking more specifically into coal in primary energy demand, Table 3.1 shows the country of origins of imported coal. Majority of imports are from Russia with 16 million tons, equivalent to 40% of its total imports. Germany imports 7 million tons of hard coal from the United States of America, 56% percent less than the volume imported from Russia.

Table 3.1 *Hard Coal Imports (Tons)*

Country of origin	*2013*	*2014*	*2015*	*2016*	*2017*
Total	44,971,128	46,060,513	43,689,557	44,664,519	40,101,830
EU-Countries	4,911,808	4,691,765	3,789,813	2,648,983	3,309,552
Third countries, total	40,059,320	41,368,748	39,899,744	42,015,536	36,792,278
Russian Federation	11,829,117	12,616,681	14,392,932	15,927,293	16,323,103
South Africa	3,132,170	6,097,665	2,612,646	1,284,573	1,047,503
United States of America	10,380,603	8,528,718	7,478,513	7,582,194	7,099,802
Canada	1,175,857	1,484,645	1,298,828	1,454,377	.
Colombia	8,131,385	5,912,468	7,027,565	8,151,950	4,716,654
Australia	4,565,610	5,650,236	6,152,409	6,659,356	.
Other third countries	844,578	1,078,335	936,851	955,793	1,166,867

3.7. Historical Background & Legislative Framework

German energy transition has been an evolutionary process. It cannot simply be defined by a single revolutionary policy, but rather by historical events leading to this evolution. In the literature, it is widely accepted that German energy transition dates back to the historical events of more than 30 years ago and legislations enacted during the same period (Hake et al., 2015). In this regard, it is crucial to understand the historical developments which successively led to the formation of "Energiewende".

Passed legislation has paved the way for the German energy transition of today. During this timeline, many changes and amendments were made to deal with the changing cycles of the global energy market and technological trends. Therefore, this subchapter is delineated into three subcategories each representing the chronological developments in different fuel sources, namely, coal, nuclear and renewables.

3.7.1. Coal

A few years after the second World War, the German energy market focused on the reconstructing of the energy infrastructure while putting its main focus on domestic lignite and hard coal (Hake et al., 2015). In 1950s, 90% of Germany's energy consumption was from coal (Renn & Marshall, 2016). More than half a million people were working in coal industry and the labor unions had strong political powers.

During the oil crises in 1973-74, energy policies of Germany shifted towards energy supply security. This shift was mentioned in the Federal Energy Program of 1973 and further revised in 1974 as a result of the severe impacts of oil crises. By 1981 Energy Program was revised three times. During this period, 7 additional coal-fired power plants were commissioned.

In 1960s, raising awareness on the health effects of burning coal triggered anti-coal movement. While in 70s there were new coal-fired power plants being built, anti-coal movement kept their strong opposition. However, anti-nuclear movement during the same period shadowed the anti-coal ideology to grow more (Lauber & Jacobsson, 2015). That is why anti-coal movement remained rather at a local level. During 80s, new lignite coal mines were licensed. Although local protest were ongoing, the environmental NGOs were not eager to fight both against nuclear and coal at the same time. In addition, coal was regarded as a domestic source important for energy security. More importantly, employment opportunities attached great importance to coal. Until Chernobyl accident in 1986, coal and nuclear coexisted in the energy mix of Germany.

After Chernobyl, Social democrats switched their position on nuclear and moved towards an anti-nuclear but pro-coal policy framework. Their coal strategy included two parts:

- Sustaining coal subsidies for uneconomical hard coal mines until 2018 and then phase out hard coal mining in 2018,
- Leaving out lignite phase-out plan due to energy security reasons.

Therefore, due to energy security reasons lignite remained to be an integral part of German energy policy.

327 billion euros were spent as subsidies for hard coal between 1970 and 2014 (Renewable Energies Agency, 2015). There were only 2 hard coal mines left operational in 2016. Hard coal phase-out plan (without phasing out lignite) launched during the Kohl Administration in 1986-1998. The opposition to coal-fired power plants increased in 1990s with the discussions growing over climate change (Renn & Marshall, 2016). Although environmental concerns were at the forefront, the main concerns were rather political and economic. Although lignite has a more pollutant nature compared to hard coal, from an economic perspective, it is cheaper than hard coal. Moreover, due to employment opportunities lignite mines provide many coal

mines remained operational due to political motivations (Lauber & Jacobsson, 2015).

The perception of coal has significantly shifted with the reunification of Germany in 1989. Coal mining was more prevalent in the eastern part of the country. The unification opened the coal mining districts of Eastern Germany to public. The devastated areas being widely recognized by Western Germany, opened a new space for pro-coal movement. The debate on coal transformed into how to decrease the negative impacts of coal with the most recent technological advancements rather than implementing a strict phase-out plan. The elections of 1998 resulted with the victory of SPD and the Greens. Continued use of domestic coal was one of the several key action areas determined by the government. Phasing out coal fired power plants was not on their policy agenda.

The fierce debate on the role of coal in the energy mix of Germany has been ongoing since the establishment of coal fired power plants. While it is widely accepted that coal consumption should be reduced, stringent policies like total phase-out is being avoided mostly for political and social reasons. Coal remains to be a domestic energy supply providing employment opportunities to more than 120.000 workers (Lauber & Jacobsson, 2015). Over time, German energy policy was revised. The revised policies included the introduction of a coal reduction regime. The new policy aims to decrease fossil fuel consumption to 20% of the 1990 levels by 2050.

Unlike coal, Germany had sharper nuclear policies over time. The rise of anti-nuclear movement simultaneously with anti-coal movement will be discussed in the following subchapter.

3.7.2. Nuclear

History of nuclear energy lies at the very center of “Energiewende”. The discussions on nuclear has started in 1950s mainly with the Paris Agreements and has been on the policy agenda since then. During 1970s, Germany has encountered with first anti-nuclear movement. With the establishment of Green Party in 1983, the government was divided over nuclear policies. Following subchapters discusses the pro and anti-nuclear movements throughout the history and provide ideological background on the "nuclear phase-out" policy of Energiewende.

3.7.3. Pro-Nuclear

The Paris Agreement was signed and put into effect in 1955. The main objective of this agreement was to show the importance of nuclear energy and make it the second pillar of the energy supply system of Germany (Hake et al., 2015). During 1950s, German politicians and society believed that nuclear energy was to become an energy source that would have great social significance (Hake et al., 2015). In 1955-56, Federal Ministry for Nuclear Affairs and Atomic Commission was established, commonly referred as the 1st German Nuclear Program.

In 1960s, competition between mineral oil and hard coal intensified, despite policies that subsidized coal and heavily taxed petroleum. With increasing dependence on imported fuel sources, nuclear energy once again shined as the important backbone to secure domestic energy supply (Hake et al., 2015). In 1960, the "Act on the Peaceful Utilization of Atomic Energy and the Protection against its Hazards" was enacted. This Act regulated the approval process of construction of nuclear power plants.

2nd nuclear program was launched in 1963, called Spitzingsee Program (Hake et al., 2015). The program focused on education and training of nuclear physicists and other experts that would be involved in the nuclear projects. During this period, the German government allocated a lot of budget into nuclear research and programs. Germany has commissioned 24.000 MW's of nuclear energy capacity between 1968 and 1989 (Mez & Piening, 2002). Especially during the mid-1970s, with the oil crises, the importance of nuclear power was once again on rise (Hake et al., 2015).

During 70s, Christian Democrats, Social Democrats and Liberals kept their positive attitude towards use of nuclear power in power generation.

Anti-Nuclear

Late 1970s mark the rise of anti-nuclear movement in Germany. Protests against the construction of Wyhl Nuclear Power Plant in 1973 -1975 named Whyl as the "birthplace of anti-nuclear movement" (Meyer, 2014). By the end of 70s, anti-nuclear movements became political actors in German politics. Based on the 70s movements, the Green Party was founded in 1980. Green Party took place in the Bundestag, the German parliament, for the first time in 1983. In early 80s, environmental policies started to get more attention in the Bundestag. In addition, electricity prices dropped so low in early 80s that it shadowed the necessity for additional nuclear generation. Therefore, decreasing electricity prices and increasing environmental concerns caused nuclear to lose its political and public popularity.

3 nuclear incidents should be noted as major drivers of anti-nuclear movement: The Three Mile Island incident which took place in the United States in 1979, the Chernobyl accident in Ukraine in 1986 and more recently Fukushima meltdown in Japan in 2011.

The Chernobyl accident brought questions regarding nuclear safety. After the accident, German politics were shaken up. The German government reacted very rapidly and established the Federal Ministry for the Environment Natural Conservation and Nuclear Safety (BMU) (Hake et al., 2015). With the changing public opinion on nuclear after Chernobyl, Social Democrats turned towards anti-nuclear policies aligning with the Green Party on their "nuclear phase-out" ideals (Hake et al., 2015).

Although the existing government kept its position on nuclear, during late 80s and 90s, construction of all planned nuclear power plants were canceled. In 1990s, regardless of the politics, the economics of nuclear made further expansion of nuclear power plants highly difficult. The government then advocated that at least the operational nuclear power plants should be kept online.

The elections of 1998 resulted in a victory of a coalition of Social Democrats and the Greens. During the election campaigns both parties prioritized their anti-nuclear policies. The first condition of the coalition was the decommissioning off all existing nuclear power plants. Although Social Democrats had questions on immediate closure due to its economic and social consequences, the coalition agreement was made on compromises from both sides. The agreement stated that:

> “The withdrawal from the use of nuclear energy will be extensively and irreversibly regulated by law within this legislative period (...), the new government will invite the utility companies to talk about a new energy policy, steps to end the use of nuclear energy and further nuclear waste management, and, if possible, to decide on these issues in a consensus. (...) the coalition will introduce an act in which the phasing out of nuclear energy is regulated, without any compensation payments; therefore, the operating licenses will be limited in time" (Hake et al., 2015).

This highly effective coalition agreement is being regarded as the turning point in the German energy politics. Long period of negotiations over nuclear phase-out resulted in the limitation of lifetimes of operational nuclear power plants to 32 years. The negotiations took place in 2000 which resulted in the enactment of “Act for the Orderly Termination of the Use of Nuclear Energy for Commercial Generation of Electricity” in 2002. While the agreement formulated the situation of existing power plants, it also prohibited the construction of new power plants. However, the agreement was being criticized for its flexibility and thus, inability to state a final date for nuclear power generation.

Christian Democrats and Liberals led my Angela Merkel won the elections of 2009. Although the government of Merkel claimed that energy policies of the former administrations would be kept in place, 2000’s nuclear phase-out agreement was left behind. In 2010, Energy Concept came into force which refers nuclear as a “central bridge” towards sustainable energy system (Hake et al., 2015). With the enactment of “Atomic Energy Act” in October 2016, the lifetimes of nuclear power plants, previously set as 32 years, were further extended by 12 years. While extending the lifetimes of operational plants, planning of new nuclear power plants were still forbidden in consistent with the coalition agreement of Social Democrats and Greens.

The latest major nuclear disaster that took place is the Fukushima incident fundamentally changed the nuclear policies of Germany. On March 11th, 2011 the Great East Japan Earthquake led to a considerable amount of damage in the region. At the time of the earthquake, eleven reactors at four nuclear plants within the region were in operation, and all were shut down automatically resulting in almost 10.000 MW of capacity turning offline. Three of the Fukushima Daiichi reactors’ power supply and cooling mechanism disabled, resulting in the melting of the nuclear cores in the reactors (WNA, 2018). This incident is a major game changer for German energy markets. After the incident, seven nuclear reactors were immediately shut and Merkel announced a “nuclear moratorium”. The decision on extension of lifetimes were cancelled. “Ethics Commission for a Safe Energy Supply” was initiated very shortly after the accident which proposed a total nuclear phase-out by 2021. The Bundestag later voted and passed the 13th Amendment to the German Atomic Act which stated the final date for nuclear phase-out as 2022.

Public Opinion

Public opinion is an integral part of policymaking. Governments seeking for public support often shifts their policies towards public opinion. Public opinion on nuclear in Germany has shifted over time.

During 1950s, both the society and the politicians believed that nuclear would become an energy source with great “social significance” (Müller-Rommel, 1985). Harrisburg incident marks the date which has tremendous effect on public opinion regarding nuclear. After the incident, although nuclear was still believed to be essential for energy supply, its potential dangers were being discussed.

In 1980s with the rise of the anti-nuclear movement, socio-political environment has also shifted. After the Chernobyl disaster in 1986, public support has sharply decreased. Right after the accident, 86% of the respondents reported their support for nuclear phase-out (Renn, 1990)

A research conducted in 2005 by Allensbach Institute for Public Opinion Research and Eurobarometers showed that 64% of the German public were convinced that nuclear power sources in their country were safer than those of other countries. The study also showed that 51% of the country believed that nuclear power was a cheap and economical fuel alternative while 52% believed that it helped preserve fossil fuel sources (Arlt & Wolling, 2015).. Another study conducted by the same institute in March 2010 showed the public opinion was divided on the issue. While 37% of the population was against nuclear, 44% supported use of nuclear as a power source (Arlt & Wolling, 2015). Public support shifted after the Fukushima accident in 2011.

Polls conducted at a global scale show the changes on public opinion regarding nuclear energy use. According to a study carried out by Worldwide Independent Network-Gallup International in 2011, a snap poll was taken of 47 countries with regards to the public opinion of nuclear energy use. The results reveal that before the incident 57% of the participants were in favor of using nuclear power, while after the incident the support dropped to 49% (Arlt & Wolling, 2015). The same shift occurred more radically in Germany. In 2010, 31% presented strong view against the further use of nuclear energy, while this opposition reached 73% after Fukushima, signaling a major drift toward a nuclear phase-out program (Arlt & Wolling, 2015).

3.7.4. Renewables & Environmental Policies

Anti-nuclear movement in Germany was mainly triggered by increasing environmental awareness in 1980s. The history of renewables even goes back to the

70s. In 1970s, following the oil crises, energy security became a critical point of policy discussions which put renewables at the center of energy policies. In 1974, Ministry of Research and Technology has launched an R&D program on renewables worth 10 million German marks. In 1977, government introduced a 25% investment subsidy on solar panels and heat pumps. It is calculated that 150 million German marks were spent on renewable research by 1982 (Hake et al., 2015). Although the administration of that time cut the allocated funds for renewables by half, studies and pilot projects on renewables have accelerated in 1980s. "Growian", a pioneer wind turbine type, was commissioned in 1980s. Although the Growian failed to work properly, the idea of renewables playing a crucial role in shifting towards a lower carbon economy rose in 1980s.

The report on "Preventive Measures to Protect the Earth's Atmosphere" published in 1990 formed one of the first written statement on Germany's climate policies and emission reduction targets. In 1990s the awareness on climate change increased substantially. The ratification of United Nations Framework Convention on Climate Change (UNFCCC) Report by Germany in 1998, put renewables in the forefront of the policy agenda.

The administration of 1990 to 1998 prioritized grid integration of renewables. During 90s, environmental policies and policies regarding renewables were regarded as integrated and cannot be separated from each other. Renewables, a carbon free energy source, was considered to be essential to combat climate change. During 90s, German politics reached a consensus regarding climate change policies (conflicts remained over nuclear). All election campaigns of 1998 highlighted the importance of renewable integration.

To support renewables, German government had a feed-in-tariff (FiT) agreement with the private power companies since 1979 despite it's non-binding nature. Germany first began the pursuit of using binding FIT with the Electricity Feed-In Act, also known as Stromeinspeisungsgesetz (StrEG). This law was enacted in 1991 and was considered to be the first green electricity FIT mechanism in the World.

With this law under effect, grid companies were obligated to connect renewable sources in the grid and pay them a guaranteed FiT for 20 years. As this renewable scheme did not result in the intended volume integration into the electricity system, it was further followed by offering of low interest loans under different government programs. These low interest loans were then challenged by EU anti-subsidy rules. As the mechanism showed many flaws, such as wind rich regions having more of a financial burden, and the volatility of electricity prices proving uneven, it did not ensure investment security.

In 1998, the elections resulted in a political change of a 16 years coalition. First time in German politics a party which has environmental policies on their prioritized policy agenda was elected. Social Democrat and Greens coalition, often referred as Red-Green coalition, had been pleading for increasing renewable penetration in the energy system. The coalition agreement mentioned:

> "The new government will ensure a future-proof, environmentally friendly and cost-effective energy supply. Renewable energies and energy efficiency have priority (…). The government believes that the entry into new energy structures will be characterized by growing economic dynamics, which will be further supported by redesigning the energy laws. This includes, in particular, non-discriminatory grid access and the creation and safeguarding of fair market opportunities for renewable domestic energies through a clear legal regime and a fair distribution of the costs of these sustainable energies" (Hake et al., 2015).

Since then, Germany had renewables at the very center of its energy policy. However, efforts discussed above to increase renewables proved to be inefficient. Due to the problems that arose in the Electricity Grid Feed Act, the Renewable Energy Sources Act was introduced, which came into force on the 1st of April 2000, known as the EEG (Erneurebe-Energien-Gesetz). This act granted priority for renewable energy sources with focus on three principles:

- Investment security through with feed-in tariffs with preferred dispatch such sources, allowing access of small and medium enterprises to the grid over conventional energy sources such as nuclear, coal and gas,
- The surcharge payments regarding subsidies will be derived through EEG surcharges on electricity consumers as opposed to taxation, thus it will not be considered as public subsidies,
- The feed-in tariffs will decrease at particular intervals to put pressure on costs associated with plant operators and manufacturers, resulting in more cost-efficient overtime (Lang & Lang, 2015).

During the red-green coalition, CDU/CSU and FDP continued to oppose both nuclear phase-out and EEG policies. The victory of CDU/CSU and SPD in the 2005 elections heated the discussions regarding nuclear and renewables. With regards to EEG, CDU/CSU no longer demanded the abolition of EEG but rather suggested more efficient instruments. Moreover, the coalition agreement included more stringent targets. Some of the major targets are as follows:

- Increasing the share of renewables to at least 12.5% by 2010,
- Increasing the share of renewables to at least 20% by 2020,
- Expanding offshore wind turbines,
- Developing power grids faster (Bundesregierung, 2005).

In 2007, during the EU Presidency of Germany, Merkel convinced EU leaders to commit increasing renewable share to 20% by 2020, which later became the cornerstone of EU's 20-20-20 policy. The same year, Merkel has attended the G8 meeting where she leaded the announcement of "serious consideration" of reducing global CO2 emissions by 50% by 2050 of the member states. The leading position of Merkel on climate in the international area made her the "climate chancellor" in the German media. Following the international efforts, national policies were initiated during this period. The coalition agreed on "Integrated Energy and Climate Program" in 2007 and "Energy Concept" later in 2010, both included targets on renewables (further discussed in the following subchapters: Integrated Energy and Climate Programme (IECP), The Energy Concept 2050).

Germany had another national election in 2013. The new government again led by Merkel signed a coalition agreement the same year. During those years, due to increasing electricity bills, criticisms rose over increasing renewables through EEG. The coalition agreement included some solutions to the problems arising from EEG (Konrad-Adenauer-Stiftung, 2014a). The coalition agreement announced a slowing of renewable development through so called "development corridors" (Konrad-Adenauer-Stiftung, 2014a). In this regard, an Amendment to EEG law was passed in 2014. The Amendment includes:

- Targets for each renewable source,
- Reduction in biomass FiT,
- A tax on self-generated solar panels,
- Replacement of tendering with FiT for solar PV sites (Lang & Lang, 2015).

In Germany, renewables is at the cornerstone of energy policy of each coalition since 1990s. Since then, in addition to nuclear phase-out and coal reduction regime, increasing the share of renewables forms the backbone of Energiewende.

3.8. Energy Policies towards Energiewende

The policy shifts in German energy markets took place with the radical changes of policies within the European markets. The European context illustrates major policy developments regarding deregulation and liberalization of energy markets, issues regarding global climate changes, and energy security (Renn & Marshall, 2016). In 1998, when a coalition took place between the SPD and Green Party, the new formed government announced that they will focus on sustainable development. The key principles that this development would entitle included supply security, financial and economic efficiency and environmental compatibility (Renn & Marshall, 2016). During this period many action priorities were identified such as, the mitigation of climate change, energy efficiency, continuing use of domestic coal and lignite, a more competitive liberalized energy market, extended use of renewable energy, creating a level-playing field for European energy companies. Germany on the other hand set much more ambitious goals regarding emission and fossil fuel dependency targets.

In Germany, each government successively put forth their plans and policies regarding sustainable development. In this regard, the set of detailed objectives stated over a time span of more than 30 years, define the concept of "Energiewende". Therefore, policies on energy and climate over the years should be analyzed to further understand the energy transition of Germany. The major benchmarks of German energy policy are Integrated Energy and Climate Programme in 2007, Energy Concept in 2010 followed by a complementing Energy Programme in 2011 and Climate Action Plan in 2016. Each of these policies will be analyzed in the following subchapters.

3.8.1. Integrated Energy and Climate Programme (IECP)

In 2007, the German Cabinet met in Meseberg and agreed on a set of policies on energy and climate, commonly referred as "Meseberg Decisions" (BMUB, 2007). The programme is based on three major principles: security of supply, economic efficiency and protection of the environment. The Programme includes 29 measures from various aspects. Some of the included targets are as follows:

- Doubling the power generation from CHP to 25%,
- Decreasing GHG emissions by 40% by 2020 compared to 1990 levels,
- Approving underground grid to transport offshore wing power,
- Approving energy-related requirements for new residential areas and target 30% reduction in the energy use,
- Providing incentives for smart metering,

- Increasing tolls and vehicle taxes to reduce CO2 emissions. (Grantham Institute, 2019)

Among the 29 Actions stated in the Programme 3 of them were related to Carbon Capture and Storage (CCS). According to the Programme, government would support the CCS strategy and the commercial deployment of CCS integrated plants are expected in 2020.

3.8.2. The Energy Concept 2050

In 2009, The CDU and FDP coalition has agreed on a treaty which laid the foundation for the "Energy Concept" (BMUB, 2011). With the enactment of the Concept in 2010, German government has set concrete targets for the country's later called "energy transition". The Concept formulates an encompassing strategy for a period of 40 years until 2050. The broad aim is to lay down the overall orientation of where German energy markets would go while keeping the markets flexible for new technological adaptations. In this regard, the Energy Concept focuses on three fundamental areas: promotion of renewable energy and energy efficiency, reduction of CO2 emissions and enhancement of power grids. The Concept and the decision of the Bundestag, lower house representing the nation as a whole, set out the policies as follows:

- 40% reduction in greenhouse gas emissions by 2020 and 80 to 95% reduction in greenhouse gas emissions by 2050,
- Increasing the share of renewables in the gross final energy production to 18% by 2020 and 60% by 2050,
- Reduction of primary energy use by 20% by 2020 and 50% by 2050,
- Reduction of electricity use by 10% by 2020 and 25% by 2050 (Unnerstall, 2017).

Deployment of Carbon Capture and Storage (CCS) is also included in the Energy Concept as covered in the IECP. Under the Energy Concept the government seek for a legal basis for testing the available locations for carbon storage. In addition to these policies the Concept also focused on the role of nuclear power plants. The Concept states that;

> "Nuclear energy is a bridging technology on this road. We are aiming for a market-oriented energy policy that is free of ideology and open to all technologies, embracing all paths of use for power, heat and transport." (BMUB, 2011)

However, after the Fukushima accident in 2011, the role of nuclear mentioned in the Energy Concept was reassessed. Regarding nuclear power plants, the oldest seven and one relatively younger power plants were shut down immediately following the accident. Moreover, remaining power plants were decided to be shut down permanently by 2022.

After the reassessment of the Energy Concept, the German government announced an "Energy Package" on June 2011 which is complementing the Energy Concept with an additional focus on the implementation process of the suggested policies. The combination of the policies in the Energy Concept and nuclear phase-out until 2022 is commonly referred as "Energiewende", energy transition.

3.8.3. The Climate Action Plan 2050

In November 2016, the German government announced the one of its kind climate action plan referred as "Climate Action Plan 2050" (BMUB, n.d.). This comprehensive climate plan confirms the former policies and additionally specifies broader policies regarding the climate change mitigation. According to the Plan;

- In the medium-term, Germany is set to decrease GHG emissions by 55% by 2030 compared to 1990 levels,
- In the long-term, Germany is set to become carbon neutral by 2050 (BMUB, 2016)

Moreover, the Plan also identifies sector specific targets in line with the country's Paris Agreement commitments. It emphasizes the implementation of the policies and sets out a process for monitoring. The Plan is not only focused on power generation but also includes targets regarding buildings and transport sectors, agriculture and forestry and many other subsectors presented in Figure 3.6.

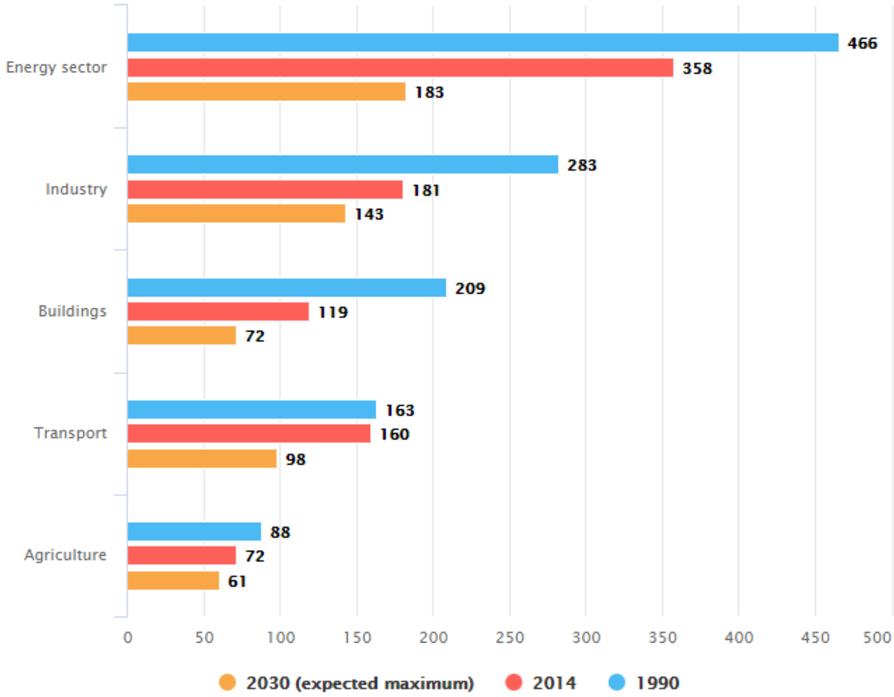


Figure 3.6 Sectoral Targets in the Climate Action Plan 2050[4]

3.9. Major Motivators

In order to fully grasp Energiewende, we must understand the major motivations behind these policies. These motivations can be summed up as the reduction of

[4] The sector targets are shown in 2030 from the Climate Protection Plan 2050 (in millions of tonnes of CO2 equivalents

global CO2 emissions, the phase-out of nuclear energy, the reduction of dependence on fossil fuels and the promotion of innovation with export opportunities for Germany's national economy (Unnerstall, 2017). Moreover from social acceptance perspective, employment opportunities provided by renewables is also a major motivator of Energiewende. Each of these motivations will be studied in detail in the following sections.

3.9.1. Nuclear Phase-Out

After the Chernobyl accident in 1986, nuclear phase-out, became one of the major motivator of Energiewende. Nuclear phase-out has become an "essential ingredient of Germany's Energiewende" especially after the Fukushima meltdown in 2011 (Kunz & Weigt, 2014). At the beginning of 2011, 17 power plants were in operation; in 2017 only remaining 8 nuclear power plants were in operation. It is expected that the phase-out process will be moving smoothly without creating capacity shortages (Kunz & Weigt, 2014). It seems highly unlikely that Germany would reverse it's decision on nuclear phase-out. The best indicator of this is the industry response. Siemens, company which built 17 of Germany's nuclear plants, will no longer build any new nuclear power plants (WEC, 2018). According to Energiewende, the last nuclear power plant is planned to be shut down in 2022 (Figure 3.7).

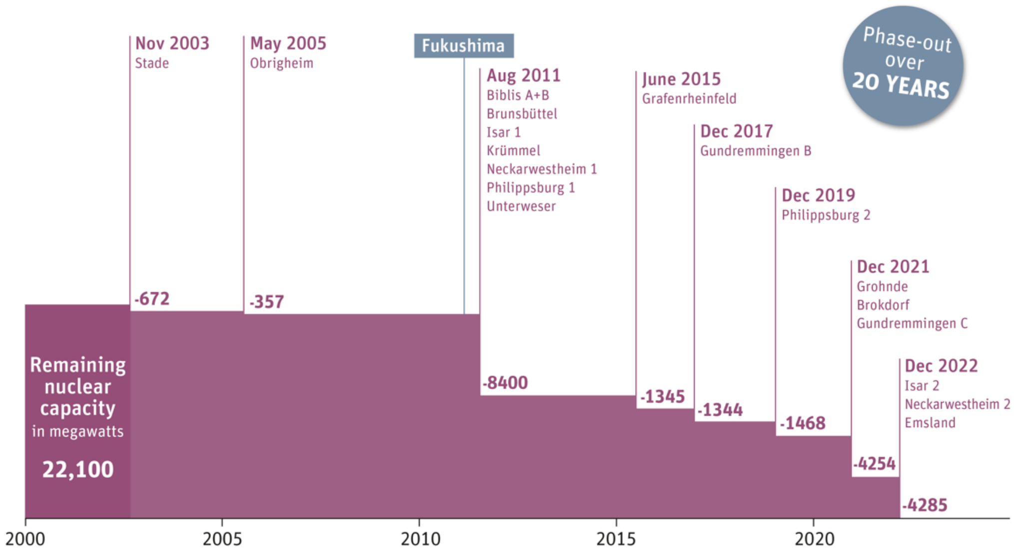


Figure 3.7 Nuclear Power Plant Shutdown in Germany, 2000 - 2022

3.9.2. Increasing Environmental Awareness

Environmental issues has increasingly gained salience for German policymakers. The raising awareness on climate change is considered to be the major motivator of Energiewende policies, namely; reducing CO2 emissions, increasing renewable share while decreasing fossil fuel share.

3.9.3. Job Creation

One of the major drivers of Energiewende which created positive public opinion is regarding increasing employment opportunities. With technological advances in the coal marketplace, we a see a very rapid decline in the number of workers in coal sector. This decline has continued since 1950s and dropped record low in the past few years as shown in Figure 3.8. On the other hand, with technological advancement and R&D development, the jobs in the renewable marketplace has been increasing very rapidly. This is in fact one of the pushing points for Energiewende program.

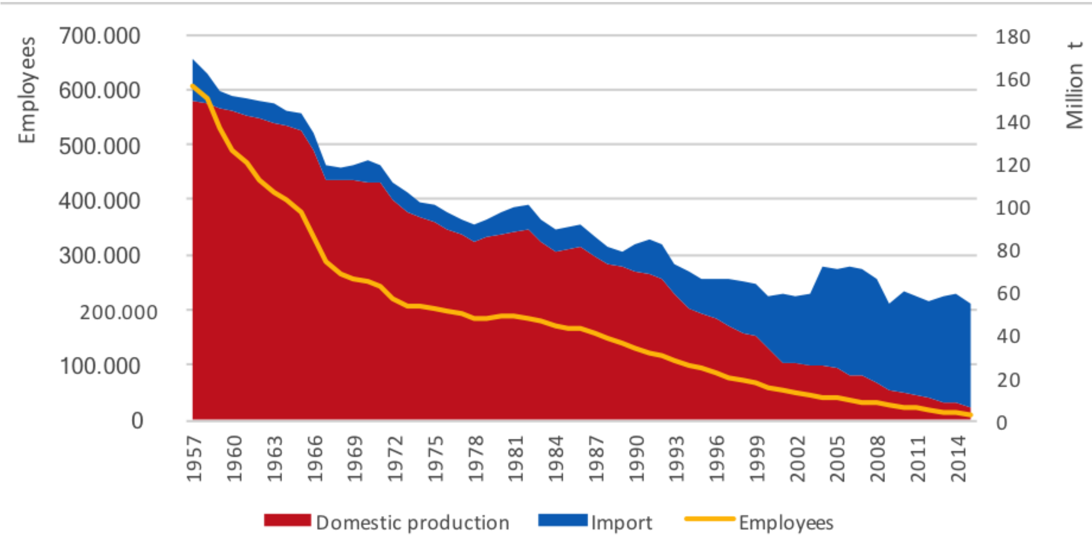


Figure 3.8 Coal Sector Employment in Germany

Jobs in the renewable sector has surpassed the jobs in coal mining and conventional fuels by over sevenfold (see Figure 3.9). R&D, manufacturing and other aspects of renewable generation have had a positive impact on the German workforce.

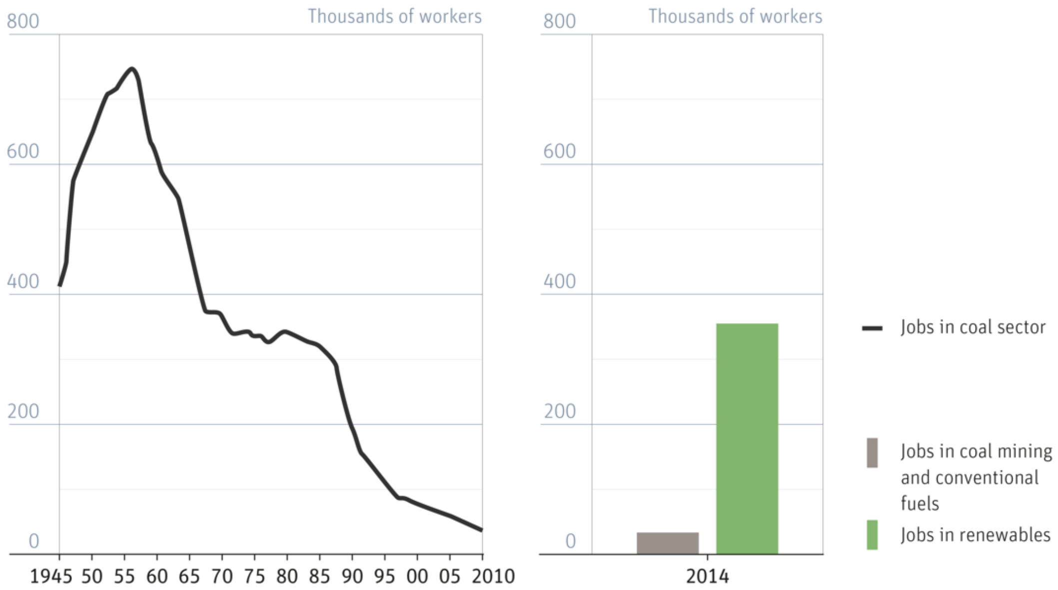


Figure 3.9 Renewable vs Coal Employment Figures in Germany

In 2017, employment in the wind energy sector has proven to be the leader in the renewable energy sources, followed by biomass, biogas and solar PV. 142.900 jobs in the renewable energy field are directly related to the wind energy sector, which can be noted as an important figure. When the entire market is added, we can see a total sum of 340.000 employment in the renewable energy sector (see Figure 3.10).

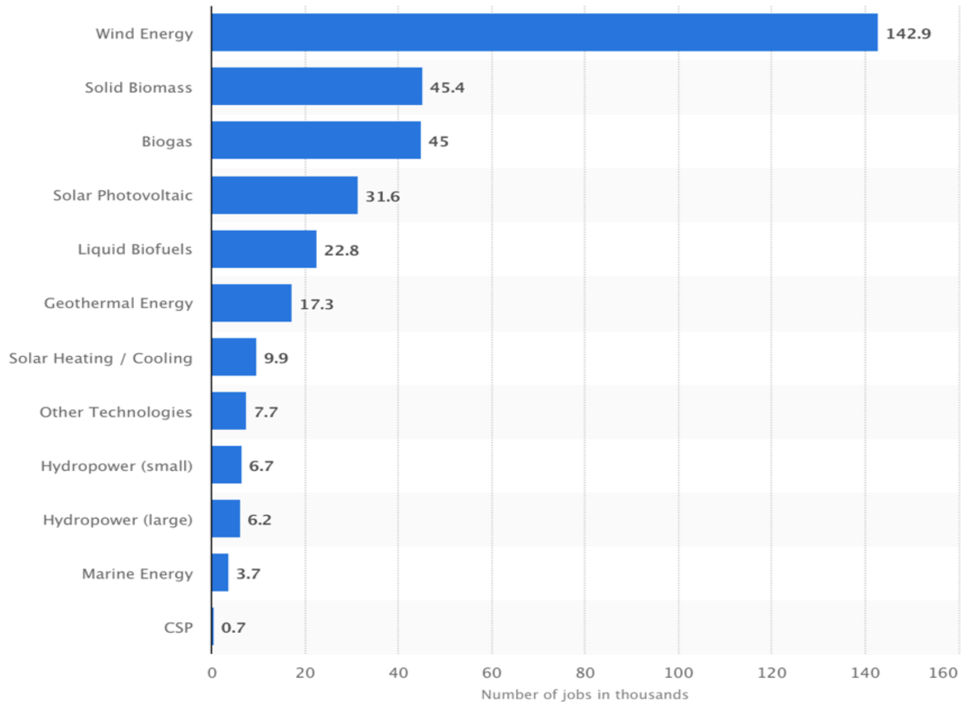


Figure 3.10 Employment in the Renewable Energy Sector in Germany (2017) - x1.000 Jobs

Based on these motivations, Energiewende policy was formed which includes;

- Phasing out nuclear power,
- Expansion of renewable energies,
- Introduction of a coal phase-out regime.

3.10. Major Challenges

Each set of policies are associated with their unique challenges. Germany also faces a number of challenges to achieving the targets of Energiewende. According to the plan, Germany has to decrease power generation from fossil fuels, in addition to phasing-out of nuclear while keeping CO_2 emissions at lower levels. This ambitious targets set out by Energiewende faces problems regarding the lack of infrastructure and high electricity costs for consumers.

The main challenges that Energiewende is associated with are mostly related to renewable integration. It is discussed that penetration of variable renewable sources into the grid requires high investments. Moreover, subsidized renewable energy generation is reflected as high prices to the consumers' electricity bills. As discussed earlier in this chapter, Germany has been a frontrunner in the global climate talks and has set ambitious national targets. According to many studies mentioned below, these targets are very unlikely to be reached. Thus, emission reduction is also constitutes a problem for the success of Energiewende.

There are several long-term challenges that need to be addressed in order to reach the targets defined under Energiewende. This subchapter analyzes major obstacles that Energiewende has and later discusses how far those targets are reached until 2018.

3.10.1. Infrastructure Problems: Technical & Financial

Germany has been investing heavily in renewables, as part of the Energiewende movement. As renewable energy generation volume increases, it also leads to technical difficulties. Huge investments are required in grid infrastructure development and back-up or storage facilities for further development of untraditional power plants as they are more dispersed as opposed to traditional power plants (Buchan, 2012). It is argued that the German government has failed to install enough back-up or storage facilities to be prepared for the times with low wind or irradiation rate.

Difficulties in bringing in wind energy that is to replace nuclear energy, from the point of production to the point of consumption creates an important challenge. Major problems are expected to arise especially due to offshore power plants, which is expected to be both technically and economically difficult to bring the required electricity to land (Schreurs, 2012). Also, the potential wind energy rich north of the country has lower demand then more industrialized and producing south. This in return creates a need for the generated electricity in the north to be transmitted to the south. In Figure 3.11 you can find the wind power plant locations in Germany. As seen in the map, it is very clear that these power plants need major transmission lines in order to deliver the energy to where electricity is demanded.

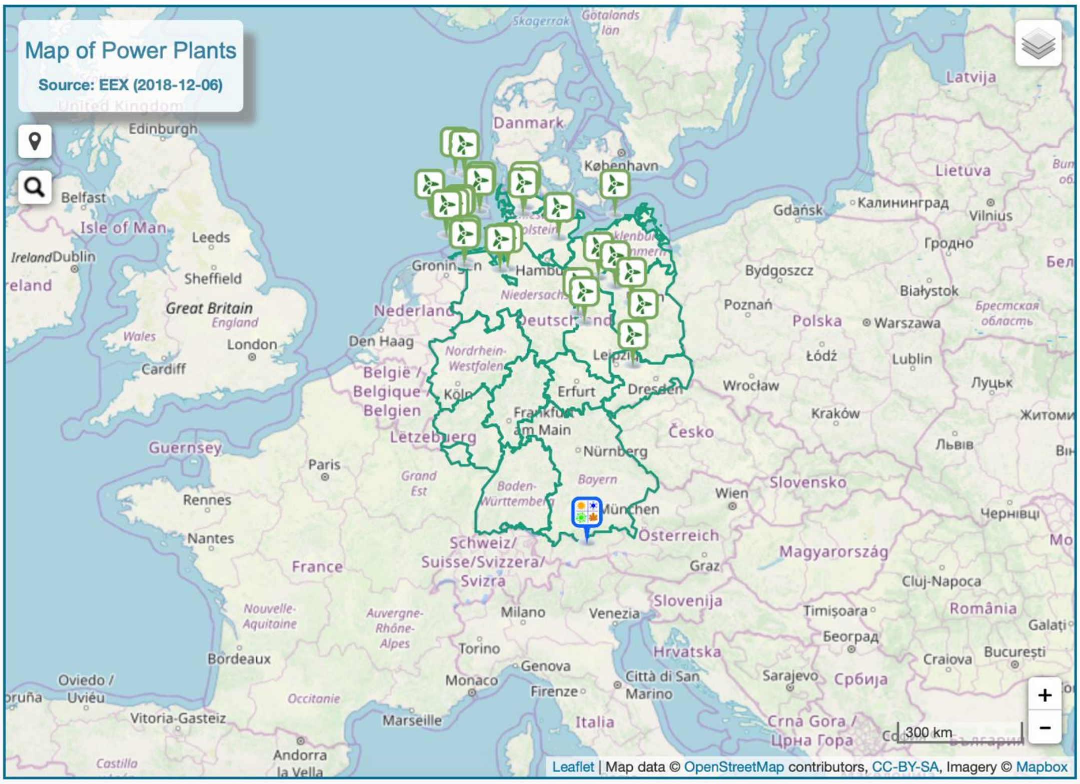


Figure 3.11 Map of Germany's Wind Power Plants

There are numerous studies that quantifies the required investment for Energiewende. A study conducted by The Federation of German Industries (BDI), an industrial lobby group, projects that the movement will cost between €150 billion and €350 billion up to 2030 (Gloystein, 2012). While large companies argue that the phase-out of their large-scale nuclear power plants will inevitably increase prices, Vattenfall Europe have claimed that customers will carry this burden and face additional costs of €150 billion by 2020.

In 2013, this topic was further analyzed with current economy and energy minister, Peter Altmaier stating that "the costs of the Energiewende and of the transformation of our energy supply could add up to around one trillion euros by the end of 2030s". It was stated that legal commitments would cost around 680 billion euros by 2022, while the costs of grid modernization and extension, back-up power generation and storage capabilities and further implementations would be added separately to the bill (Amelang, 2018b).

In 2017, Agora Energiewende, an energy think tank compared different comprehensive studies on the additional costs of Energiewende. These studies were later compiled by other think tanks (Amelang, 2018b) and six common positions of these papers could be identified as followed:

- The energy transition will require a significant amount of investments; estimates of the total investment will vary around 15 to 40 billion euros, which is equivalent to 0.5 to 1.2% of Germany's GDP,
- If the climate-related damage cause by CO2 emissions is equivalent to 50-60 euros per tonne, or if a drastic increase in fossil fuel prices occur then the cost of transition will crease as the associated costs with emissions or energy imports would be significantly lowered,
- Energiewende related investments stimulates the economy and will help improve the growth in Germany; the efficiency measures decreasing the need for fossil fuel imports will decrease and keep costs given to other countries within Germany,

- Exports of renewable energy technology will help preserve Germany's status as the clean energy technology leader and stimulate exports of technology,
- Germany's fixed system of renewable energy support will inevitably last a long time as the support mechanism support rates for up to 20 years; thus, the extra financial burden will continue to exist on customers even until 2033 (Amelang, 2018a).

One of the latest reports regarding the financial burden put out by the Energiewende movement was analyzed by the Dusseldorf Institute for Competition Economics (DICE) on behalf of the Initiative New Social Market Economy (INSM). The report states that a €408 billion cost will be associated with the surcharge for financing renewable energies due to the Renewable Energy Sources Act mechanisms, the expansion of distribution and transmission grids that is expected to cost €55.3 billion (Stromkosten, 2016).

3.10.2. High Surcharges for Consumers

In Germany feed-in-tariff (EEG) is the main policy tool to increase the share of renewables. The cost of EEG is reflected on the final consumers through a direct surcharge on their electricity bills. Therefore, with the expansion of renewable capacity the surcharges transferred to final consumers has rapidly increased. Figure 3.12 shows the evolution of EEG surcharges over time and by generation type. With the first EEG entering into force on 1 April 2000, the additional surcharge was established as 0.19 euro cents per kWh. In 2012, this surcharge has increased eighteenfold resulting in a surcharge cost of 3.59 euro cents per kWh, reaching 6.17 euro cents per kWh in 2015.

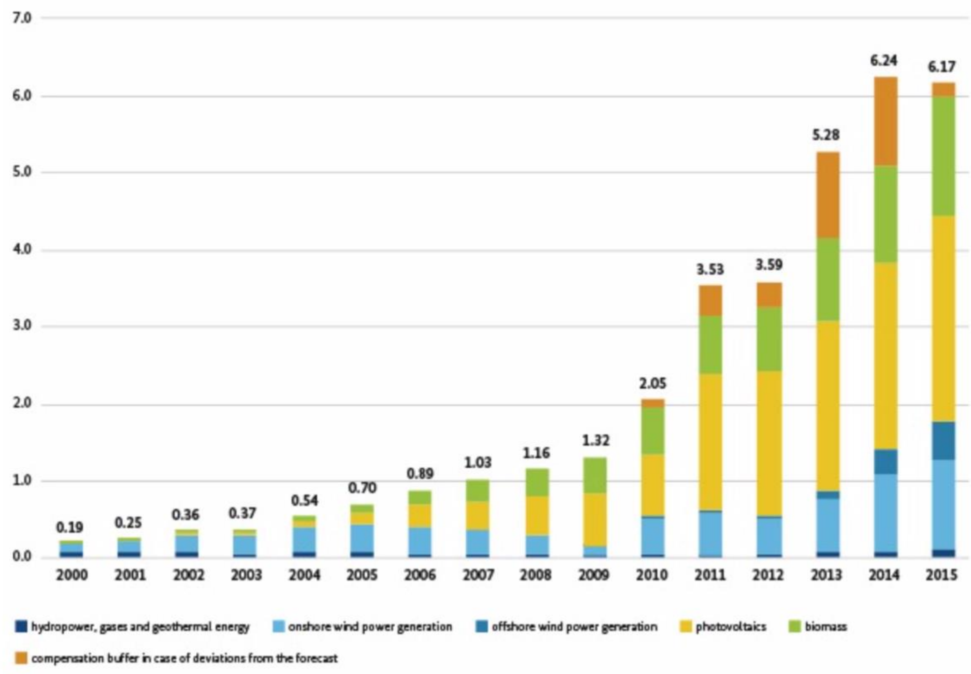


Figure 3.12 EEG Surcharge in Euro Cent per kWh

This increase in surcharges are no longer driven by the increase in FiT levels. As a matter of fact, the high FiT for PVs were cut in March 2012. With the lower prices for PV, solar PV prices remained in the 13.5-19.5 euro cents per kWh range, close to the average wholesale market price for German households. In 2011, while the price for household consumer was 13.95 euro cents per kWh, price for industrial consumers was around half this price, ranging around 7.32 euro cents per kWh (Haller et al., 2016).

The main driver of increase in the surcharges was increasing renewable capacity rather than increasing tariffs. In 2011, 7.5 GW of solar PV capacity was added, which is two times higher than originally planned. This unforeseeable rapid capacity increase became the main driver of the surcharge costs (Haller et al., 2016).

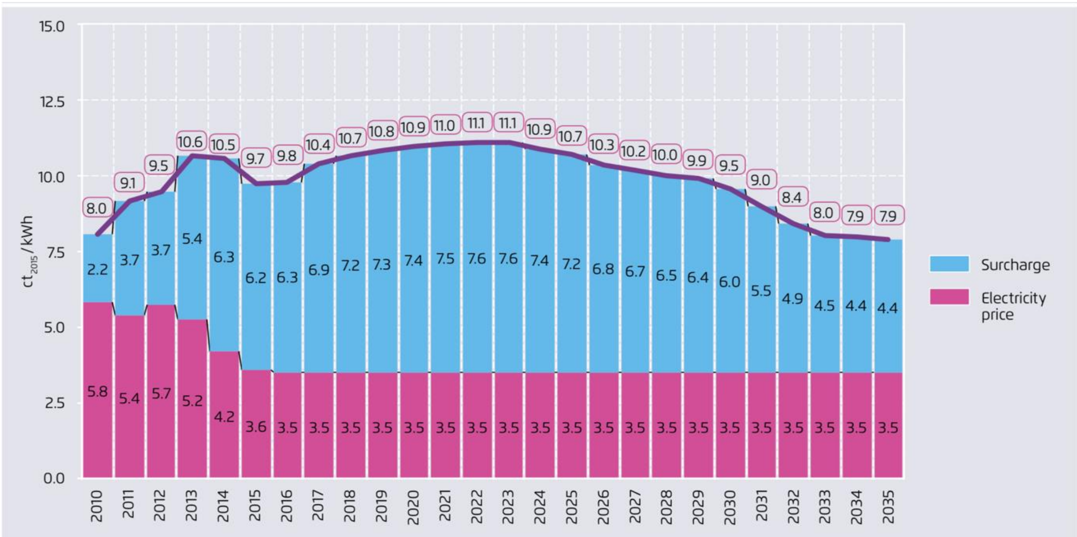


Figure 3.13 Sum of Electricity Price (Phelix Base Year Future) and EEG Surcharge

The study conducted by Deko-Institue in 2015 presents the sum of the electricity price with the Phelix Base Year Future (the wholesale electricity price in Germany) from 2010 to 2035 (Figure 3.13). The surcharge costs that ranged from around 35% of electricity price in 2010, surpassed the electricity price in 2013 (Haller et al., 2016).

The deep penetration of renewable energy into the grid also effect the price of electricity in the spot market, as the variable cost of renewables are virtually zero compared to other fossil fuel power plants. Figure 3.14 displays the yearly fluctuations in the German spot electricity market. According to this Figure, strong price drops are observed during 2010s, the period of increasing solar and wind capacity. Prices fall to around €20 per MWh in 2015.

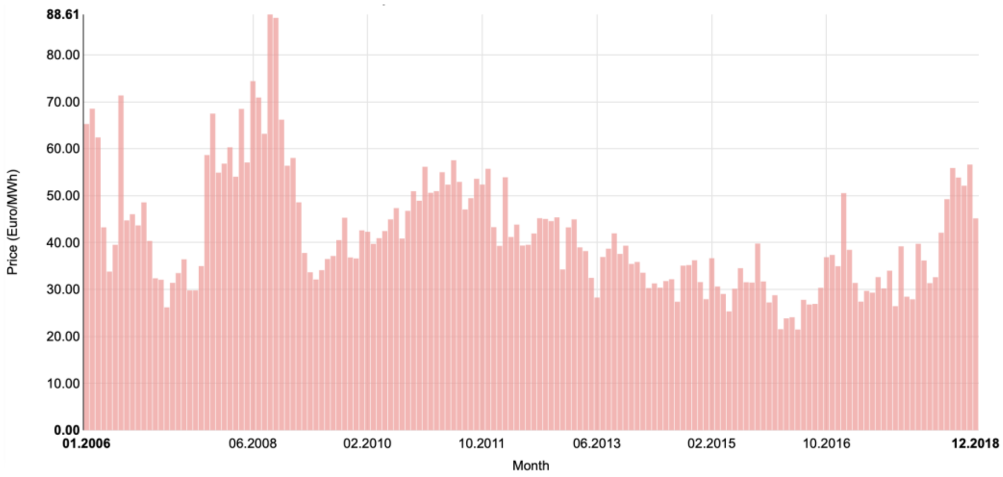


Figure 3.14 Monthly Spot Electricity Prices in Germany

3.10.3. Increasing CO2 Emissions

The introduction of vast renewable energy capacity is considered to be crucial for Germany's low-carbon energy transition. However, the electricity generated from additional renewable capacity was to replace nuclear which is another low-carbon source. Considering the carbon emission targets, replacing renewables with another low-carbon source wouldn't help enough to achieve the emission reduction targets of Germany.

Figure 3.15 below depicts different emission intensities of electricity generated by fossil fuels, renewables and nuclear. Lignite is the highest emission producing fossil fuel, followed by coal and oil. Nuclear on the other hand is one of the lowest emissions producing generation type, with an average of 28 tonnes of CO2/GWh. Thus, the major increase in renewable shares, can be expected to have a low impact on overall greenhouse gas emissions.

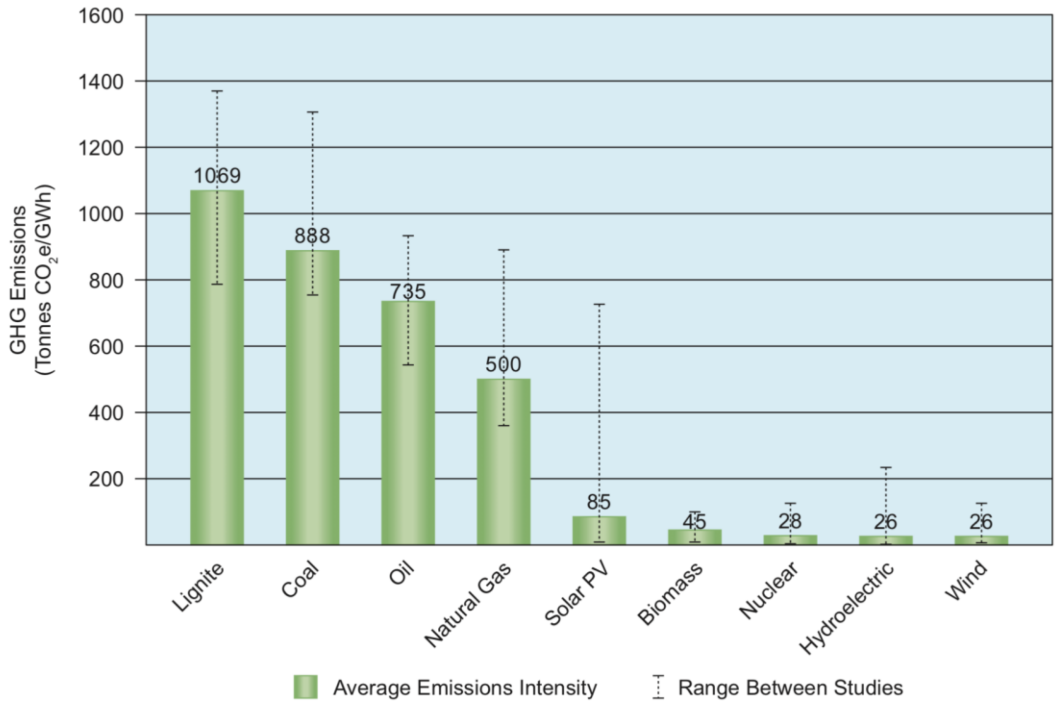


Figure 3.15 Emissions Produced from Different Fuel Sources from Electricity Generation

The rapid increase in renewable energy created a paradoxical situation in the market. As Energiewende increased the share of renewables spot market prices fell, which in return led to an increase of the CO2 levels as lignite power plants became one of the few sources that would be able to compete with spot prices (Chrischilles & Bardt, 2015). This mandatory switch from low-carbon to high-carbon fuel mixes due to the nuclear phase-out created major problems for carbon emissions of Germany. In the Figure 3.16 it is clear that there is no gradual decrease in the year to year emissions of Germany. The values fluctuate yearly, with years like 2010 where GHG actually increased according to the year before.

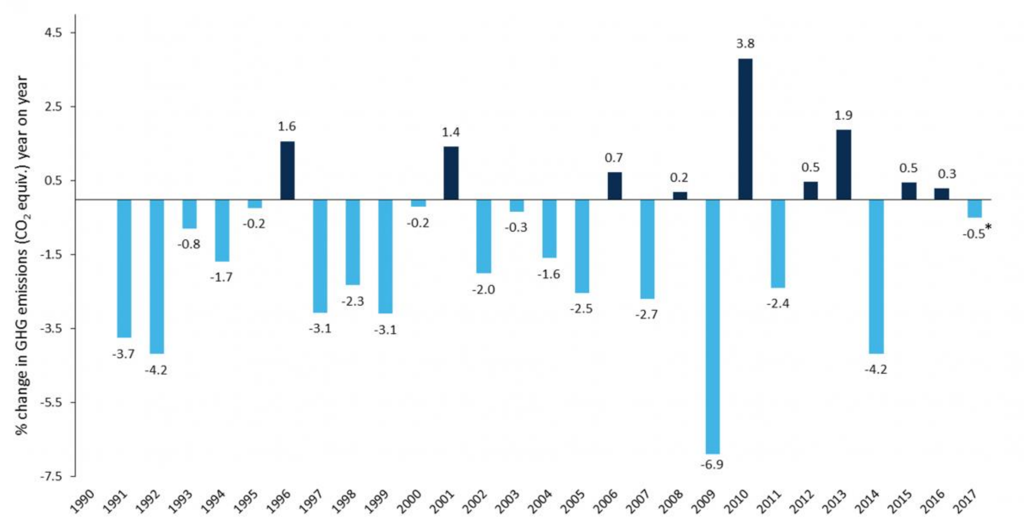


Figure 3.16 Percent Change in Germany's GHG Emissions Year-on-Year

3.10.4. Hard Coal Lignite Trade-off

The decrease seen in hard coal is also another key statistic that needs to be elaborated. Despite being used as one of the main fuel source during post-war era, hard coal mines in Germany have lost their competitive advantage. Only a small portion of the coal mined within Germany is being used as a fuel source for power plants, instead coal is imported from different countries such as Russia (34.1%), the United States (16.5%), Australia (16.1%) and Columbia (15.8%) (AGEB, 2017). 83 billion tons of hard coal reserves still remains underground in Germany, where less than half of this amount is considered mineable due to is complex geological location making it much more costly compared to importing. In 2015, the average cost of mining one ton of hard coal in Germany was around 180 euros, while the average price for importing the hard coal was around 86 to 96 euros per ton in 2017 (Appunn, 2019).

The continuing use of lignite coal is raising a controversy due to it’s highly pollutant nature. On top of large land use compared to hard coal, the average CO2 emissions resulting from lignite coal in Germany is around 0.34 kg/kWh. In addition to higher CO2 emissions, lignite is also heavier on other greenhouse gases such as nitrogen oxides (Kohlen, 2015). However, lignite can be produced in open pit mines making it less costly compared to hard coal (Renn & Marshall, 2016).

Table 3.2 *Electricity Production in Billions of Kilowatt/Hours in Germany*

	1990	*1995*	*2000*	*2005*	*2010*	*2015*	*2016*	*2017*
Lignite Coal	170,9	142,6	148,3	154,1	145,9	154,5	149,5	147,5
Hard Coal	140,8	147,1	143,1	134,1	117,0	117,7	112,2	92,6
Nuclear Energy	152,5	154,1	169,6	163,0	140,6	91,8	84,6	76,3
Natural Gas	35,9	41,1	49,2	72,7	89,3	62,0	81,3	86,5
Oil	10,8	9,1	5,9	12,0	8,7	6,2	5,8	5,9
Renewables	19,7	25,1	37,9	63,1	105,2	188,6	189,8	218,3
Other	19,3	17,7	22,6	24,2	26,8	27,3	27,4	27,7
Total	549,9	536,8	576,6	623,2	633,5	648,1	650,6	654,8

In addition to being cheaper than its alternatives, Germany has a considerable amount of coal reserves, especially lignite which is expected to be around 40,500 million tonnes (WEC, 2018). In fact, the Rhineland region in the country is the has the highest single formation lignite production in Europe, resulting in Germany being the second largest lignite producing country globally, after the United States (FactFish, 2018). As shown in

Table 3.3, it is clear to see that the lignite production in Germany has been steady and showed no decrease even with the efforts of the Energiewende movement.

Table 3.3 *Lignite (Brown Coal) Production*

Year	*Lignite Brown Coal Production (thousand metric tons)*
2016	171,547
2015	178,065
2014	178,178
2013	182,696
2012	185,432
2011	176,502
2010	169,403
2009	169,857
2008	175,313
2007	180,409
2006	176,321
2005	177,907
2004	181,926

3.11. How far Energiewende targets are achieved?

So far, we have discussed the set of policies and motivations behind Energiewende. The challenges were further analyzed to understand how the stated targets could be achieved and which obstacles should be addressed. The long-term targets of Energiewende are set. Now the remaining question is how to accomplish these targets. Better to state, how to operate an ambitious transition from coal and nuclear dominated system to a low carbon system at the lowest cost possible while ensuring energy security? In this regard, the German government has its own monitoring tool "Energy of the Future". This process, measures the implementation process of Energiewende. The results of these reports show mixed results for each target.

3.11.1. Renewables

Most of the targets are set for a long time horizon mostly 2030 and 2050. However, it is important to analyze how far the market has come so far and what remains to be done. Germany is getting closer to its target of 65% share of renewable energy in the energy mix by 2030. As shown in Figure 3.17, renewables accounted for over 40% of electricity production. Solar power increased by 16% to 45.7% TWh while wind power constitutes 20.4% with 111 TWh generation. Wind power is the biggest source of energy after domestically mined brown coal power which accounted for 24.1% (Eckert, 2019).

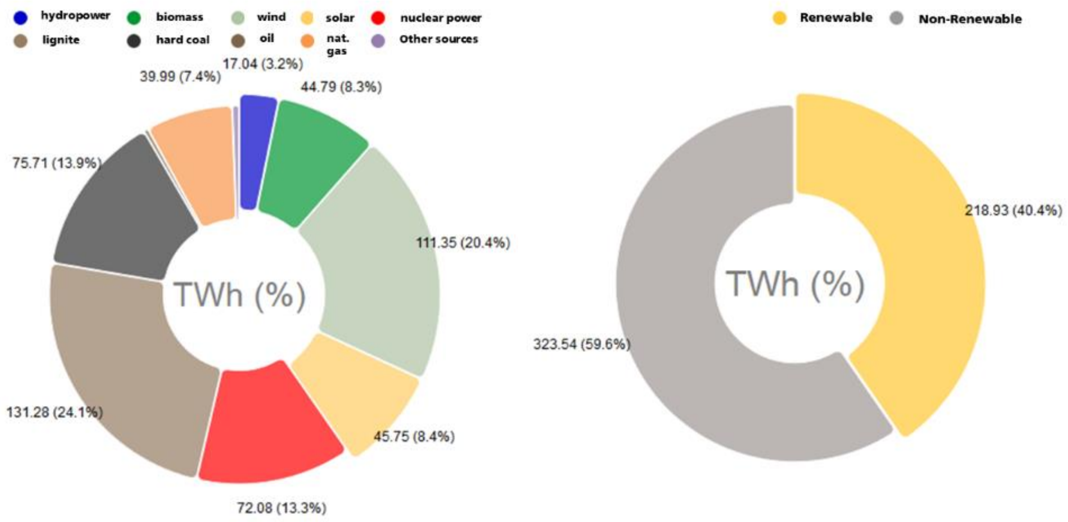


Figure 3.17 Share of Renewables Contributing to the Net Electricity Generation in The Public Power Supply

According to a research from the Fraunhofer Institute for Solar Energy Systems, for the first time, renewables overtook coal as Germany's main source of energy in 2018 (Frauenhofer ISE, 2019). Germany covered around 100% of electricity use with renewables for the first time on January 1, 2018. During the first six months of 2018, Germany has set a new record for renewable power production. Renewables mainly biomass, wind and solar energy generated 113 terawatt hours of electricity equivalent 41.5% of total generation. Wind turbines provided the highest amount of renewable power with 22.2% share. Biomass and solar generated 8.4% and 8.2%, respectively while hydropower filled the rest (Wentworth, 2018). The data by Federal Network Agency provided that 85% of Germany's power consumption were produced by wind power alone. The rest was covered by hydropower and biomass. For the first time, wind power with a rising number of turbines left behind hard coal and nuclear. Towards to end of 2018, renewables covered 38% of Germany's total electricity consumption. In contrast, coal's share of the energy mix fell by almost 7%, in the similar way, natural gas was down almost 8%. During this period, the largest source of renewables became onshore wind energy. It generated 63 billion kWh with an increase of more than 13%. Then, solar PV (41 billion kWh), biomass (34 billion kWh) and hydropower (13 billion kWh), followed respectively (Buchsbaum, 2018).

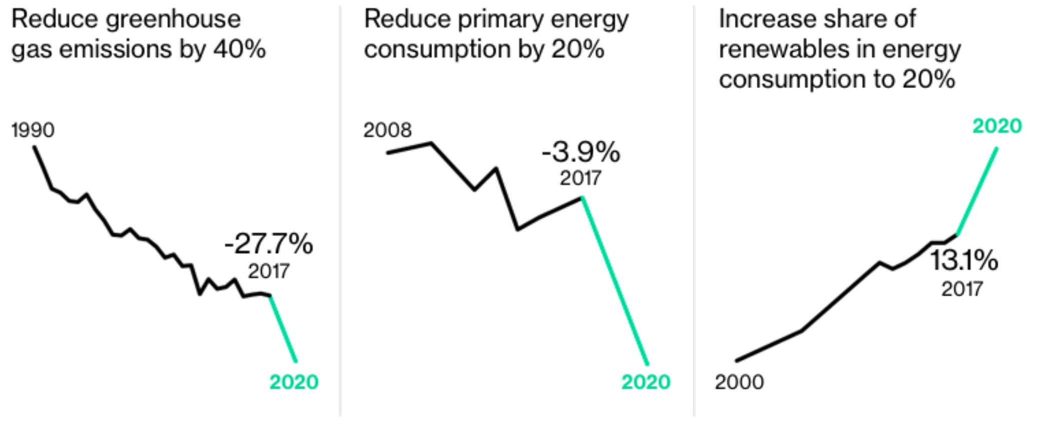
Emission Reduction Target

Even though Germany made several progresses on using renewable energy sources, emission reduction targets were not achieved in 2018, third time in a row. That means Germany is far away to its 2020 climate targets. The reason for total emissions stagnated again is that more oil and gas were used in transport, heating and industry. There are some warnings about missing 2020 climate targets because of high emissions from coal-fired power plants and transport. Germany's target is not going to be easy to reach cutting emissions by 40%. CO_2 emissions remain constant largely because of rising transportation emissions even if renewables have increased and energy consumption has decreased (Buchsbaum, 2018).

At the beginning of 2018, Merkel and Schulz came to an agreement on German energy issues and climate policy. This agreement clearly stated that 2020 target of 40% greenhouse gas emission reduction is not realistic. Germany had already cut 27% of its emissions by 2015, but the remaining 13% seems harder to achieve. According to forecasts, Germany is moving to achieve a 30% reduction by 2020.

There are two scenarios, one is to accelerate the deployment of renewable energy by raising the 65% target in 2030. The other one is increasing the current target to 50%. In 65% scenario, coal accounts for 100 TWh of electricity generation in 2030, decreasing from current levels of 250 TWh and 200 TWh in 50% scenario. Both scenarios forecast a decrease in coal power generation. On the other hand, the effect for GHG emissions will be visible. The German coal power plants generated around 250 Mt of CO_2 in 2016. In this scenario, the remaining coal plants by 2030 are expected to emit 165 Mt (Berntsen & Nordeng, 2018).

Climate Protection Report said that the expectations about reduction of the greenhouse gas emissions are to decrease by 32% by 2020 and there will be a gap of about 8%. Additional policies were initiated by the government called "Climate Action Programme". But, these policies are not enough to fill this gap to cut emissions by 40%. OECD warned Germany to obtain new measures in order to reduce emissions (Amelang, 2018a).



Sources: German Environment Agency, AG Energiebilanzen e.V.

Figure 3.18 Germany Set to Miss 2020 Climate Goals

The report published by Bloomberg on 15 August 2018 is reflecting that the failure of Germany in terms of climate goals (Figure 3.18). Germany's energy agenda is having a big impact on the mix of fuels used to generate electricity. Renewables are close to replacing coal as the primary source, and natural gas use is declining. The real problem is that Germany is also trying to phase out nuclear reactors. And with the 2020 goals looking like a stretch, there's increasing concern that tighter goals the country is planning for 2030 will be completely out of reach (Wilkes et al., 2018).

3.11.2. Phasing out Fossil Fuels

German government has appointed a commission which told that Germany should shut down all of its coal-fired power plants by 2038. The government and 16 regional states accepted and followed Germany's strategy to shift to renewables that overtook coal for the first time and to stop nuclear power. As a first step, the report indicated that plant operators including RWE, Uniper, EnBW and Vattenfall will be asked to shut down about 12.7 GW of capacity by 2022, equivalent to about 24 large power station units. Under the proposed plans, coal power capacity in Germany would be reduced by more than half to 17 GW by 2030. The report also said that even though the expectations to exit coal is the date of 2038, the phase out could be completed by 2035 (Wacket, 2019).

The coal commission agreed the final document. It shows Germany plans to reduce its 42.6 GW of coal power capacity to about 30 GW by 2022, falling to around 17 GW by 2030. Greenpeace has called for an end date of 2030, but other environmental groups in the country supported 2035 as the final date. Almost three quarters of the population believe an exit from coal is important, according to a poll of 1,285 people by ZDF. Merkel said that, as the country ditches coal and closes its last nuclear plants in 2022, "we will need more natural gas, and energy needs to be affordable." (Vaughan, 2019).

3.12. Review

The global energy transition towards low-carbon energy is undeniable. Germany is a pioneering example as it has undergone major transitions in its energy markets. The energy transition of Germany Energiewende is the planned transition of Germany towards nuclear-phase out and increasing renewable capacity generation.

Energiewende policies dates back to more than thirty years ago. The movement, started around 1970s, has matured and set forth goals for the German energy markets since then. Three pivotal targets that has been set out by Energiewende can be summarized as follows:

1. Shutdown of all nuclear power plants by 2022,
2. Renewable energy penetration in the electricity market – at least 80% by 2050,
3. Increasing electricity efficiency at a minimum rate of 1.6% per year (Unnerstall, 2017).

The main objectives of these goals can be summed up in four motives:

1. Reduction of CO2 emissions,
2. Nuclear phase out,
3. Reduction of fossil fuel dependency,
4. Economic advantages with innovation and export for renewable technologies (Unnerstall, 2017).

Experiencing this rapid transition on the other hand, created many challenges and raised questions about the complexity of such a transition. Energiewende leaves Germany with quite ambitious and far reaching goals of emission reduction of 40% by 2020, 55% by 2030 and 80% by 2050 according to the baseline year of 1990. Such ambitious goals point out the importance of using low-carbon generation plants and phasing out high carbon emitting plants.

Comparing the years 2010 and 2011, it is evident that there is a major leap of installed capacity in renewables, mainly PV and onshore wind. 9.3 GW onshore wind and solar capacity was added during this period mainly replacing the reduced nuclear installed capacity. The nuclear capacity decreased from 20.4 GW to 8.3 GW, a 41% decrease while coal (both hard coal and lignite) decreased from 49.7 GW to 45.6 GW, only an 8% decrease. The years that follow show a steady generation capacity of lignite and a slight decrease in hard coal.

One of the main problems associated with increasing renewable generation is intermittency. Despite sharp falls in the costs of battery storage technologies, they remain to be too expensive. Additionally, they don't store electricity long enough. "Substantial cost reductions are likely needed to economically justify large-scale deployment of storage technologies." (de Sisternes et al., 2016). To solve this problem, natural gas takes the role as back up fuel source in Germany. This is return generates further problems of import dependency for Germany, as the country has limited natural gas production. In 2014, Germany's natural gas demand was 70.9 bcm while its production was only 7.7 bcm. Therefore, Germany became the world's largest importer of pipeline natural gas, reaching imports of 85 bcm in 2014, with 38.5 bcm from Russia, 27.2 bcm from Norway and 18.1 bcm from Netherlands (WEC, 2018). Especially the dependency of Russian natural gas is an issue of debate in Europe, which is deepening with the construction of the Nord Stream 2 pipeline which is expected to be completed in late 2019, with an annual capacity of 55 bcm (Sherman & Wettengel, 2018).

Following the Fukushima accident, the nuclear phase out plans of Germany were expedited. The opposition faced by the general public, raised questions about nuclear safety. However, the phase-out plan by itself does not address the safety problem due to other nuclear power plants at close proximity. For instance, France, one of its neighboring countries generates 75% of its electricity from nuclear sources (WNA, 2018). Thus, to address all the concerns regarding nuclear a unanimous phase-out plan should be deployed in Europe. Nuclear waste on the other hand is another key problem related to the decommissioning. The radioactive waste that is being produced until 2022, must be disposed in Germany which has long-term risks (Unnerstall, 2017). The issue here becomes evident when "what happens with the waste?" comes into question, as a final repository for highly radioactive wastes in Germany, arranged as storage for medium and long-term radioactive materials is still not certain (Appunn, 2015).

Germany's Energiewende is not only important at national level, but is also increasingly affecting the international policy dynamics. For example, Germany pioneered support schemes for renewables by the late 1990s. As discussed throughout the chapter, advantages and disadvantages of the German experience of EEG offer a valuable insight for other countries, which introduced support mechanisms later on or have plans to do so. According to a research by Konrad-Adenauer-Stiftung: "both Russia and India mainly viewed Germany's Energiewende as a programme to expand the use of renewable energies and phase out nuclear power" (Konrad-Adenauer-Stiftung, 2014b). The second part of the same research shows similar results for BRICS countries (Brazil, Russia, India, China and South Africa) (Konrad-Adenauer-Stiftung, 2013).

When making general assessments of Energiewende within the context of global trends it is important to take into consideration different dynamics of energy markets of different countries. Particularly, it is important to lay down the long term economic and energy related targets. In this regard, to be able to understand how Energiewende might impact Turkish energy policies, the next chapter focuses on the energy transition of Turkey.

CHAPTER 4

ENERGY TRANSITION IN TURKEY

4.1. Introduction

In line with the global developments, Turkey has gone through major transitions. In this regard, Turkey, as a developing country, has a lot to learn from other country experiences as well as Germany. The landmark energy transition, Energiewende has many similarities compared to the Turkish experience. Therefore, this chapter is highly beneficial as it formulates a critical approach for the research question "Is Energiewende a unique energy transition model applicable to developing countries?".

The second chapter elaborated on energy transition experiences of various countries. Moving forward, the third chapter focused on Energiewende, the German energy transition. Adding on to these two chapters, this chapter analyzes the Turkish energy transition based on the methodology of the previous chapter. Both these chapters are formulated in the same order so that the following analysis can be conducted easily. Hence, Chapter 3 and Chapter 4 serve as baselines to the multidimensional analysis of Chapter 5.

This chapter focuses on the energy transition of Turkey, a developing and resource scarce country with growing demand. The growing demand led by the increasing population and economic activity has driven the recent developments in the country's energy system. To meet its growing demand, Turkey took extensive measures both in fossil fuel and renewables fronts. While import dependency and supply security have been the major drivers of the energy transition in Turkey, the discussions evolved beyond this point. Turkey experienced major transitions as well tremendous challenges throughout the process. There are still remaining questions over the lack of infrastructure requirement and high carbon emissions.

The aim of this chapter is fivefold: firstly, it provides basic indicators and figures to have a brief understanding on general economic and energy outlook of Turkey; secondly, it traces the legal and institutional framework that led to the energy transition in Turkey; thirdly, it provides policy papers and action plans including the main targets and measures to analyze the implementation process of the energy transition; fourthly, it analyzes the key motivations and challenges of these transition policies; finally, putting an overview into perspective, it analyzes how far Turkey has achieved its goals so far and what issues remain to be addressed.

4.2. Basic Indicators and Figures

4.2.1. Population

As of the end of 2018, 82.003.882 people that consists more than 1% of the world's population lives in Turkey (TÜİK, 2018). According to Turkish Statistical Institute (TÜIK), the population is projected to reach 87 million by 2023 and exceed 104.7 million by 2050 (Table 4.1).

Table 4.1 *Population by years, 2018-2050*

Year	*Population*
2018	82 003 882
2020	83 900 373
2025	88 844 934
2030	93 328 574
2035	97 176 768
2040	100 331 233
2045	102 843 989
2050	104 749 423

Source: (TÜİK, 2018)

4.2.2. GDP and Growth Rate

According to the World Bank data, with $851.1 billion GDP, Turkey is the 17th biggest economy in the world. The average GDP growth rate of Turkey was 5.8% on average between 2002 and 2017. Turkey has grown 7.4% in 2017 which made Turkey the fastest growing economy among G20 countries and the second among OECD countries (World Bank, 2019a). In parallel with the GDP increase Turkish electricity demand has been increasing 5.5% annually since 2002. It is expected that this increase will continue for a while in parallel with the economic growth. While the consumption was 132,553 GWh in 2002, it more than doubled and reached 294,919 GWh in 2017 (Figure 4.1).

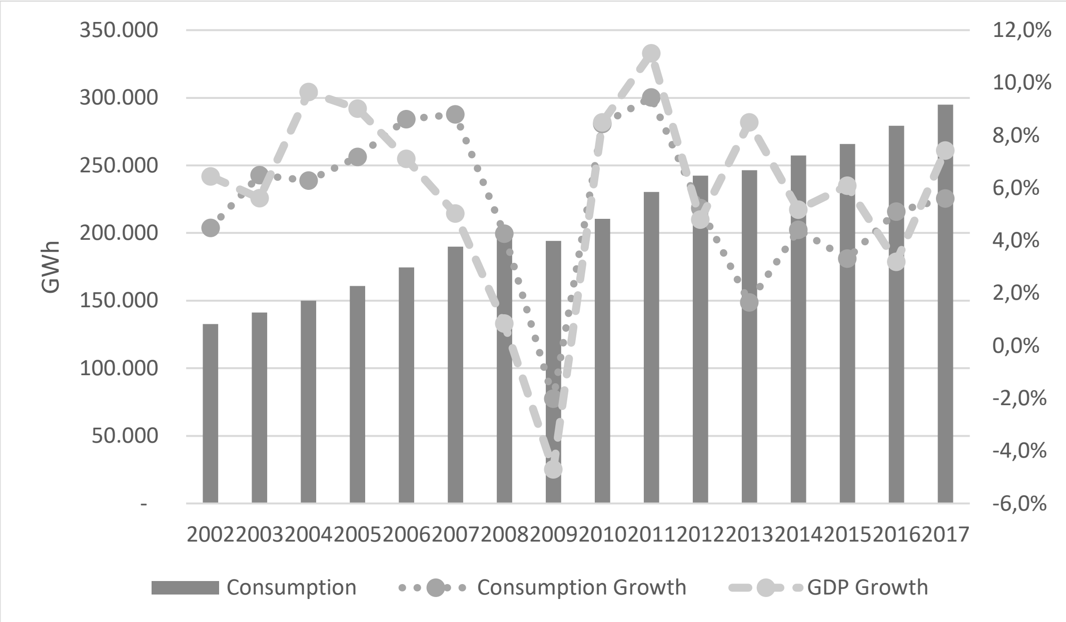


Figure 4.1 Consumption Growth vs. GDP Growth

Source: (World Bank, 2018) and (TEİAŞ, 2018)

4.2.3. Primary Energy Supply

Turkey’s primary energy consumption relies heavily on fossil fuels. Total primary energy supply in 2017 was 145,308 mtoe in total with natural gas, coal, petroleum, hydro and renewables consisting 30.5%, 27.2%, 30.5%, 3.4% and 6.7% of total share, respectively. Increase in primary energy supply was on average 4.37% per annum between 2002 and 2017 (Table 4.2).

Table 4.2 *Primary Energy Supply, 2001-2017 (Thousand TOE)*

	Coal	Petroleum	Nat. Gas	Hydro	Renewables	Others	Total
2001	20,006	30,676	13,479	2,065	1,413	6,211	73,850
2002	21,144	31,049	14,598	2,897	1,413	5,974	77,075
2003	23,316	31,719	17,633	3,038	1,264	5,748	82,720
2004	23,662	32,778	18,518	3,963	1,212	5,532	85,665
2005	24,033	32,199	22,416	3,402	1,297	5,325	88,672
2006	27,978	32,304	25,730	3,813	1,168	5,172	96,165
2007	31,144	33,326	30,263	3,097	1,231	5,008	104,067
2008	31,120	31,992	30,465	2,861	1,615	4,771	102,824
2009	32,228	29,091	29,535	3,092	2,119	4,674	100,739
2010	33,114	29,793	31,456	4,454	2,582	4,489	105,888
2011	34,897	30,430	36,861	4,501	3,174	3,508	113,371
2012	37,197	30,618	37,338	4,976	3,756	3,427	117,312
2013	33,433	32,130	37,628	5,110	4,614	3,399	116,314
2014	36,426	31,625	40,201	3,495	5,512	3,246	120,505
2015	34,593	39,209	39,651	5,775	6,974	2,938	129,140
2016	38,357	42,204	38,338	5,782	8,705	2,843	136,229
2017	39,459	44,278	44,319	5,007	9,710	2,531	145,305

Source: (MENR, 2018)

Turkey's total final primary energy consumption was around 111.7 mtoe[5] in 2017. Energy consumption more than doubled with an average annual increase of 4.5% between 2002 and 2017. The largest consumer in Turkey is industry with 31.7% share in 2017. Transport and residential sectors follow with 25.5% and 20.5% shares, respectively.

Table 4.3 *Primary Energy Consumption by Sectors in 2017 (Thousand TOE)*

Sector	*Consumption*	*Share*
Industry	35.318	31,7%
Transport	28.429	25,5%
Residential	22.836	20,5%
Commercial and Services	13.179	11,8%
Agriculture and Stockbreeding	4.227	3,8%
Non-Energy Consumption	7.372	6,6%
TOTAL	111.362	100%

Source: (MENR, 2018)

4.2.4. Installed Capacity

Electricity consumption in Turkey has been steadily increasing. The average increase in electricity consumption is 5.3% between 2002 and 2018. Turkey consumed 292.2 TWh electricity in 2018. During the same period, peak demand recorded 47.7 GW in 2017. Ratio between installed capacity over peak demand was 51.9% in 2018.

[5] The difference between total final consumption and total sectoral consumption is resulting from statistical difference. It is 289 thousand toe in the energy balance table for 2017.

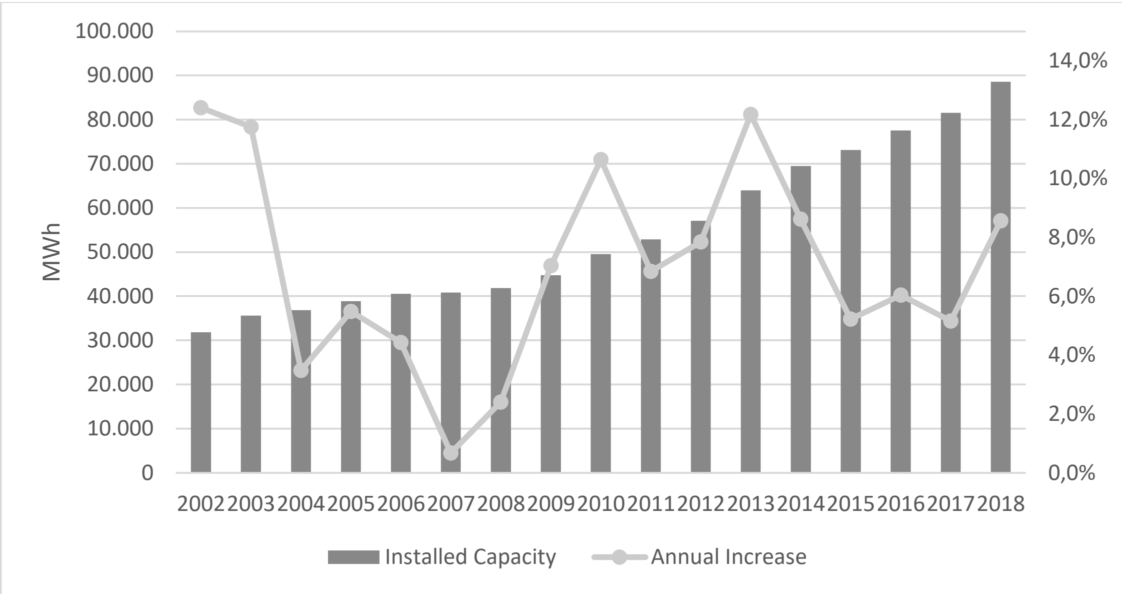


Figure 4.2 Installed Capacity

Source: (TEİAŞ, 2018)

In line with consumption, electricity generation capacity has been increasing. As shown in Figure 4.2, the total installed capacity has reached 88.6 GW by the end of 2018 with an increase of 178% since 2002. As of February 2019 the installed capacity has reached 89.1 GW.

4.2.5. Energy Imports

Turkey is a net energy importer. Energy import dependency has been increasing, reaching 75.7% in 2017 (Table 4.4). Energy production, imports and exports balance is provided in Table 4.4.

Table 4.4 *Energy Production, Imports and Exports Balance (Thousand TOE)*

	Prod. (+)	*Imports (+)*	*Exports (-)*	*Bunker (-)*	*Stock Chg.*	*Net Imports*	*Total Supply*	*Import Share*
2001	24,686	51,387	2,620	624	1,021	49,164	73,850	66.6%
2002	24,430	57,156	3,162	1,233	(115)	52,646	77,076	68.3%
2003	24,530	63,470	4,089	644	(546)	58,190	82,720	70.3%
2004	24,250	66,033	4,022	631	34	61,414	85,664	71.7%
2005	24,235	70,813	5,171	628	(577)	64,437	88,672	72.7%
2006	26,274	77,376	6,572	588	(325)	69,890	96,164	72.7%
2007	27,514	84,009	6,922	92	(442)	76,553	104,067	73.6%
2008	28,758	82,115	7,144	761	(144)	74,066	102,825	72.0%
2009	29,606	78,878	6,764	656	(325)	71,133	100,739	70.6%
2010	31,558	84,606	7,991	1,695	(589)	74,331	105,888	70.2%
2011	30,771	90,344	6,205	2,946	1,407	82,599	113,371	72.9%
2012	30,445	98,399	6,875	3,453	(1,204)	86,867	117,312	74.0%
2013	29,106	96,145	5,215	3,813	91	87,208	116,314	75.0%
2014	28,591	102,384	6,246	4,262	38	91,913	120,505	76.3%
2015	30,936	112,798	8,119	4,599	(1,877)	98,203	129,139	76.0%
2016	35,374	113,117	7,250	4,478	(534)	100,855	136,229	74.0%
2017	35,357	124,425	7,853	4,575	(2,050)	109,948	145,305	75,7%

Source: (MENR, 2018)

Turkey imported 99% of its natural gas and 90% of oil supply in 2017 (Table 4.5). Although imported crude oil is refined at domestic refineries and delivered to the final consumers, almost 60% of petroleum product supply is imported.

Turkey has substantial domestic coal reserves totaling 17.3 billion tons. Since these reserves are mostly low quality lignite, Turkey also imports hard coal to meet its demand.

Table 4.5 *Energy imports (2017)*

Type	*Amount*	*Share*
Natural Gas	55.249,95 mcm	99%
Crude Oil	25.766.549 tons	90%
Coal	37.465.679 tons	34%
Petroleum Products	16.886.871 tons	59%

Source: (EPDK, 2018)

4.3. Historical Background and Legislative Framework

Turkey's policies on transforming the economy to a liberalized free market shaped the energy markets before 2001. The first market oriented laws and regulations were enacted for the petroleum market in 1954. Until 1984, the electricity market was a monopoly and there was no natural gas market. Until the establishment of the Regulatory Authority in 2001, electricity and natural gas market related activities were considered as a public service which must be provided by the state directly or through private sector.

Enactment of the Electricity Market Law Nr. 4628 on the 20th of February 2001 marks a historical day for the Turkish energy markets. First time in history, an independent regulatory body was inaugurated to regulate and audit the electricity market. The regulatory body was initially established under the name of Electricity Market Regulatory Authority. Only two months later, the Natural Gas Market Law Nr. 4646 was enacted on 02 May 2001. By this law, the area of authority of the regulatory body was widened so as to include natural gas market and its name changed to Energy Market Regulatory Authority (EMRA). In the upcoming years, markets for petroleum and liquefied petroleum gases (LPG) were established and EMRA was authorized to regulate these markets as well.

Figure 4.3 provides important regulatory developments in the Turkish Electricity Market in a chronological manner. This section analyses these developments with discussions on the implications of these developments.

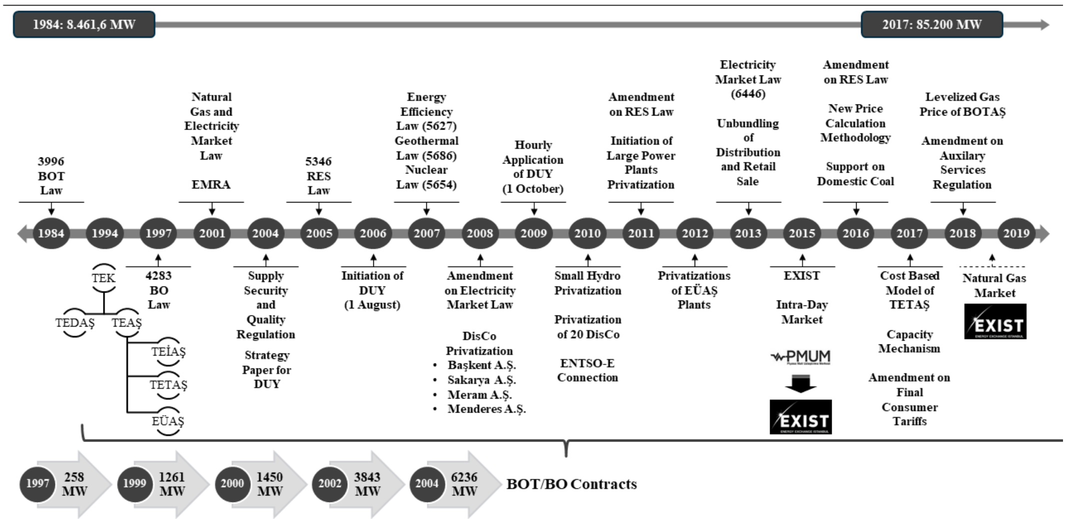


Figure 4.3 Electricity Market Developments

Source: (TETAŞ, 2017)

4.3.1. Electricity

Electricity generation in Turkey dates back to early 20th century. However, electricity demand started to increase since founding of the Republic in 1923. Increasing demand required substantial amount of investment on all segments of electricity including generation, transmission and distribution. In this regard, Turkey started to implement ambitious policy measures to create a competitive electricity and natural gas markets since 1960s. This part of the chapter mainly focuses on electricity market since the major developments in the natural gas market followed similarly. This subchapter discusses the evolution of the electricity sector in a chronological manner starting from the establishment of the Turkish Republic until today.

4.3.2. Founding of the Republic of Turkey (1923 – 1970)

During the beginning of the founding of the Republic of Turkey installed electricity capacity remained low. Nationalization of the electricity sector begun with the founding of Etibank and Electrical Power Resources Survey and Development Administration (EIEI). Until 1970s, several national institutions including Etibank and EIEI invested in electricity generation, transmission and distribution. During that times, transmission and distribution systems were not interconnected. They were run by different public institutions mainly by municipalities. Electricity generation, transmission and distribution was consolidated under one state entity Turkish Electricity Authority (TEK) in 1970.

State Driven Period (1970 – 1984)

TEK was founded as a state-owned economic enterprise in 1970 responsible for all electricity generation, transmission, distribution and trade activities. TEK was a monopoly for all the electricity related activities until 1984. The economic crises Turkey faced during late 1970s in line with the global energy crises which led to high petroleum prices, caused insufficient investment to meet the demand. After the post economic crises of late 70s and political turmoil in early 80s, Turkey, with a comprehensive policy shift, decided to open up the markets for private sector in 1984. The policy shift towards a more liberal market rather than a heavy state controlled economy was also reflected in the energy sector.

Turkish electricity consumption increased 9.6% per annum from 1970 to 1984 (TEİAŞ, 2018). Up until 1984, the ratio of installed capacity over peak demand was around 70%. Turkey had an intention to establish an environment for the private investors that is essential for a competitive electricity market. In this regard, the Government issued the Law Nr. 3096 on 4th of December 1984 regarding the Appointment of the Entities other than Turkish Electricity Authority for Electricity Production, Transmission, Distribution and Trade.

1980 - 2001

The Law Nr. 3096 dated 1984 paved the way for private companies to enter electricity market (*Official Gazette*, 1984). Announcement of the Built-Operate-Transfer (BOT) model in 1984 weakened the monopoly of TEK with private companies having opportunity to take place in the market.

The other important motivation for the law was to meet the increasing electricity demand and avoid possible energy shortages due to lack of installed capacity. The law provided investors to construct electricity generation facilities with BOT model (*Official Gazette*, 1984). In accordance with this law, eighteen hydro, four natural gas and two wind power generation facilities with a total capacity of 2.387,83 MW were constructed in 1990s (MENR, 2018). Even though, BOT model increased the installed capacity, their share remained only 6% in total installed capacity when the last BOT commissioned in 2005. The transfer obligation of the BOT model discouraged private sector to make additional investments. Owners of the BOT power plants were not eager to rehabilitate their plants because of the transfer obligation (TBMM, 1997). In this regard, Due to insufficiency of the Law of 1984 for the development of BOT power plants, a new Law was enacted in 1994 with a specific focus on BOT model. The new Law provided treasury guarantees for power plants with power purchase agreements. The BOT Law of 1994 attracted massive attention from both Turkish and foreign investors resulting in more than 200 project proposals.

Electricity sector reforms continued in 1990s. TEK was first divided into two companies with the Decree of the Council of Ministers dated 12 August 1993 and Nr. 93/4789 (*Official Gazette 1993*, 1993). Both of these companies were state owned-enterprises. One company named Turkish Electricity Generation and Transmission Company (TEAŞ) was responsible for the electricity generation, distribution and wholesale and the other company named Turkish Electricity Distribution Company (TEDAŞ) was responsible for the distribution of the electricity to the end users. Until the establishment of the Electricity Market

Regulatory Authority in 2001, electricity market activities were conducted mainly by these two state owned enterprises.

Turkey started to grant licenses for power plants with Built-Own (BO) model with the enactment of Law Nr. 4283 in 1997. Five power plants with 5.810 MW capacity in total were constructed under BO model (MENR, 2018). TEAŞ and TEDAŞ were designated as buyers of electricity from BOT and TOOR companies and autoproducers connected to the transmission and distribution grids, respectively. The autoproduction model enabled industrial companies to own and operate their own power plants for their consumption. Until 1984, most of the autoproduction facilities were in state-owned companies like sugar factories. With the enactment of Law Nr 3096 in 1984 and following additional regulations until 1999, companies were provided rights to jointly own and operate power plants which increased the investment in autoproduction facilities. With these changes, around 2300 MW of installed capacity was added until 2001.

Until 2000s, supply security concerns paved the way for BOT and BO models in the Turkish power market. However, treasury guarantees and expensive take or pay requirements discussions started to rise as supply security concerns started to ease. Thus, replacing these mechanisms with market-based approach was on the new policy agenda.

Turkey was hit by a severe economic crises in 2000-2001. A comprehensive reform package was announced following the crises. The reform package mainly covered the banking sector, albeit, energy market liberalization was a part of the package. The main laws and regulations regarding energy markets, mainly electricity and natural gas, were enacted in 2001.

Post-2001 Period

Turkish parliament has enacted two major laws in 2001: Electricity Market Law and Natural Gas Market Law. Although, these laws mainly established electricity and gas markets and Energy Market Regulatory Authority, specific measures related to market openness and bilateral contracting were provided. The following subsection elaborates on the key developments in the electricity sector after the enactment of Electricity Market Law.

Electricity Market Law Nr. 4628

An electricity market has been established in Turkey by the Electricity Market Law Nr. 4628 (*Official Gazette*, 2001). The main target of the Law was to form a competitive market structure with potential to attract private investment. The purposes and statements that were provided in the preamble of the law are important for understanding the philosophy underlying the law. It is also important to understand the conditions and motivations of that time which led to the formation of the law.

Turkey is a resource scarce country in terms of energy resources. The country's import dependency reached 75.7% in 2017. In 1999, only 35% of the primary energy demand could be met by domestic sources. Moreover, electricity demand had increased 8.5% per annum for two decades. Increase in the electricity demand was met by publicly financed projects between 1980 and 1990. Due to the economic crisis causing austerity measures in 1990s, Turkey followed a policy to increase private sector share in the energy investments over public investments. However, targets could not be reached due to legislative reasons and Turkey faced with the risk of energy shortages (The Grand National Assembly of Turkey, 2018).

By the Electricity Market Law, Turkey inaugurated a new market structure that ensures a free, competitive, cost based, transparent and non-discriminatory environment. As a first step, electricity market activities were unbundled. All activities were subject to licensing granted by the regulatory authority. Electricity Market Regulatory Authority (EMRA) was established under the Law and has been authorized to take regulatory measures, supervise and monitor the electricity market.

EMRA was responsible to prepare secondary legislation required for licensing, tariffs, market rules and procedures and balancing and settlement.

Some other important provisions of the law are as follows:

- TEAŞ is divided into three companies named the Turkish Electricity Transmission Company (TEİAŞ), the Electricity Generation Company (EÜAŞ) and the Turkish Electricity Trading and Contracting Company (TETAŞ),
  - TEİAŞ was established as the transmission system operator,
  - EÜAŞ was responsible from electricity generation,
  - TETAŞ was responsible from wholesale activities including the long-term power purchase agreement contracts,
- Licensed activities of the electricity market are defined as generation, transmission, distribution, wholesale, retail, import and export,
- Total installed capacity of any private power generation company including its affiliates cannot exceed 20% of the total installed capacity of Turkey in a respective year,
- As a natural monopoly, all the transmission activities is conducted by TEİAŞ,
- Total market share of any private wholesale company with its affiliates cannot exceed 10% of the total generation in Turkey in a respective year,
- Electricity Market Regulatory Commission is authorized to determine connection and system use tariffs, transmission tariff, wholesale tariff, distribution tariff and retail tariff,
- Market Financial Settlement Center (PMUM) is established by and under TEİAŞ in order to settle debts and credits of market players,
- No Treasury Guarantee will be granted to the electricity investments after the enactment of the law. (*Electricity Market Law*, 2013)

The law Nr.4628 frames a transformation towards *"competition in the market"* from *"competition for the market"* (TETAŞ, 2008). Before the enactment of the law, private companies were in a competition to invest on power plants with power purchase guarantees under Build-Operate (BO) or Build-Operate-Transfer (BOT) contracts. With the enactment of the law, any licensed company can build a power plant and sell electricity competitively. The same approach is applicable to the wholesalers and retailers. They can choose providers and customers freely.

Electricity Market Law Nr. 4628 of 2001 is a milestone for the Turkish electricity market as it forms the current structure of the market. Strong intention for a liberal electricity market is perceived from the provisions of transition period. Up until the repeal of the law by the new one in 2013, market share of private entities in generation increased from 18% in 2003 to 40%, 2142 licenses were granted, day-ahead and balancing markets were established, market openness ratio increased to 84%, 24 distribution companies and power plants held by EÜAŞ were privatized (EPDK, 2018).

Electricity Market Law Nr. 6446

Turkey has repealed the Electricity Market Law Nr. 4628 by the new Electricity Market Law Nr. 6446 on 14 March 2013 considering the development level of the electricity sector (*Electricity Market Law*, 2013). The law Nr. 4646 redefines the market operation activities as "the operation of organized wholesale power markets and the financial settlement of the transactions made in these markets". In accordance with the law, a separate entity to run the market operations was established. Energy Exchange Istanbul (EPİAŞ) has been established to operate day-ahead, intra-day and balancing markets.

With the new law, retail sales and distribution activities were unbundled and responsibilities of the market players were redefined. Until the enactment of the law, both the distribution and retail activities were carried out by regional distribution companies, commonly referred as DistCos. After the law, "assigned supplier companies" were established as a separate entity to run retail activities.

The new Law also increased the roles of EÜAŞ and TETAŞ. Both companies were regarded as active players in the market. EÜAŞ was given equal rights as the private sector licenseholders. TETAŞ was also given equal rights equal to any of the private wholesale companies. However, since the DistCos were obliged to buy a certain amount of electricity from TETAŞ, the prices to DistCos were regulated. State-owned companies were considered as important players to enable smooth transition towards a competitive market.

The final market structure after the enactment of Law Nr. 6446 is presented in Figure 4.4.

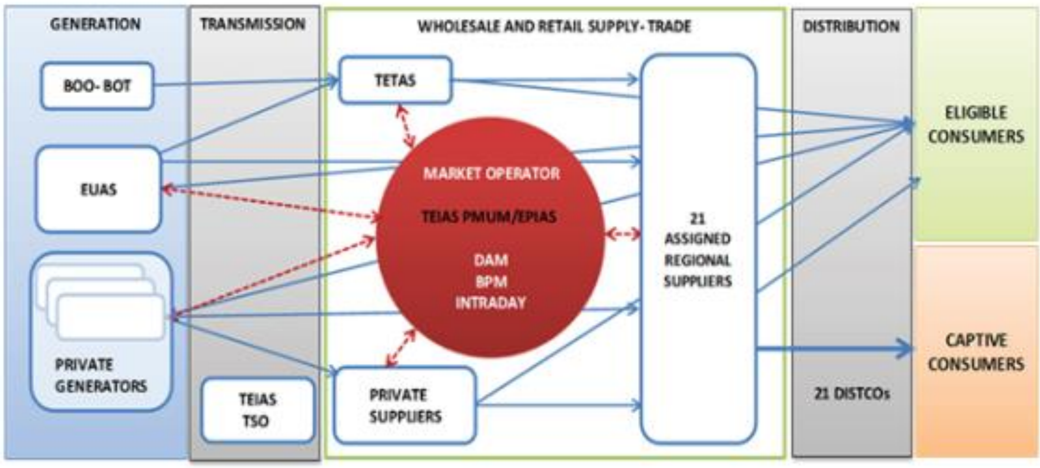


Figure 4.4 Final Market Structure

Source:http://documents.worldbank.org/curated/en/249831468189270397/pdf/ACS14951-REVISED-Box393232B-PUBLIC-EnergyVeryFinalEN.pdf

Unlicensed market activities were also defined for the first time under the Law Nr. 6446. After the law, unlicensed solar generation has shown significant boost with the support of the incentive mechanism under Renewable Energy Sources Law. The new law did not bring many structural changes to the market but it brought significant regulatory changes that are compatible with the market developments.

The developments in the electricity market had tremendous effects on all energy markets. The liberalization of the electricity market enabled reforms in all other subsectors. Market reforms in Turkey were observed in nuclear, coal as well as renewables. This section is followed by discussing the institutional and legal framework in all these subsectors.

Nuclear

Turkey's efforts for the construction of nuclear power plants date back to 1960s. As a first step, the General Secretariat of the Atomic Energy Commission was established in 1956. With the enactment of Law Nr. 2690 in 1982, the Commission was renamed as Turkish Atomic Energy Authority (TAEK). TAEK was empowered as both the supervisory and regulatory authority. In 2018, a new agency, Nuclear Regulation Authority (NDK), has been established to regulate the nuclear energy market.

Although, there have been lots of attempts to build a nuclear power plant since 1960s, all the potential projects failed. Only after the enactment of Law Nr. 5710 in 2007 a concrete step was taken in 2010 with the signature of the intergovernmental agreement of Akkuyu Nuclear Power Plant Project with the Russian Federation. This agreement followed by an intergovernmental agreement for Sinop Nuclear Power Plant Project with Japan in 2013. With the construction of these two nuclear plants, Turkey targets to include nuclear energy in its electricity generation by a 10% share until 2023.

Nuclear Law Nr. 5710

Law on Construction and Operation of Nuclear Power Plants and Energy Sale Nr. 5710 was adopted in 2007. The law aimed to involve private sector to construct nuclear power plants in Turkey. According to the law, necessary rights for plant would be granted to private companies by a tender under a BOO model in which the investments are supported by power purchase agreements with state entities TETAŞ being the offtaker.

According to this model, a tender for a power plant in Akkuyu site was held in 2008. There was only one consortium that was interested in the tender and the tender got cancelled. After several failed attempts for competitive tendering, the government decided to build nuclear power plants through intergovernmental agreements. In this regard, “Agreement between the Governments of the Republic of Turkey and of the Russian Federation for Cooperation on the Establishment and Operation of a Nuclear Power Plant at Akkuyu Site in the Republic of Turkey” was signed on the construction of Turkey’s first nuclear power plant on 12 May 2010. Second nuclear power plant is also planned to be constructed. In this respect, an Intergovernmental Agreement between Turkey and Japan was signed in May 2013.

Coal

Turkey has been investing in operation and exploration of coal reserves since the founding of the Republic. In this regard, Mineral Research and Exploration General Directorate (MTA) was established in 1935. To this day, MTA carries out exploration of coal activities in Turkey. In 1983, a separate entity, Turkish Hard Coal Enterprises (TTK), was established for exploration of hard coal. Regarding coal policies, Turkish Coal Enterprises (TKİ) founded in 1957 is responsible to utilize coal reserves in line with overall energy policies. Moreover, TKİ also decides on the volume and source of coal imports. Another important institution is EÜAŞ, state-owned electricity Generation Company, produces lignite for the power plants in the company’s portfolio. In total, there are four state-owned companies operating in the sector, MTA, TTK, TKİ and EÜAŞ. Moreover, private sector has an important role. Until 2013, state companies owned and operated coal fired power plants. These plants were privatized after Turkey initiated liberalization process for the large power plants in 2011. In due process, Seyitömer (600 MW, 2013), Kangal (457 MW, 2013), Yeniköy (420 MW, 2014), Kemerköy (630 MW, 2014), Yatagan (630 MW, 2014), Tunçbilek B (365 MW, 2015), Orhaneli (210 MW, 2015), and Soma B (990 MW, 2015) lignite fired power plants were privatized (IEA, 2016a).

Renewables

Early development of renewables in Turkey has started in 1935 with the establishment of General Directorate of Electrical Power Resources Survey and Development Administration (EIEI). EIEI was responsible from developing hydroelectric projects until the establishment of State Hydraulic Works (DSI) in 1954. Until 1980s, there were no policies on other renewable energy sources. EIEI started to research and measure wind power potential of Turkey in 1980s. The first geothermal power plant became operational in 1984. Although there were several attempts to increase renewable deployment through BOT model, the number of projects remained very low until 2001. Only hydro power was used for electricity generation in an average 30% of total generation.

Turkey has made successful reforms to utilize renewable energy in its energy mix since 2000s. The development of renewable capacity in Turkey started with the enactment of the Electricity Market Law in 2001 and increased significantly with the enactment of Renewable Energy Sources Law in 2005. After the enactment of the law notable increase in market players and renewable installed capacity were observed. Reforms concerning electricity trade and market structure including privatization have also supported renewable investments.

Renewable Energy Sources Law Nr. 5346

"Law on the Use of Renewable Energy Sources for the Purpose of Electrical Power Generation" (2005 RES Law) was enacted in May 2005. Turkey, for the first time, has announced its concrete support for the renewable energy sources by this law. 2005 RES Law promotes renewable energy sources for power generation as well as providing a sale and purchase mechanism for the generated electricity. The purposes of the law are as follows:

- Increasing the share of the renewable energy sources on the power generation,

- Decreasing import dependency,
- Gaining the economic value of renewable energy sources,
- Extending the lifetime of the domestic fossil sources of the country by decreasing their regular consumption share,
- Supporting the supply security by diversification of energy sources,
- Decreasing the GHG emissions in parallel with the international obligations,
- Gaining the economic value of the waste,
- Protection of the environment,
- Developing the required industry for the realization of the abovementioned purposes (TBMM, 2018).

High investment cost of the renewable power plants were taken into account under 2005 RES Law and some facilitating measures and incentives were provided to increase investments in renewables. The law eased the land acquisition procedure for renewable power plants and additionally offered 50% discount on acquisition fee for the state-owned lands. Moreover, the most important incentive in the law was the purchase obligation imposed on the retail sale entities. In a respective year, retail sale entities were obliged to purchase electricity from renewable energy power plants at a certain amount equivalent to 9% of their total power sales of the previous year. Such purchase guarantee was granted for 7 years to every renewable power plant after its commissioning. Moreover, the annual average of the wholesale electricity price was applied to the retail sale companies' purchases. The Council of Ministers had an authority to increase the price by up to 20%.

2005 RES Law brought momentum to the renewable power plant investments but the investment level remained below the targeted level. Considering the fact that the law was a transition regulation, it leaded up to developments of necessary industry for the utilization of the renewable energy sources and set a background for future regulations.

Amendment of RES Law

The 2005 RES Law provided power purchase guarantee for electricity generation from renewables. However, the feed-in-tariff level set by the law failed to attract interest from the market players since the market players preferred to sell their electricity in the market in which the prices are higher. Due to the low level of feed-in-tariff investment level remained low as well. To overcome this problem, amendment to the RES Law was introduced on the 29th December 2010.

The amendment brought structural changes to the support mechanism granted by the RES Law. A new feed-in tariff mechanism was granted to renewable power plants under a mechanism called Renewable Energy Resources Support Mechanism (YEKDEM). Introduction of YEKDEM, increased the investment in renewables and enabled solar power plants with high investment costs to be added to the electricity mix.

YEKDEM consists of feed-in-tariffs for electricity manufacturers producing electricity from renewables. Within the scope of the support scheme, assigned retail companies are obligated to purchase electricity from the power plants operating under YEKDEM. The support scheme consists of two parts: a feed-in-tariff and an additional local premium. In addition to the feed-in-tariff, electricity manufacturers can benefit from additional premium if they use locally manufactured equipment in their power plants. Both feed-in-tariffs and local premiums vary depending on the energy source.

The varying amounts which is included in the annex of the Law are presented in Table 4.6 and Source: (*6094 Sayılı Yenilenebilir Enerji Kaynaklarının Elektrik Enerjisi Üretimi Amaçlı Kullanımına İlişkin Kanunda Değişiklik Yapılmasına Dair Kanun*, 2011)

Table 4.7 below:

Table 4.6 *Feed-in Tariffs for the renewable power plants*

Renewable source	*Feed-in tariff (USD cent/kWh)*	*Power plant capacity*	*Period of time*
Wind	7,3	All sizes	10 years
Hydropower	7,3		
Geothermal	10,5		
Biomass	13,3		
Biogas	13,3		
Solar PV	13,3		

Source: (*6094 Sayılı Yenilenebilir Enerji Kaynaklarının Elektrik Enerjisi Üretimi Amaçlı Kullanımına İlişkin Kanunda Değişiklik Yapılmasına Dair Kanun*, 2011)

Table 4.7 *Premiums for the use of domestically manufactured equipment*

Renewable hardware components		*Premiums (USD cent/kWh)*
Wind	Blades	0,8
	Generator and power electronics	1,0
	Tower	0,6
	All mechanical parts	1,3
Hydro	Turbines	1,3
	Generator and power electronics	1,0
Geothermal	Steam or gas turbines	1,3
	Generator and power electronics	0,7
	Steam injector gas compressor	0,7
Solar PV	Panel integration	0,8

Table 4.7 (continued)

	Modules	1,3
	Cells which constitute modules	3,5
	Invertors	0,6
	Tracking system	0,5
Concentrating solar heat	Tubes	2,4
	Mirrors	0,6
	Tracking system	0,6
	Mechanical components of heat storage	1,3
	Mechanical components of heat collection	2,4
	Stirling engine	1,3
	Panel integration and mechanical construction	0,6
Biomass and landfill gas	Bearing with fluid based steam boiler	0,8
	Liquid or gas fueled steam boiler	0,4
	Gasification or gas cleaning components	0,6
	Steam or gas turbine	2,0
	ICE or Stirling engine	0,9
	Generator and power electronics	0,5
	Cogeneration	0,4

Source: (*6094 Sayılı Yenilenebilir Enerji Kaynaklarının Elektrik Enerjisi Üretimi Amaçlı Kullanımına İlişkin Kanunda Değişiklik Yapılmasına Dair Kanun*, 2011)

According to the Law, all renewable power plants that became operational since 18 May 2005 (effective date of 2005 RES Law) and will be operational by the end of 2015 are able to benefit from the feed-in tariff mechanism, provided in Table 4.6 and Source: (6094 Sayılı Yenilenebilir Enerji *Kaynaklarının Elektrik Enerjisi Üretimi Amaçlı Kullanımına İlişkin Kanunda Değişiklik Yapılmasına Dair Kanun*, 2011)

Table 4.7, for 10 years. The deadline was later extended to the end of 2020 (*6094 Sayılı Yenilenebilir Enerji Kaynaklarının Elektrik Enerjisi Üretimi Amaçlı Kullanımına İlişkin Kanunda Değişiklik Yapılmasına Dair Kanun*, 2011).

After the enactment of the Amendment to the RES Law and related secondary regulation, significant boost was observed in the renewable power plant investments, in particular solar.

Electricity Market Law Nr. 6446

The Electricity Market Law enacted in 2013 that paved the way for unlicensed renewable power plants was another turning point for renewable energy deployment. According to the law, renewable power plants with an installed capacity below 1 MW will no longer be required to obtain license from EMRA.

Regulation on Renewable Energy Resource Areas (RE-ZONE)

Turkey changed the renewable energy investment scheme by taking into account two important concerns. Firstly, technological improvements on renewable energy power plants have decreased the investment costs eventually causing feed-in tariffs in most of the countries to be considered as very high compared to market level. Secondly, increasing share of renewable energy sources in the energy mix was decreasing the energy import dependency on one hand; Turkey became import dependent on equipment for the renewable investments on the other.

In light of these concerns, the Ministry of Energy and Natural Resources announced a Regulation on Renewable Energy Resource Zones (RE-ZONE) on October 9, 2016 which introduced a new investment model to increase renewable energy investments while incentivizing local equipment production (*6719 Sayılı Elekrik Piyasası Kanunu Ile Bazı Kanunlarda Değişiklik Yapılmasına Dair Kanun*, 2016). In accordance with the Regulation, the Ministry of Energy and Natural Resources has authorized to grant capacity right for certain renewable energy zones to the investors through a competition with a domestic manufacturing obligation of the equipment. In doing so, Turkey aims to decrease import dependency for the renewable investments and become a self-supplier. Moreover, the investors would determine the optimal feed-in tariffs in a competitive manner.

The main purposes of the Regulation are;

- Efficient use of renewable energy,
- Rapid realization of the required investments,
- Local manufacturing of renewable equipment,
- Job creation,
- Technology transfer to support research and development. (Karagöl et al., 2017)

Environmental Policies

Environmental policies play crucial role in shaping the energy markets. To better understand the impacts of environmental goals on energy policies it is important to discuss the brief history of international climate agreements.

The United Nations Framework Convention on Climate Change (UNFCCC), convened in 1992 at the United Nations Conference on Environment and Development (UNCED) in Rio, is considered to be the major global climate agreement that paved the way for the rise of both Kyoto Protocol and Paris Agreement.

UNFCCC is built on the "Common but differentiated responsibilities" principle which asserts that "The Parties should protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities. Accordingly, the developed country Parties should take the lead in combating climate change and the adverse effects thereof" (UNFCCC, 1992) (Article 3.1). In this respect, when UNFCCC was adopted, signatories of the Convention were classified under three main groups: Annex I, Annex II and non-Annex I. Annex I includes mainly the industrialized countries that are OECD members and countries with economies in transition (EIT). Annex II Parties are a subset of Annex I Parties which consists of OECD members without including EIT Parties. Lastly, non-Annex I include mostly the developing countries

A member country's responsibility varies depending on their group as provided in the Convention. According to the Convention, Annex I countries are obligated to "adopt national policies and take corresponding measures on the mitigation of climate change. Annex II Parties "shall provide new and additional financial resources". These "financial resources" are allocated to support technology transfer and climate change mitigation efforts of developing countries. Unlike Annex I and II Parties, non-Annex I Parties have significantly less responsibilities. They are obligated to "formulate, implement, publish and regularly update national […] programmes containing measures to mitigate climate change" (UNFCCC, 2006).

Turkey has been a signatory party to UNFCCC since 1992. As a founding member of the OECD, Turkey is included in both Annex I and Annex II under UFCCC listing. Realizing the potential consequences of the responsibilities brought by Annexes after the adopting the Convention, Turkey started diplomatic efforts to change its listing. In this regard, Turkey has rejected the ratification of the Convention until 2000s.

During COP3 in 1997 when the Kyoto Protocol was signed, Turkey stated in its position paper submitted to the secretariat that: "Turkey has a long standing demand of deletion of its name from the Annexes, to be able to become a party to the

UNFCCC"(Republic of Turkey Ministry of Foreign Affairs, n.d.). During COP7 in 2001 a decision to "[...] delete Turkey's name from the Annex II and to place Turkey among the Annex I countries, taking into account its special circumstances, differentiating it from other Annex I countries [...]" was adopted (Republic of Turkey Ministry of Foreign Affairs, n.d.). The Decision 26/CP.7 of COP7 "Invites the Parties to recognize the special circumstances of Turkey, which place Turkey, after becoming a Party, in a situation different from that of other Parties included in Annex I to the Convention". When the decision came into force, Turkey became only an Annex I country. Shortly after, in 2004, Turkey has ratified the Convention.

At COP16 in 2010, all Parties formally accepted Turkey's "special circumstances". With the realization of "special circumstances", Turkey became eligible for financial support under the framework of the Convention. During COP18 and 20, Annex II countries were further forced to provide financial support to Annex I Parties with special circumstances like Turkey which enabled Turkey to receive funding from Global Environmental Facility (GEF).

Turkey's *"special circumstances"* lies in its economic indicators. According to the Intended Nationally Determined Contribution of Turkey (INDC) "Turkey achieved 230 per cent increase in GDP between 1990 and 2012. Its population has increased more than 30 per cent since 1990. Turkey's energy demand increases by 6-7 percent every year" (United Nations, 2012). Thus, in order to ensure sustainable growth and meet increasing energy demand, Turkey's position is that the country should to be treated in a different manner and benefit from climate finance mechanisms. Turkey should access the technology, capacity building and financial support to challenge adverse effects of climate change. Turkey submitted provision to remain eligible to utilize GEF after 2020 (Republic of Turkey Ministry of Foreign Affairs, n.d.). Turkey became a party to the Kyoto Protocol in 2009 without emission reduction commitment despite being an Annex I Party. As a member of Annex I, Turkey has not been eligible to receive any funding from Clean Development Mechanism (CDM) under the Kyoto Protocol.

After the Kyoto Protocol, the Parties were invited to submit their INDC's to the secretariat of the UNFCCC before Paris Conference in 2015. Turkey's final INDC is "Up to 21 percent reduction in GHG emissions from the Business as Usual (BAU) level by 2030." (United Nations, 2012). Turkey also provided its plans and policies to reach INDC target for all the sectors. Energy related plans and policies are as follows:

- Increasing capacity of production of electricity from solar power to 10 GW until 2030,
- Increasing capacity of production of electricity from wind power to 16 GW until 2030,
- Tapping the full hydroelectric potential,
- Commissioning of a nuclear power plant until 2030,
- Reducing electricity transmission and distribution losses to 15 percent at 2030,
- Rehabilitation of public electricity generation power plants, and
- Establishment of micro-generation, co-generation systems and production on site at electricity production (Karagöl et al., 2017).

The Paris Agreement has entered into force on 4 November 2016. Turkey has not ratified the agreement yet. Turkey demands to be eligible for compensation for some of the financial costs of compliance for the ratification of the agreement. Turkish President Recep Tayyip Erdoğan stated in a news conference in the G20 leaders summit in Hamburg, Germany on 8 July 2017 that "So we said if this [eligibility for compensation] would happen, the agreement would pass through parliament. But otherwise it won't pass" (Reuters, 2019). Turkey demands to be removed from Annex I and have access to climate finance. However, the proposal of Turkey on the draft agenda concerning the removal of Turkey from Annex 1 was not accepted in the COP24 in Poland on 2-16 December 2018. For now, the Parties agreed to establish a working group for the climate finance to be granted to Turkey.

To summarize the developments in global environmental talks and Turkey's position history of environmental negotiations are listed in Figure 4.5 in a chronological manner.

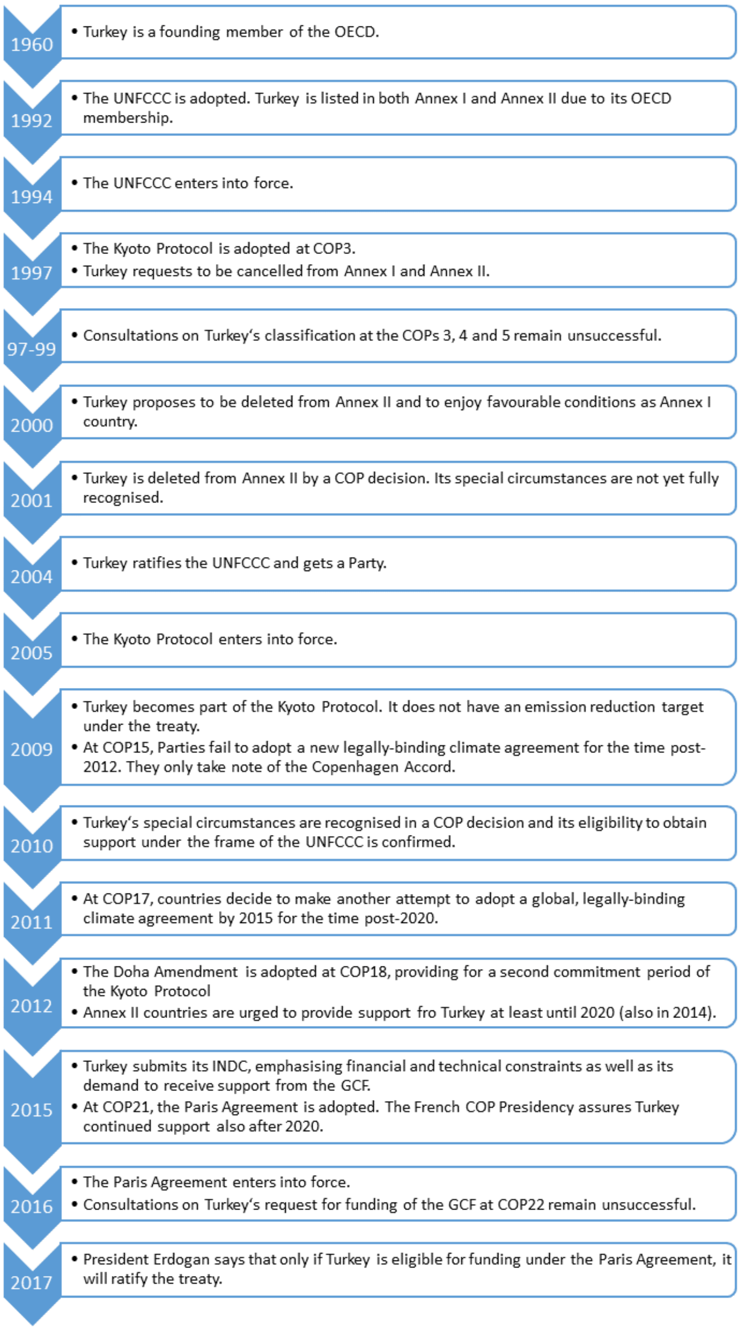


Figure 4.5 Turkey's Position History of Environmental Negotiations

Source: http://climateobserver.org/tangled-case-turkey-status-unfccc-paris-agreement/

4.3.3. Energy Efficiency

Energy efficiency is a backbone of a transition towards low carbon economy. Turkey has made substantial improvements in establishing a legal framework to support energy efficiency. Between 1981 and 2007, EIEI was the institutional body responsible from energy efficiency policy making, implementation and monitoring. Energy Efficiency Law came into force in 2007. With the enactment of the law, an Energy Efficiency Coordination Board (EECB) was established to coordinate related plans and policies. Moreover, in 2011 EIEI was abolished and the responsibilities were given to the General Directorate for Renewable Energy (General Directorate of Energy Affairs since 2018). The legislative framework discussed below provides the legal basis for all the policies that are being implemented.

The Energy Efficiency Law Nr. 5627

The Energy Efficiency Law Nr. 5627 was enacted in 2007 and its secondary legislation was implemented in 2011. Purposes of the law is to increase efficient use of energy by avoiding waste, decreasing the burden of energy costs on economy and protecting the environment (Karagöl et al., 2017).

The Energy Efficiency Law aims increasing and promoting efficiency in energy generation, transmission, distribution and consumption in the sectors of industry, buildings, power generation and transportation. It also addresses raising energy awareness and increasing utilization of renewable-energy sources. The Ministry of Energy and Natural Resources[6] is responsible for the duties below:

- Trainings (energy manager, survey project and international trainings),
- Survey (industrial enterprises, commercial and service buildings, public buildings, dwellings),
- Authorizations (Energy Efficiency Consulting Companies, Universities and Trade Association),
- Measuring, Monitoring and Evaluation, Audit,
- Energy Efficiency Supports (Increasing Efficiency Project and Voluntary Agreements),
- Promotion and Awareness,
- Energy Efficiency Forum and Fair,
- National and International Projects Development,
- Planning and Coordination of the Activities related to the Efficiency,
- Actions and Training Activities on Efficiency, Greenhouse Gas Emission and Monitoring. (MENR, 2017)

Regulations

A year following the enactment of the Energy Efficiency Law, the Regulation on Increasing Efficiency in The Use of Energy Resources and Energy was published.

"The purpose of this regulation is to set out the principles and procedures applicable to increasing efficiency in the use of energy resources and energy for ensuring efficient use of energy, avoiding the extravagance of energy, alleviating the burden

[6] Department of Energy Efficiency and Environment established under the Ministry of Energy and Natural Resources in January 2019 and authorized to conduct all activities related to energy efficiency.

of energy costs on the economy and protecting the environment" (Official Gazette, 2008).

There are many other regulations that came into force since the enactment of the Law. These regulations target specific areas ranging from energy performance standards of the buildings to promotion of energy efficiency in transportation, energy labelling for air conditioners, support for small and medium-sized enterprises (SME) and many others. All these laws and regulations lay the groundwork for further policy implementations.

4.4. Energy Policies towards Transition

Turkish energy markets can be described by two main characteristics: growing demand and import dependency. These characteristics are also the major challenges that are being faced. According to the IEA, Turkey would observe the fastest medium to long-term growth in energy compared to other IEA members (IEA, 2016a). Energy import dependency based on primary energy resources in around 70% (IEA, 2016a). To meet its growing energy demand while decreasing import dependency at the same time, Turkey started implementing major market reforms and transform its energy markets. The main objectives were to establish financially viable, stable, transparent, and competitive markets under independent regulation to ensure reliable and affordable energy supply to consumers in an environmentally friendly manner (Bayraktar, 2018).

Turkey has gone through a major energy transition since 2002. The energy transition of Turkey can be delineated into two periods: Transition 1.0 and Transition 2.0. During Transition 1.0, market activities were unbundled and the vertically integrated state monopoly model was turned into a well-functioning competitive market model together with the privatization of generation and distribution assets (Bayraktar, 2018). Opening the market to competition while meeting the increasing demand was not an easy process. During the same period, the government's role has shifted more towards regulation and policy-making.

In 2017, 16 years following the first transition period, the Ministry of Energy and Natural Resources announced its National Energy and Mining Policy (NEMP). NEMP is established on three main pillars: security of supply, localization, and predictability in the markets. The new approach brought by these policies marks the second transition period, Transition 2.0. This policy clearly defined the strengths, shortcomings, threats, and opportunities of the Turkish energy sector. This period is referred as Transition 2.0 due to its comprehensive approach ranging from energy to industry, industry to employment.

This subchapter elaborates on Transition 1.0 and Transition 2.0 with a specific focus on the strategy papers and action plans published during these periods which pave the way for the enactment of the policies leading to the energy transition.

4.4.1. Transition 1.0 (2001 – 2016)

Two electricity sector specific strategy papers were published regarding the measures to be taken during the transformation period and formation of the future market structure after the establishment of electricity market in 2001. The first strategy paper dated 17 March 2004 is about the reforms of the electricity sector and privatization of the state utilities. The paper includes detailed schedule for the privatization process and targets to establish a temporary balancing and settlement mechanism for the transactions among the market players.

Distribution in Turkey was divided into 21 regions by the strategy paper and their privatization was scheduled to complete until the end of the first quarter of 2005. It was foreseen that the privatization of the power plants was completed by the end of 2009 (MENR, 2004).

This paper was revised and enlarged in 2009 under the name of Electricity Market and Security of Supply Strategy Paper (MENR, 2009). However, distribution privatization and power plant privatization could not be finalized until 2010 and 2012, respectively.

The temporary balancing and settlement mechanism framed a free market based on bilateral sale and purchase contracts. The intention of the mechanism was to apply regional cost-based tariffs for distribution companies and national fixed tariffs for non-eligible customers in a compatible manner. The mechanism came into force in 2006 and was used until the establishment of the Energy Exchange of Istanbul (EXIST) in 2015.

According to the Law Nr. 5018, all public bodies in Turkey have to prepare a five year strategic plan which includes mid-term and long-term goals, base policies, targets and priorities as well as practices and sources. MENR published its first strategic plan in 2010 for the period of 2011-2014. In 2015, a new plan for 2015-2019 was approved and is still in place.

Energy efficiency is an integral part of the energy transition in Turkey. In this regard, during Transition 1.0, Energy Efficiency Strategy Paper was published providing a detailed roadmap of energy efficiency action plans for various sectors from transportation to buildings to industry.

2010 – 2014 Strategic Plan

The first comprehensive strategic plan for Turkish energy sector was published in 2010 covering the 2010-2014 period (MENR, 2010). Among the themes, goals and objectives, the most important part of the plan was considered as the Strengths, Weaknesses, Opportunities, Threats (SWOT) analysis of the energy sector. Although, strengths and weaknesses focused on MENR's organizational structure, there were important findings concerning Turkish energy sector under opportunities and threats:

Table 4.8 *Opportunities and Threats in 2010-2014 Strategic Plan*

Opportunities	*Threats*
• Geostrategic advantages of Turkey	• High import dependency on primary energy demand.
• Substantial renewable sources	• High capital necessary for the efficient use of the domestic and renewable sources for the electricity generation
• High potential on energy efficiency	• High volatility of energy prices.
• Increasing regional cooperation opportunities.	• Political instability of the region.
	• Foreign effects concerning the use of the cross-border hydro sources.
	• Contradiction of Turkey's energy hub policy with other countries' energy policies.
	• Increase in greenhouse gas emissions and climate change including Turkey's international commitments on climate change.
	• Lack of confidence of investors regarding market measures.
	• Investment requirements as well as restrictions arising out of the accession procedure of EU regarding in particular climate change.

Source: (MENR, 2010)

Threats analysis of the strategic plan needs particular attention. It can be asserted that starting from 2010, energy policies and energy transition of Turkey can be characterized to deal with these threats. Some of the objectives under 2010-2014 Strategic Plan and their results are provided below:

Table 4.9 *Objectives and application results of 2010-2014 Strategic Plan*

Objectives	*Results*
• Completion of the ongoing installation of 3.500 MW domestic coal power plants until the end of 2013	• Only 100 MW capacity has been put into operation.
• Start of the construction of nuclear power plant until 2014	• Marine infrastructure construction started in 2015 and Groundbreaking Ceremony for the terminal was held in 2018.
• Completion of the 5.000 MW hydro power plants until the end of 2013	• Between 2010 and 2013, 7.736 MW hydro power plant added to installed capacity.
• Increasing the wind installed capacity from 802,8 MW as of 2009 to 10.000 MW by 2015	• 4.139,5 MW capacity of wind power plant added to the installed capacity by 2015.
• Increasing the geothermal installed capacity from 77,2 MW as of 2009 to 300 MW by 2015	• Geothermal installed capacity increased to 546,7 MW by the end of 2015.
• 10% decrease of energy intensity until 2015 in comparison to 2008	• 13,8% decrease of energy intensity reached by the end of 2013.

Table 4.9 (continued)

• Doubling the natural gas storage capacity by 2015 that is 2,1 bcm as of 2009	• Natural gas storage capacity was not changed in the Strategic Plan period.
• Ensuring the natural gas source diversification by decreasing the import share of the first source country under 50%	• Share of Russia in total natural gas imports was 54.76% in 2014.
• Decreasing the greenhouse gas emissions increase rate attributable to the energy after 2014.	• In 2010 84.99% of total greenhouse gas emissions was emitted by energy use. In 2016, this share was increased to 86.1%.

Source: (EPDK, 2018) (TEİAŞ, 2018)

As seen in the Table 4.9 above, hydro, geothermal and energy intensity related objectives were exceedingly reached. Since, there was almost no additional capacity of coal power plants and limited wind capacity was added to the system compared to the targeted level, a total of 16.250 MW renewable capacity including hydro was added during the strategic plan period. Moreover, 6.702 MW of natural gas power plants were put into operation which compensated the shortfall in the targeted level of coal power plants (Table 4.10).

Table 4.10 *Installed capacity by sources 2009-2015 (MW)*

Year	*Thermal*	*Hydro*	*Geothermal*	*Wind*	*Solar*	*Total*
2009	29.339,1	14.553,3	77,2	791,6		44.761,2
2010	32.278,5	15.831,2	94,2	1.320,2		49.524,1
2011	33.931,1	17.137,1	114,2	1.728,7		52.911,1
2012	35.027,2	19.609,4	162,2	2.260,6		57.059,4
2013	38.648,0	22.289,0	310,8	2.759,7		64.007,5
2014	41.801,8	23.643,2	404,9	3.629,7	40,2	69.519,8

Year	*Thermal*	*Hydro*	*Geothermal*	*Wind*	*Solar*	*Total*
2015	41.903,0	25.867,8	623,9	4.503,2	248,8	73.146,7

Source: (TEİAŞ, 2018)

Overall, the objectives concerning the electricity sector and energy intensity under the 2010-2014 Strategic Plan can be considered as achieved. However, the progress regarding natural gas sector still falls beyond the objectives.

2015 – 2019 Strategic Plan

MENR published its second strategic plan, 2015 – 2019 five years Strategic Plan, in 2015 (MENR, 2015). The plan includes 8 themes, 16 goals and 62 objectives. It was stated in the plan that the unsuccessful or partially successful objectives of the 2010 – 2014 Strategic Plan was reevaluated and inserted to the new plan with necessary changes. Since the main focus of the energy transition in on the electricity sector, the evaluation below concerns the electricity part of the strategic plan.

2015 – 2019 Strategic Plan includes results of SWOT analysis of every theme. Table 4.11 below provides electricity related findings of these SWOT analysis.

Table 4.11 *Findings of SWOT Analysis in 2015-2019 Strategic Plan*

Theme	*Findings*
Theme 1 - Security of Energy Supply	• Natural gas dependency on electricity generation is as an important risk. • Sustainable sectoral growth needs investments on transmission and distribution infrastructure. • In order to utilize renewable sources to energy mix, financial opportunities should be improved, legislation should be updated and transmission infrastructure

Table 4.11 (continued)

	should be strengthened; furthermore investor awareness should also be increased • Turkey, due to its position, is suitable for being an energy transition center (hub); however relevant infrastructure, market formation and regional effectiveness should be provided. • Legislation and market structure should be developed for enabling an active demand management implementation.
Theme 2 - Energy Efficiency and Energy Saving	• Necessary financial and technical support should be provided for the utilization of its high energy efficiency potential. • The MENR required to take active role on awareness campaigns for energy efficiency and energy saving as well as model applications. • Country-wide energy intensity analysis should be implemented with the coordination of relevant authorities and non-governmental organizations. • It is necessary to complete rehabilitation and modernization of public power plants.
Theme 5 - Technology, R&D and Innovation	• An "Energy and Natural Resources R&D Strategy" and the preferential areas should be determined. • Commercialization of existing R&D studies are necessary. • Cooperation among public, university and industry is not satisfactory. • Information acquired by the parties which generate information and technology are not gathered in a central unit.

Table 4.11 (continued)

Theme 6 – Improvement of Investment Environment	• The share and impact of the public is required to be decreased in the market in line with liberalization process

Source: (MENR, 2015)

Taken into account the SWOT analysis, MENR provided certain objectives for the span of the plan. Table 4.12 below presents the related objectives and their progress as of 2017.

Table 4.12 *Objectives and their progresses of 2015-2019 Strategic Plan*

Objectives	*Progresses*
• Electricity and natural gas transmission system shall be constructed and operated according to (n-1) criteria, disabling of a critical part of the system, in line with short and medium term supply demand balance and long term generation development plan.	• Completed.
• Electricity generation from domestic coal shall be increased to 60 billion kWh annually by the end of the plan period.	• 46.4 billion kWh in 2017. Includes lignite, hard coal and asphaltite.
• The share of renewable energy resources in primary energy supply and electricity generation shall be increased.	• Share of geothermal, wind and solar installed capacity was 7.3% in 2010. As of 2017 it reached 12.9%. Share of generation increased to 9.8% in 2017 from 6.5% in 2015.

Table 4.12 (continued)

• Nuclear energy shall be included into electricity generation portfolio.	• The first unit of Akkuyu NPP is planned to commission in 2023.
• The share of natural gas in electricity generation within total generation shall be reduced to 38% until the end of the plan period.	• The share of natural gas in electricity generation within total generation was 37.18% in 2017.
• Loss and illegal consumption rate in electricity distribution shall be reduced to 10% until the end of the plan period.	• In 2017, average transmission and distribution loss was 12.47%.
• Transition system shall have a permanent connection with ENTSO-E.	• Completed

Source: (EPDK, 2018) (TEİAŞ, 2018)

Some of the targets within the 2015 – 2019 Strategic Plan could not be reached yet, it is a matter of time to see the exact results before commenting on the general success. Increase in the share of the renewable energy sources and decrease in the share of natural gas in electricity generation are significant results of the plan. Targets in the performance indicators concerning renewables have already been reached. For geothermal, solar and biomass the targets are exceeded. Considering the power plants that under construction, 4.000 MW hydro and 3.177 MW wind, the respective 32.000 MW and 10.000 MW targets would be reached.

Additionally, the plans and policies regarding environmental policies submitted in the INDC have also taken place in the 2015-2019 Strategic Plan and subsequent National Energy and Mining Policy Paper.

Energy Efficiency Strategy Paper

Turkey's Energy Efficiency Strategy Paper is an executive policy annex to the Energy Efficiency Law which covers the years between 2012 and 2023. The target stated in the paper is to decrease primary energy intensity by 20% until compared to the base year 2011 (MENR, 2015). Industry specific subtargets for each sector is also determined by the paper. According to the Strategy Paper, each industry subsector is obliged to reduce energy intensities in each industry by at least 10% by 2023.

The strategy paper provides a detailed roadmap of energy efficiency actions for many sectors. Additionally, it identifies the policy mechanisms to achieve these targets.

The strategy also establishes an Energy Efficiency Advisory Committee composed of members from both public and private sectors as well as NGOs. The main responsibility of the committee is to monitor the progress of the strategy document. The strategy is examined and revised by the by the Energy Efficiency Coordination Board every four years.

4.4.2. Transition 2.0 (2017 – beyond)

The points discussed in Transition 1.0 refer to past developments and achievements. Turkish energy markets are still in a transition period. Liberalization and intensive investments are ongoing amidst climate change challenges and supply security concerns. To address these issues the Ministry of Energy and Natural Resources announced a comprehensive policy in 2017: The National Energy and Mining Policy (NEMP). The new approach brought by these policies marks the second transition period, Transition 2.0.

Energy efficiency constitutes an integral part of Transition 2.0. With increasing energy demand causing an increase in import dependency, the Government prioritizes energy efficiency policies. In this regard, Turkey announced the National

Energy Efficiency Action Plan (NEEAP) in early 2018. NEEAP sets out actions to implement a reduction in primary energy consumption via several sectoral measures including buildings and services, energy, transport, industry and technology, agriculture, and cross-cutting areas.

National Energy and Mining Strategy Paper

Turkey announced National Energy and Mining Policy Paper in 2017. The reforms towards restructuring of the energy sector since 2002 had been particularly focusing on liberalized energy markets. In due course of time, the energy markets has reached a level of maturity to handle energy transition policies. Assuming the policies and strategies from 2002 until 2017 were the first stage of energy transition of Turkish energy sector, it can be asserted that the second stage of the transition has started by the National Energy and Mining Policy Paper.

The strategy paper is built on three main pillars, namely, "Energy Supply Security", "Localization" and "Predictability in the Market". Table 4.13 below provides the important strategies and targets included in the strategy paper.

Table 4.13 *Strategies and targets under NEMP Paper*

	Strategies	*Targets*
Security of Supply	• Source and route diversification on crude oil and natural gas, • Increasing entry capacity of the natural gas transmission system and storage capacity,	• 10 billion cubic meters of natural gas and 5 million tons of oil storage capacity, • Exploration activities in the Black Sea and Mediterranean, • Natural gas supply to all of the cities, • 8.4 billion USD savings in energy costs.

Table 4.13 (continued)

	• Acceleration in the hydrocarbon exploration and drilling activities, • Development of the energy transmission and distribution infrastructure, • Increasing energy efficiency.	
Localization	• Improvement in the renewable energy areas by RE-ZONES, R&D and domestic manufacturing, • Including nuclear energy in the energy mix,	• Minimum 30% of renewables share in the power generation, • Minimum 10% share of nuclear in the power generation by 2023,
Predictability in the Market	• Improvement of procurement infrastructure, • Restructuring the public institutions, • Boosting the electricity and natural gas markets.	• Development of natural gas storage, FSRU and LNG infrastructures, • Restructuring the public utilities like Electricity Transmission Company (TEİAŞ), Petroleum Pipeline Company (BOTAŞ), Turkish Petroleum and Eti Mine for the integration of energy exchange, • Increasing the operability of the energy exchange.

Source: (SETA, 2017)

National Energy Efficiency Action Plan

The National Energy Action Plan which came into force in 2018 contains 55 actions defined under 6 categories namely buildings and services, energy, transport, industry and technology, agriculture and cross-cutting areas. The measures include increasing the use of renewable energy, district heating in the buildings, supporting combined heat and power use across industries, promoting energy efficient vehicles, reducing traffic intensity among many others. Moreover, the Action Plan envisages the establishment of a financing mechanism and preparing a regulatory framework for heating and cooling market (MENR, 2016). Expected energy savings is 23.9 mtoe cumulatively by investing 10.9 billion USD by 2023. This saving is equal to decreasing primary energy consumption of Turkey by 14% by 2023 compared to the baseline scenario. Expected savings by 2033 is 30.2 billion USD (MENR, 2019).

During the official launch of the Action Plan Minister of Energy and Natural Resources stated that 66.6 million tons of CO_2 emissions deduction would be reached with the realization of the actions. Considering the 246 million tons CO_2 deduction commitment by 2030 of Turkey under the Paris Climate Agreement, energy efficiency becomes more important for Turkey. If Turkey is able to avoid 66.6 million tons of CO_2 emissions through energy efficiency, then it would be easy to utilize domestic resources – lignite in particular – for meeting future energy demand.

So far, the legislative and institutional framework that paved the way for energy transition in Turkey were discussed. Following the discussion, the policy and strategy papers providing the policy agenda to achieve transition goals were examined. In addition, it is highly crucial to discuss the major motivations that are core to all previous discussions and major challenges that remains to be addressed. The following subsections elaborate on these motivations and challenges of the energy transition in Turkey.

4.5. Major Motivators

In order to fully grasp energy transition in Turkey, we must understand the major motivations behind these policies and legislative framework. These motivations can be summed up as reducing import dependency both in terms of fuel and equipment and increasing supply security. Both of these motivations will be studied in detail in the following subsections.

4.5.1. Import Dependency

For the last 15 years Turkish primary energy demand has increased substantially. As a developing country Turkey has shown 5.86% GDP increase between 2002 and 2017. In parallel to increase in GDP, Turkish electricity demand has been increasing 5.5% annually since 2002 (Figure 4.6). It is expected that this increase will continue in parallel with the economic growth. While the consumption was 132,553 GWh in 2002, it more than doubled and reached 294,919 GWh in 2017 (Figure 4.6).

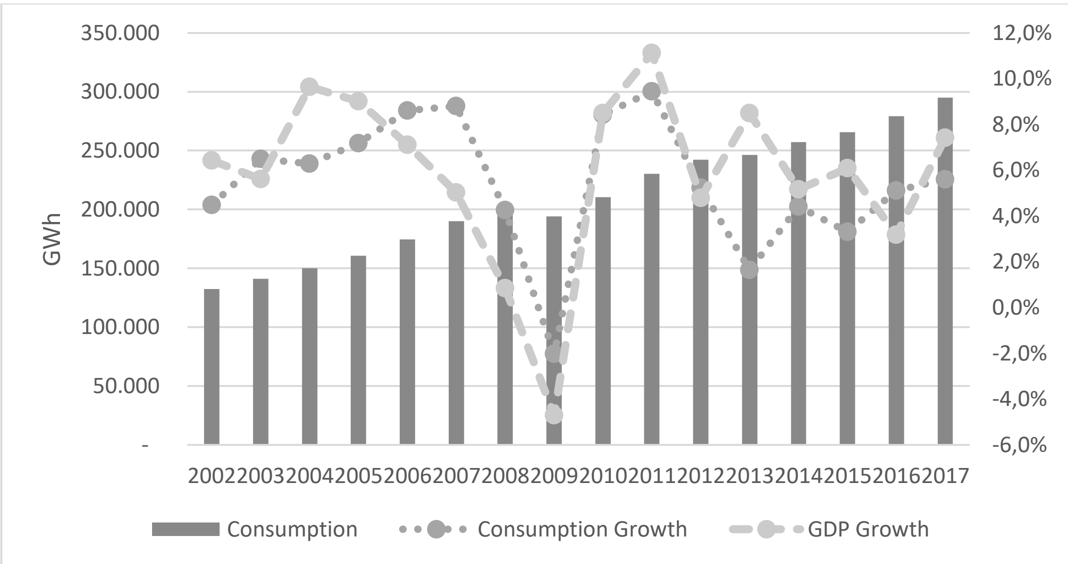


Figure 4.6 Consumption Growth vs. GDP Growth

Source: (World Bank, 2018) and (TEİAŞ, 2018)

The increasing demand also led to an increase in imported resources as Turkey is a resource scarce country in oil and natural gas. In this regard, reducing import dependency has always been at the very center of the policies since the beginning of the energy transition in 2001.

Turkish energy mix is mainly composed of oil, natural gas and coal which are import dependent sources with approximate shares of 30% each. Turkey imports 90% of its crude oil and almost all of its natural gas consumption. While crude oil is used primarily in transportation after being refined in domestic refineries, almost half of the natural gas is used for electricity generation. In addition to oil and gas, Turkey also imports hard coal. In 2017, Turkey imported 37.5 million tons of coal to be used in the power plants. The total installed capacity of the power plants dependent on imported fuel is 36.277,7 MW equivalent to 42% (Table 4.14).

Table 4.14 *Installed Capacity as of 2017 (MW)*

	Fuel Type	*Capacity*	*Count*
Import Dependent	Fuel-Oil + Naphtha + Diesel	303,6	12
	Imported Coal	8.793,90	11
	Multi Fuel Liquid + Natural Gas	3.433,60	47
	Multi Fuel Solid + Liquid	682,9	22
	Natural Gas + LNG	23.063,70	243
	Total Import Dependent	36.277,70	335
Domestic	Domestic Coal (Hard Coal + Lignite + Asphaltite)	9.872,60	30
	Geothermal	1.063,70	40
	Hydro w/o Reservoir	7.489,70	501
	Hydro with Reservoir	19.776,00	117
	Renewable Biomass	575,1	98
	Solar	17,9	3
	Wind	6.482,20	161

Table 4.14 (continued)

	Thermic (Unlicensed)	201,1	67
	Wind (Unlicensed)	34	46
	Hydro (Unlicensed)	7,4	10
	Solar (Unlicensed)	3.402,80	3.613
	Total Domestic	48.922,50	4.686
	Grand Total	85.200,00	5.021

Source: (EPDK, 2018) and (TEİAŞ, 2018)

For the last 15 years, Turkish primary energy demand has increased 4.2% per annum in parallel to GDP growth (TEİAŞ, 2018). In 2017, 76% of its primary energy demand was met by imported resources. In the national energy balance table of 2016, share of energy imports amounted to 83% (EPDK, 2018).

Petroleum demand has decreased since 2001. Increasing share of natural gas fueled power plants over retired liquid fueled power plants is the main reason for the decrease. In addition, increasing efficiency of internal combustion engines has an important effect despite the increasing number of vehicles.

Natural gas demand tripled between 2001 and 2016 and reached 55 bcm in 2017. Since, the policies targeting countrywide use of natural gas gained importance, increasing share of natural gas for the electricity generation became the main reason for a sharp increase in demand. Natural gas constituted 34% of the total energy imports. Almost half of the natural gas is being used for the electricity generation. In 2017, natural gas power plants generated 108.8 TWh electricity in 2017 representing 37.2% share in total generation (EPDK, 2018).

The share of the power plants that use imported fuels (mainly hard coal and natural gas) in the installed capacity is 42.6% in 2017. In addition, these power plants generated 50.6% of total electricity consumption in 2016.

High import dependency has severe economic burdens on the Turkish economy. Foreign trade deficit of Turkey was 76.8 billion USD in 2017. Energy imports amounted to 37.2 billion USD within a total 233.8 billion USD imports representing a share of 15.9%. Energy foreign trade deficit was 32.9 billion USD representing 42.8% of total foreign trade deficit.

High energy bill is an important burden on the Turkish economy. Due to a decrease in oil and natural gas prices in 2015, energy bill of Turkey almost halved in 2016 and 2017 in comparison to 60.1 billion USD in 2012. Volatility to global developments in oil and gas markets, coupled with currency rate fluctuations increases this burden.

Table 4.15 *Energy Imports/Exports over Total Imports/Exports (million USD)*

	2002	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
Total Exports	36,059	152,462	151,803	157,610	143,839	142,530	156,993
Total Imports	51,554	236,545	251,661	242,177	207,234	198,618	233,800
Exports/Imports	69.9%	64.5%	60.3%	65.1%	69.4%	71.8%	67.1%
Energy Exports	692	7,708	6,725	6,112	4,518	3,211	4,327
Energy Imports	9,204	60,117	55,917	54,889	37,843	27,169	37,205
Exports/Imports	7.5%	12.8%	12.0%	11.1%	11.9%	11.8%	11.6%
Energy Exports Share	1.9%	5.1%	4.4%	3.9%	3.1%	2.3%	2.8%
Energy Imports Share	17.9%	25.4%	22.2%	22.7%	18.3%	13.7%	15.9%

Source: (MoTrade, 2018)

Therefore, decreasing energy imports by using domestic resources or increasing energy efficiency places on top of energy strategies and policies of Turkey.

Energy import dependency can be analyzed from twofold: fuel and equipment. Firstly, dependency rate can be decreased by reducing the amount of imported fuel usage either by increasing efficiency or utilization of domestic resources. Turkey decided to utilize its own domestic lignite coal and renewable resources in order to reduce its import dependency as well as increase energy efficiency measures.

Economic burden of import dependency is not only caused by fuel dependency but also the equipment used in the power plants are mostly imported. One of the main target of Turkey is to become an important energy equipment manufacturer in the world. For this purpose, the National Energy and Mining Strategy Paper includes actions concerning R&D and domestic manufacturing. In parallel with the strategy paper, 1.000 MW solar and wind RE-ZONE tenders held in 2017 included R&D and domestic manufacturing obligations. For these two competitions, Turkey obligated investors to manufacture 80% of the equipment to be used for the plant domestically, make R&D and employ 80% of engineers locally. Primarily, Turkey supported domestic production with the YEKDEM mechanism in the 2005 Renewable Sources Law. According to the mechanism, the power plants using domestic equipment would be incentivized by an additional feed-in tariff premium. But the domestic equipment use has not reached desired level. After then Turkey decided to implement RE-ZONE model to increase local content share and furthermore create an energy industry which is capable of exporting energy equipment to the regional countries (Yeşil Ekonomi, 2019).

Overall, to reduce the economic burden and diminish the effects of price and fuel shocks reducing import dependency rises as a major motivator of the energy transition. Turkey's Transition 2.0 targets mainly focus on increasing the use of domestic sources and increasing energy efficiency. With the implementation of the Transition 2.0 targets, it is possible for Turkey to decrease its import dependency, which is currently around 76%.

Import dependency is highly interlinked with supply security. Growing import dependency is the biggest threat to supply security of a country. Therefore, the other motivation of the energy transition in Turkey is to increase supply security while decreasing import dependency.

4.5.2. Security of Supply

Energy security is a crucial concern not only for Turkish energy markets but also for all other import dependent countries. It is a multifaceted concept with many players. Any kind of global turmoil related to trade and its potential impacts on energy sector brings energy security into prominence, especially for the importing countries.

Turkey's geographical location between hydrocarbon rich countries in the East and large consumers in the West makes Turkey a strategic partner for producers and consumers. Turkey has been driving an international energy policy aiming at ensuring its and its neighbors' energy supply security. In this regard, Turkey has supported many projects in its region. Southern Gas Corridor is integral to both European and Turkish energy security as the project enables Azeri gas to reach Turkey and through Turkey to Europe. Trans Anatolian Natural Gas Pipeline (TANAP) which became operational in 2018 also plays an important role in the diversification of supply routes.

Turkey is strategically positioned to capitalize on recent discoveries in the Eastern Mediterranean. Turkey has also initiated its own exploration activities in the region and also in the Black Sea. Any potential finding would contribute Turkey's energy supply security. Moreover, expansion of liquid natural gas in the global market, with US entering as a big player into the market, provides opportunities for Turkey's energy security.

Turkey puts security of supply at the very center of its energy policy due to its high import dependency ratio discussed in the previous subsection. Turkey aims to ensure supply security through diversifying its supply routes. The diversification aspirations are further coupled with boosting domestic resources mainly lignite coal and renewables. Utilizing abundant renewable energy sources of Turkey is well-suited to address security of supply.

Turkey's major motivations for its energy transition are reducing import dependency and in line with this goal increasing security of supply. To achieve these targets, Turkey decided to utilize its domestic sources (coal and renewables), add nuclear into its energy mix, increase energy efficiency, diversify supply routes (TANAP, LNG contracts) and explore oil and gas in the Mediterranean and Black Sea. However, all these aspirations have their own challenges. The major challenges Turkish energy faces is to provide sufficient investment on infrastructure and deal with increasing CO2 emissions.

4.6. Major Challenges

4.6.1. Infrastructure

Investment in infrastructure is essential to maintain supply security. In this regard, Turkey needs extensive investment in power grids both at transmission and distribution levels, as well as gas networks. To ensure a sustainable energy future, investment in the energy sector is an essential challenge to address.

Turkey has invested in both power and natural gas infrastructure since the liberalization process of the energy markets. Natural gas transmission capacity has reached more than 300 mcm/day by adding two new floating storage regasification units, increasing underground storage capacity and infrastructure developments.

In 2015, an agreement between the Turkish transmission system operator TEİAŞ and ENTSO-E was signed on a permanent synchronous operation between European and Turkish electricity systems. With this development, 400 MW export and 500 MW import capacities became available for Turkey. The electricity interconnection capacity has increased by domestic network developments and new interconnections with neighboring countries. However, the interconnection capacity remains to be limited.

Another important development for market flexibility is that natural gas trade has started in Energy Exchange Istanbul in the third quarter of 2018 after electricity trade. Although these developments prove to be important steps in terms of energy infrastructure, the issue remains to be a major challenge.

The necessary capacity addition to meet the increasing demand is around 5,000 MW per year given the current installed capacity of 85,200 MW. During the 1997-2001 period, Turkey faced power shortages because of the lack of generation capacity. In order to deal with the power shortages and to guarantee further continuous power supply, more than 8,000 MW representing one fourth of the installed capacity at that time was added to the system under BOT and BO models until 2005. 6,000 MW of BOT and BO power plants are natural gas fired plants because they could be put into operation in a couple of years and provide base load to the transmission system. Share of natural gas power plants in total installed capacity reached 35% in 2005 from 16% in 1997 (MENR, 2018).

The other economic challenge for Turkey is the continuance of the energy investments as to meet increasing demand. After the initiation of the liberalization of the market, all of the energy investments have been made by private investors. The total energy investment of Turkey is 75 billion USD in the last decade (The Investment Office, 2018). While the share of the state companies in electricity installed capacity was 66.1% and in electricity generation was 58.3% in 2002, they declined to respectively 23.4% and 15.8% in 2017 (TEİAŞ, 2018).

4.6.2. CO2 Emissions

CO2 emissions became an essential part of the energy policies especially after the Paris Agreement. With global commitments on carbon emission mitigation, countries became more aware of their emission levels.

Total greenhouse gas emission of Turkey is 496.1 million tons of CO_2e in 2016. While per capita greenhouse gas emissions in 1990 was 3.8 tons, it reached 6.3 tonnes in 2016. Share of the energy is 73%, industry is 13%, agriculture is 11% and waste is 3% in the total greenhouse gas emissions.

Table 4.16 *GHG emissions by sectors, 2002-2016 (million tones CO2e)*

Year	*Total*	*Energy*		*Industry*		*Agriculture*		*Waste*	
		Amount	*Share*	*Amount*	*Share*	*Amount*	*Share*	*Amount*	*Share*
2002	280.8	201.9	71.9%	27.9	9.9%	35.5	12.6%	15.4	5.5%
2003	300.3	216.4	72.1%	29.1	9.7%	38.9	13.0%	15.9	5.3%
2004	311.2	223.1	71.7%	31.8	10.2%	39.8	12.8%	16.5	5.3%
2005	332.7	240.3	72.2%	34.6	10.4%	40.8	12.3%	16.9	5.1%
2006	356.8	260	72.9%	37.4	10.5%	42	11.8%	17.5	4.9%
2007	390.5	291	74.5%	40	10.2%	41.7	10.7%	17.7	4.5%
2008	387.9	288.4	74.3%	41.9	10.8%	39.7	10.2%	17.8	4.6%
2009	395.9	294	74.3%	43.4	11.0%	40.6	10.3%	17.9	4.5%
2010	402.6	292.3	72.6%	49.2	12.2%	42.8	10.6%	18.2	4.5%
2011	431.4	313.4	72.6%	54.4	12.6%	45.1	10.5%	18.5	4.3%
2012	445.6	320.1	71.8%	56.8	12.7%	50.6	11.4%	18.1	4.1%
2013	439	308.8	70.3%	59.8	13.6%	53.6	12.2%	16.8	3.8%
2014	451.8	321.3	71.1%	60.2	13.3%	53.7	11.9%	16.6	3.7%
2015	469.9	339.7	72.3%	59.6	12.7%	53.7	11.4%	17	3.6%
2016	496.1	361	72.8%	62.4	12.6%	56.5	11.4%	16.2	3.3%

Source: (TÜİK, 2018)

Increase in total greenhouse gas emissions was 4.3% per annum for the period of 2002 – 2016. As seen in Table 4.16 above, energy related emissions kept its share around 72% in this period. During the transformation period of electricity market starting from 2001, Turkey successfully utilized renewable energy sources to its energy mix. Since there is no significant change for the energy-emitted emissions, renewable capacity additions avoided Turkey to increase emissions caused by electricity generation. In order to figure out how much emission that Turkey mitigated because of the utilization of the renewable sources, a model for power generation by source with the exclusion of renewable sources was studied. The shares of the renewable sources in the power generation between 2002 and 2017 distributed to the other conventional sources with the proportional shares of each source for every year. Then after, greenhouse gas emissions of each sources were calculated based on the mean values of the Table 4.17.

Table 4.17 *Lifecycle Greenhouse Gas Emissions by Fuel (tonnes CO2e/GWh)*

Technology	*Mean*	*Low*	*High*
Lignite	1,054	790	1,372
Coal	888	756	1,310
Oil	733	547	935
Natural Gas	499	362	891
Solar PV	85	13	731
Biomass	45	10	101
Nuclear	29	2	130
Hydro	26	2	237
Wind	26	6	124

Source: (WNA, 2011)

Comparison between the actual power generation and projected power generation in the model indicated 5% decrease in the total emissions. If Turkey has not generated power from renewable energy sources in 2016, it would emit approximately additional 16 million tons of CO_2e greenhouse gas. For the 2002-2016 period, the total mitigation amount is around 60 million tons CO_2e.

Table 4.18 *Projected Mitigation of GHG Emissions by Fuel*

Year	*With RE*	*Without RE*	*Mitigation*	*Share in Total Emissions*	*Share in Energy Emissions*
2002	68.2	68.3	0.2	0.1%	0.1%
2003	71.9	72.1	0.1	0.0%	0.1%
2004	72.2	72.3	0.1	0.0%	0.1%
2005	85.0	85.2	0.1	0.0%	0.1%

Table 4.18 (continued)

2006	91.4	91.6	0.2	0.1%	0.1%
2007	107.0	107.3	0.4	0.1%	0.1%
2008	113.9	114.5	0.7	0.2%	0.2%
2009	108.4	109.6	1.2	0.3%	0.4%
2010	106.9	108.8	2.0	0.5%	0.7%
2011	119.4	122.3	3.0	0.7%	1.0%
2012	121.2	124.9	3.7	0.8%	1.2%
2013	117.2	122.1	4.8	1.1%	1.6%
2014	136.9	143.6	6.7	1.5%	2.1%
2015	126.2	134.5	8.3	1.8%	2.4%
2016	136.7	148.9	12.2	2.5%	3.4%
2017	151.8	167.7	15.9	N/A	N/A

To summarize, this chapter elaborated on the strategy papers that laid the foundation of energy transition in Turkey and the related action plans. Both the strategy papers and the following action plans are designed to give the country the means to address the motivations of energy transition, namely, decreasing import dependency and increasing supply security. Through an analysis of the key challenges for implementation, the next section discusses the achievements so far and what remains to be enhanced.

4.7. How Far Turkey Achieved its Energy Transition?

Energy transition targets are stated in several strategy papers and action plans. These policy papers are mainly shaped by the major motivations and challenges of the Turkish energy markets. The key elements of the energy transition in Turkey are stated as utilizing domestic resources mainly coal and renewables; adding nuclear into the energy mix; increasing energy efficiency. This section focuses on the developments in all of these key issues separately. The section discusses the achievements, current plans and remaining challenges in coal, nuclear, renewables and energy efficiency.

4.7.1. Coal

Turkey has abundant coal reserves. Turkey holds the 11th largest coal reserves in the world with 17.9 billion tones. To reduce import dependency, current policies in Turkey propose to increase domestic supply of power generation from coal-fired power plants. However, almost all of its coal reserves are low calorie lignite with 94% of all reserves having a heat content of less than 3000 kcal/kg. Turkey targets to add 12.000 MW domestic coal fired power plants to the installed capacity. Current domestic coal fired power plants total capacity is 10.791 MW. Considering 100 million tons of domestic coal production in 2018, there are still enormous potential for Turkey to use domestic coal for electricity generation. The locations of main Turkish hard coal and lignite deposits are presented in Figure 4.7.

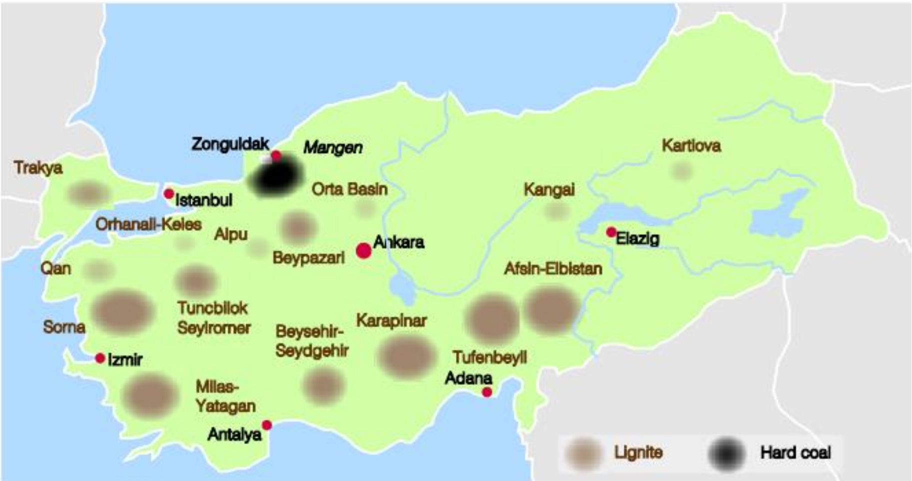


Figure 4.7 Location of Main Turkish Lignite and Hard Coal Deposits

Source: IEA Clean Coal Centre – Prospects for coal and clean coal technologies in Turkey

Coal has always been an important primary energy source for Turkey. Historically, 20% to 30% of primary energy demand has been met by coal (TEİAŞ, 2018).

Moreover, almost 30% of its electricity demand has been met by coal fired power plants. Around 68% of coal consumption is used for electricity generation (TEİAŞ, 2018).

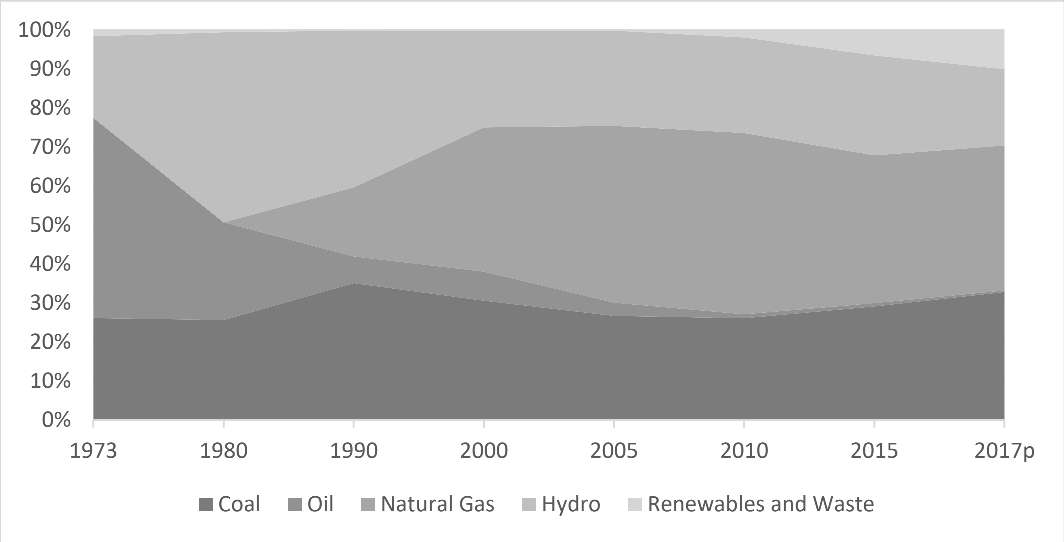


Figure 4.8 Electricity Generation by Source

Source: (TEİAŞ, 2018)

In 2000s, due to increasing demand and decreasing prices of imported coal, investment on imported hard coal increased significantly. While the share was only 3.1% in 2001 the number exceeded 10% within less than 20 years, in 2018. During the same period, share of domestic lignite dropped from 18.4% to 11%.

Targets related to increasing domestic coal share in both installed capacity and generation were included in the strategic plans for 2010-2014 and 2015-2019. However, these targets have not been reached yet. At the end of 2017, Turkey has once again announced its ambitious goals concerning the further utilization of domestic coal into electricity generation in the National Energy and Mining Strategy Paper. Table 4.19 presents the current installed capacity in operation and in construction separately.

Table 4.19 *Installed Capacity of Licensed Coal Power Plants (2018)*

Fuel Type	*Installed Capacity (MWe)*	*in Construction (MWe)*	*in Operation (MWe)*
Coal	2.616,53	0,00	2.616,53
Domestic Asphaltite	540,00	135,00	405,00
Domestic Coal	10.621,66	2.852,00	7.769,66
Imported Coal	12.455,50	4.385,50	8.070,00
Total	26.233,69	7.372,50	18.861,19

Source: (EPDK, 2018)

In this regard, the government decided to support

Policies on increasing coal in Turkey's energy mix have two major challenges: achieving emission reduction targets and access to finance. As a signing party of the Paris Climate Change Agreement, Turkey provided a 21% decrease in greenhouse gas emissions based on business-as-usual scenario until 2030. However, increasing coal share poses difficulty in achieving this target. Coal accounts to two fifths of total energy-related carbon emissions (EIA, 2019). It is claimed that if the continuing to support financing coal-fired power plants would undermine the targets of the Paris Agreement (Chen et al., 2016).

From financing point of view, there is a growing awareness from the shareholders of the project financers mainly banks to impose a ban on providing loans to coal projects (BankTrack, 2019). European Bank for Reconstruction and Development (EBRD) has announced in its strategy paper that "the strategy supports the move to lower-carbon fuel sources in response to the challenge of climate change. In alignment with other international financial institutions, the EBRD will not finance any coal-fired power generation projects except in rare and exceptional circumstances in which there is no feasible alternative energy source." (EBRD, 2018). In this regard, Turkey may face cost increases and commercial restrictions.

In addition to utilizing domestic coal, integrating nuclear into the energy mix is also crucial for Turkish energy transition.

4.7.2. Nuclear

Turkey's ambition to include nuclear power into its energy mix relies under its energy transition motivations, namely, import dependency and security of supply. To decrease import dependency and increase supply security, Turkey initiated plans to build nuclear power plants. In 2010, the first Intergovernmental Agreement with Russian Federation was signed to build a nuclear power plant in Mersin Akkuyu. Later in May 2013, another intergovernmental agreement was signed with Japan to build a nuclear power plant in Sinop. Moreover, negotiations on the third nuclear power plant is claimed to be undergoing (Anadolu Agency, 2015). It is reported that during the Belt and Road Summit in Beijing in May 2017, presidents of Turkey and discussed the construction of third nuclear power plant (FinansGündem, 2017). The locations of the discussed nuclear power plants are depicted in Figure 4.9.

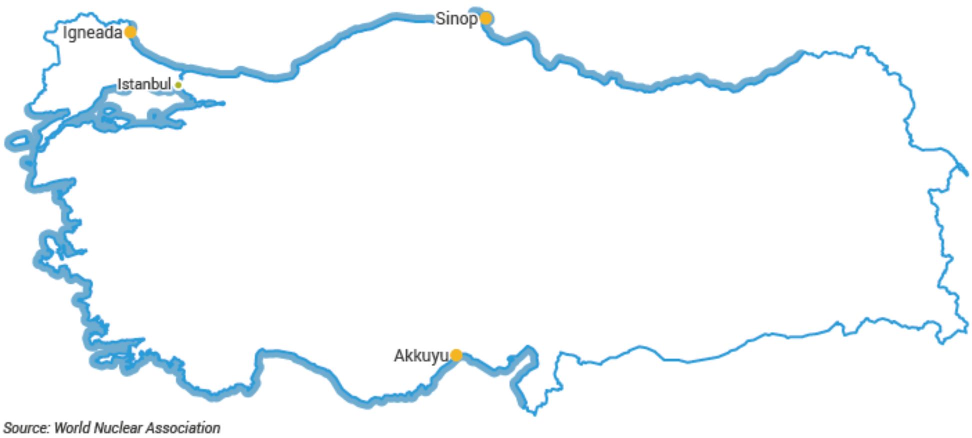


Figure 4.9 Planned Nuclear Power Plants in Turkey

Source: http://www.world-nuclear.org/information-library/country-profiles/countries-t-z/turkey.aspx

4.7.3. Akkuyu Nuclear Power Plant

Turkey and Russia signed an intergovernmental agreement in May 2010 to build the first nuclear power plant of Turkey. The agreement was later the same year by both parliaments. According to the intergovernmental agreement, a company established by Russian party is responsible for designing, building, maintaining, operating, and decommissioning of the plant for 60 years. The project company, Akkuyu Nükleer A.Ş., will construct four VVER 1,200MW units and the total installed capacity will be 4,800MW. Generation license for the plant was granted in June 2017 and the construction license was granted in April 2018 (Daily Sabah, 2018). Construction of the Akkuyu Nuclear Power Plant is ongoing and it is expected that the first unit will be operational in 2023 (Dyck, 2018; Karadeniz, 2018). Turkey granted purchase guarantee to the project company under the intergovernmental agreement of the project. According to the agreement, Turkey guaranteed to purchase 70% of the generated power from the first and second units and 30% from the third and fourth units for 15 years with an average price of 12.35 USD cents/kWh with EÜAŞ[7] being the energy purchasing party (Daily Sabah, 2018). The project company is free to trade remaining amount in the electricity market.

4.7.4. Sinop Nuclear Power Plant

Turkey also plans to add a second nuclear power plant into its energy mix. In this respect, an intergovernmental agreement between Turkey and Japan was signed in May 2013. According to the agreement, four Japan-French designed ATMEA-1 units of each 1,120MW are planned to be constructed. The project will be constructed by a consortium of which 51% of its shares belongs to private companies

[7] Intergovernmental Agreement defines TETAŞ as the purchaser state entity. However after the transformation to the presidential system, TETAŞ merged under the name of EUAŞ.

particularly Japanese and French and 49% belongs to EÜAŞ. Environmental impact assessment report of the project was delivered in December 2017 and the evaluation of the report has not been completed after one and a half year. According to the intergovernmental agreement, Turkey guaranteed to purchase generated power of the Sinop NPP as it was in Akkuyu NPP. This time the term is 20 years and purchase price varies between 10.80-10.83 USD cents/kWh.

While coal and nuclear are key for the energy transition, significant developments were observed in renewables. Renewables constitutes an integral element of the energy transition in Turkey. In this respect, the next subsection discusses the developments and achievement in renewables by source.

4.7.5. Renewables

Renewables play a significant role in the energy transition of Turkey. It forms the cornerstone of the transition policies. In this regard, legislative framework and transition policies include numerous policies targeting renewable integration.

Turkey wants to utilize its abundant renewable sources to decrease import dependency and increase security of supply. Turkey aims to increase the share of renewables in total installed capacity to reach 30% by 2023 (Karagöl et al., 2017). The country is also planning to add additional 10,000 MW solar and wind in order to increase share of renewables in power generation to 30% which was 9.8% in 2017 (Figure 4.10). The government encourages renewable deployment through favorable feed-in tariffs, unlicensed generation and RE-ZONE model for larger projects discussed in detailed in the following subchapters. The latest policy paper announced in 2017, National Energy and Mining Strategy Paper, foresees 1,000 MW of solar and wind tenders for upcoming 10 years (Karagöl et al., 2017).

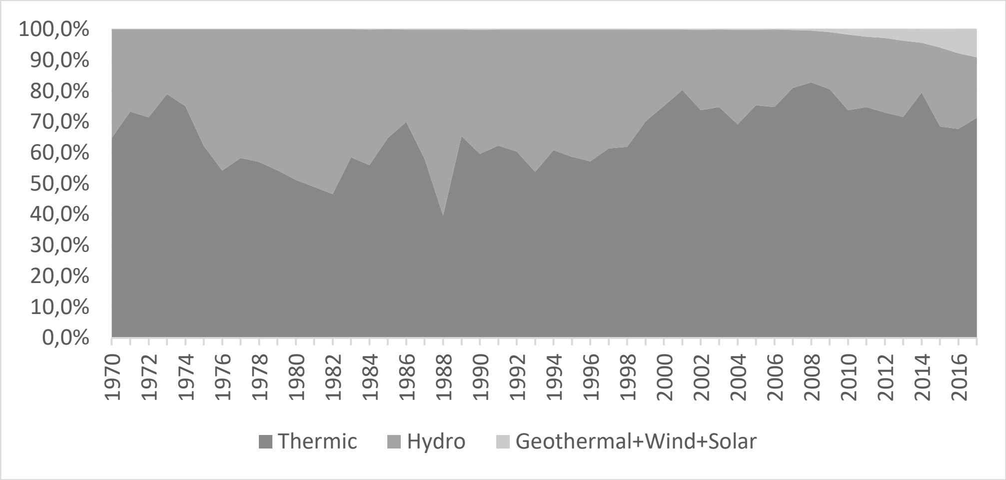


Figure 4.10 Renewable Share in Power Generation

Source: (TEİAŞ, 2018)

Turkey had significant potential of unutilized renewable energy sources when the 2005 RES Law was enacted. By the end of 2002, 73.9% of the electricity consumption of Turkey was generated from fossil fuels. Only the remaining 26% was met by hydro power plants and the share of other renewable sources were negligible (TEİAŞ, 2018). Between 2005 (enactment of RES Law) and 2011 (in 2010 the law was amended and a new incentive mechanism called YEKDEM was announced) 1,800 MW renewable capacity was added to the total installed capacity. The share of renewable power plants (excluding hydro) was 12.9% in the total installed capacity and 9.8% in the total power generation by the end of 2017 (TEİAŞ, 2018).

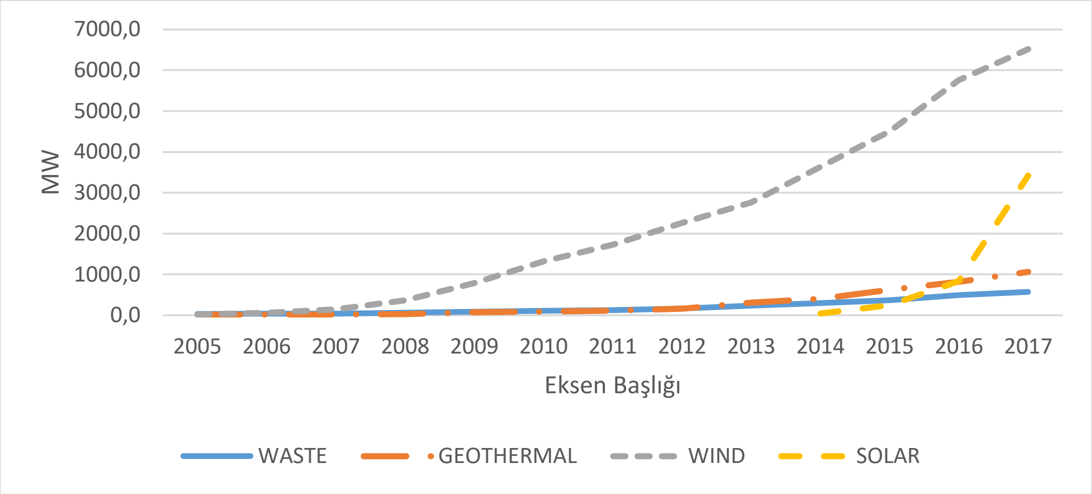


Figure 4.11 Renewable Installed Capacity between 2005 and 2017

Source: (TEİAŞ, 2018)

In 2013, the new electricity law, Law Nr. 4646, defined unlicensed power generation for the first time. The law enabled the construction of many new unlicensed solar power plants. Moreover, larger renewable projects are supported through RE-ZONE projects, a new investment model introduced in 2016.

Potential and Current Status

According to the Ministry of Energy and Natural Resources, Turkey has 40,000 MW hydro, 48,000 MW wind and 600 MW geothermal potential including annual 2,650 hours sunshine duration and 3.5 W/m^2 solar intensity. In addition to 2.6 mtoe of biomass remaining from heating there are 1.7 million tons of biodiesel and 3.5 million tons of bioethanol potential from the unallocated agricultural land (MENR, 2018; TEİAŞ, 2018).

Wind

Since Turkey's south, north and west is surrounded by seas, there are significant wind potential. According to the Ministry of Energy and Natural Resources, Turkey has 37,000 MW of onshore and 11,000 MW of offshore wind potential. By the end of February 2019, total installed capacity of 7,031 MW onshore wind power plant has been in operation. There are still untouched wind potential of roughly 40,000 MW. The total capacity of under construction onshore wind power plants is 3,177 MW. The utilization rate is 21.3%.

Solar

Turkey has a substantial potential of solar energy due to its geographical location. The average sunshine duration in a year is 2,741 hours and the average irradiation rate is 4.18 kWh.m^2/day. The total solar panel area reached approximately 20,200,000 m^2 and the total installed capacity reached more than 5,000 MW by the end of 2018 (TEİAŞ, 2018). Almost all solar power plants have a capacity below 1 MW and are unlicensed. Unlicensed solar installed capacity reached 3,402.8 MW by the end of 2017 and 4,768 MW by the end of September 2018 from almost zero in 2013 (TEİAŞ, 2018). In 2017, Turkey was among top five countries with global capacity additions of solar PV (REN21, 2018) after China, United States, India and Japan. Solar PV capacity additions of Turkey quadrupled in 2017 mainly because some expected regulatory changes (IEA, 2018b).

Geothermal

Turkey's total geothermal heat capacity is 35,500 MW. Since, 90% of these capacity is at low and mid temperatures, this capacity is commonly used for heating, thermal tourism and industrial applications. Only 10% of such capacity is practically available for power generation. The geothermal installed capacity is 1,302 MW as of February 2019 and more than 300 MW capacity is under construction (EPDK, 2018). Although, the diversified use of geothermal heat is suppressing the increase in the capacity of geothermal power plants. Turkey has already passed its targets in geothermal power which was 700 MW by the end of 2019.

Turkey has developed most of its geothermal capacity between 2013 and 2017. Only in 2017, the net additions amounted to 243 MW for a total of 1.1 GW (REN21, 2018).

Hydroelectric

Turkey's hydroelectric generation potential is around 140,000 GWh which represents roughly 40,000 MW of installed capacity. As of February 2019, 28,377 MW of such potential had already been utilized. According to EMRA, total 32,369 MW hydroelectric power plant has been licensed of which 28,300 MW is installed and 4,100 MW is under construction. After the commissioning of the under construction plants, Turkey would utilized more than 80% of its hydroelectric potential.

Renewable Energy Support Mechanism (YEKDEM)

In Turkey, renewable power generation is mainly promoted through a feed-in tariff mechanism called YEKDEM. According to the RES Law, there is a fixed feed-in tariff for each source depending on the technology and local equipment use. Table 4.20 presents the installed capacity development for each source since the enactment of the RES Law in 2005.

Table 4.20 *Installed capacity 2005-2011 (MW)*

Year	*Thermal*	*Hydro*	*Geother.*	*Wind*	*Total*
2005	25902,3	12906,1	15,0	20,1	38843,5
2006	27420,2	13062,7	23,0	58,9	40564,8
2007	27271,6	13394,9	23,0	146,2	40835,7
2008	27595,0	13828,7	29,8	363,7	41817,2
2009	29339,1	14553,3	77,2	791,6	44761,2
2010	32278,5	15831,2	94,2	1320,2	49524,1
2011	33931,1	17137,1	114,2	1728,7	52911,1

Source: (TEİAŞ, 2018)

As discussed in the legal framework (RES LAW), the feed-in-tariff is valid for the power plants becoming operational until 2020. The remaining question now is what would be the status of the support mechanism after 2020. The law does not regulate the post-2020 period and there is no declaration on the future of YEKDEM yet. Although there are some perceptions that the Ministry would end YEKDEM it is remains to be uncertain what will happen after 2020.

Unlicensed

In 2013, the new electricity law, Law Nr. 6446, defined unlicensed power generation for the first time. The law mainly enabled the construction of unlicensed solar power plants. After the enactment of the Law, the total solar installed capacity has reached 5,238.8 MW by the end of February 2019 from zero in 2013. Only in 2017, unlicensed power generation from renewables increased 166% compared to previous year. The total power generation from unlicensed power plants reached to 32 GWh of which 94% is generated from solar power plants (Enerji Enstitüsü, 2018).

Table 4.21 *Installed capacity 2012-2018 (MW)*

Year	*Thermal*	*Hydro*	*Geothermal*	*Wind*	*Solar*	*Total*
2012	35.027,2	19.609,4	162,2	2.260,6	0,0	57.059,4
2013	38.648,0	22.289,0	310,8	2.759,7	0,0	64.007,5
2014	41.801,8	23.643,2	404,9	3.629,7	40,2	69.519,8
2015	41.903,0	25.867,8	623,9	4.503,2	248,8	73.146,7
2016	44.411,6	26.681,1	820,9	5.751,3	832,5	78.497,4
2017	46.926,5	27.273,1	1.063,7	6.516,2	3.420,7	85.200,2
Feb.2019	47.097,4	28.377,1	1.302,5	7.031,1	5.238,8	89.046,9

Source: (TEİAŞ, 2018)

Renewable Energy Resource Areas (RE-ZONE)

Until 2016, Turkey supported renewable energy sources through feed-in tariff, namely, YEKDEM. Both licensed and unlicensed generation facilities were eligible to benefit from the support mechanism. Using feed-in tariff policy to accelerate investment in renewable energy has long been criticized for causing higher electricity bills. In the last decade, a shift from feed-in-tariff policy to auction has proven to reduce the power purchase guarantee prices of renewables. The auctions held in Japan, China and France in 2017 indicate that prices are 15% to 50% less than the feed-in-tariff prices (IEA, 2018d). Similar results were also experienced in Turkey after the enactment of the Regulation on Renewable Energy Resource Zones (RE-ZONE) in 2016 (Figure 4.12). The RE-ZONE tenders form an integral part of Turkey's target to meet 65% of its energy needs from renewable and domestic sources by 2023.

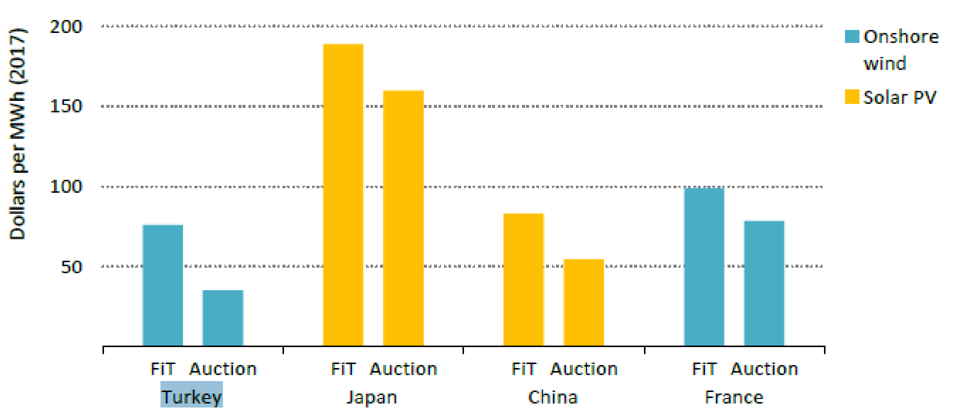


Figure 4.12 Feed-in Tariffs and Auction Results in Selected Countries, 2017

Regulation on RE-ZONE introduced a new investment model targeting mainly large scale renewable energy projects. The model is based on a reverse-auction method with a predetermined price ceiling. The winning bidder is granted a 15 year power purchase guarantee. Within this model, two RE-ZONE auctions of solar and onshore wind for 1,000 MW each were completed in 2017. First auction was held on March, for the construction of a 1,000 MW solar power plant in the Central Anatolia. The auction was won by a consortium offering the lowest bid of USD 6.99 cent/kWh. Within the scope of the project the winning consortium is obligated;

- To build a factory with a minimum 500 MWs production capacity of photovoltaic modules per year,
- To carry out R&D activities on solar technologies for the next decade,
- To employ 80% of the engineers to work in the factory and the R&D center from local personnel (Anadolu Agency, 2019a).

In addition to solar, a competitive tender was held for onshore wind in August 2017. The tender ended with the lowest bid at USD 3.48 cent/kWh. The scope of the project is very similar with the solar RE-ZONE. Both of the tenders were closed with historic low prices compared to the feed-in-tariff price (Bayraktar, 2018). In addition, RE-ZONE model targets not only to increase renewable deployment but also equipment manufacturing and employment. It is claimed that with the realization of the two RE-ZONE projects, Turkey will be a technology and equipment supplier country in its region (Bayraktar, 2018).

Turkey counts on large-scale renewable projects to achieve its renewable energy targets as well as to accomplish the energy transition laid out by the strategy papers. In 2018, another stream of RE-ZONE projects were announced. Second onshore wind RE-ZONE tender with a ceiling price USD/cent 5.50/kWh was announced with the auction date to be announced later (Anadolu Agency, 2019b). In addition, first offshore wind RE-ZONE was announced in August 2018 later postponed to 2019. Similarly, the second RE-ZONE for solar PV auction was announced in late-2018 but later canceled (Reuters, 2019). In 2018, MENR announced their plan to hold RE-ZONE auctions with different sizes (Yeşil Ekonomi, 2018). It is announced that the tender size could start from 50 MW (Anadolu Agency, 2019d). According to the projections, given that there are no delays in the realization of the RE-ZONE projects for wind, Turkey will add 3.2 GW of wind power over a 5 year time span starting from 2019 (Shura, 2019b).

In May 2019, second tender for onshore wind was held for 250 MW capacity in four different locations reaching 1000 MW in total (Temizer & Şengül, 2019). The winning bidders won the tender at an average price of 3.94 cent/kWh.

4.7.6. Energy Efficiency

Per capita final energy consumption in Turkey is in an increasing trend as a result of economic development. However, with the economic slowdown starting from 2018 the growth forecasts were decreased. Per capita final energy consumption reached 1.76 toe/per capita in 2017 from 1.12 toe/per capita in 2002 with an average annual increase of 3.3% and reached world average. On the contrary, per capita consumption of EU 28 countries and Germany has been decreasing since almost two decades. Their energy intensity (measured as a ratio between Primary Energy Supply over GDP) has also been decreasing. Given the horizontal trend line of the primary energy supply of EU28 and Germany, decrease in the per capita consumption and energy intensity can only be explained by increased energy efficiency.

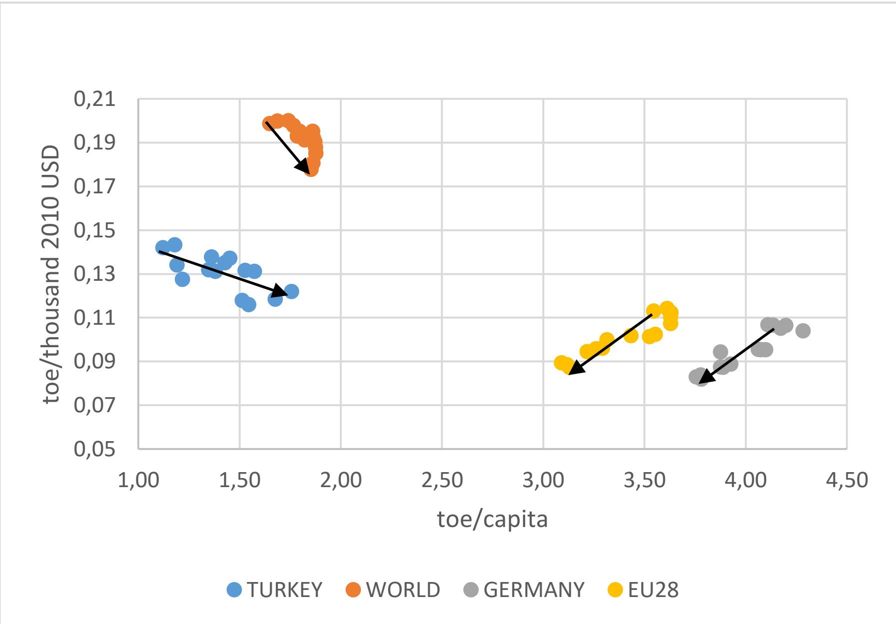


Figure 4.13 Energy Intensity vs. Consumption (2002-2016)

Source: (IEA, 2019)

In Turkey, data regarding primary energy consumption shows that there is no significant change in sectoral shares between 2001 and 2017. Thus industry, transport and residential are the most promising sectors for improving energy efficiency with a total of 73% share in primary energy consumption (*Figure 5.14*

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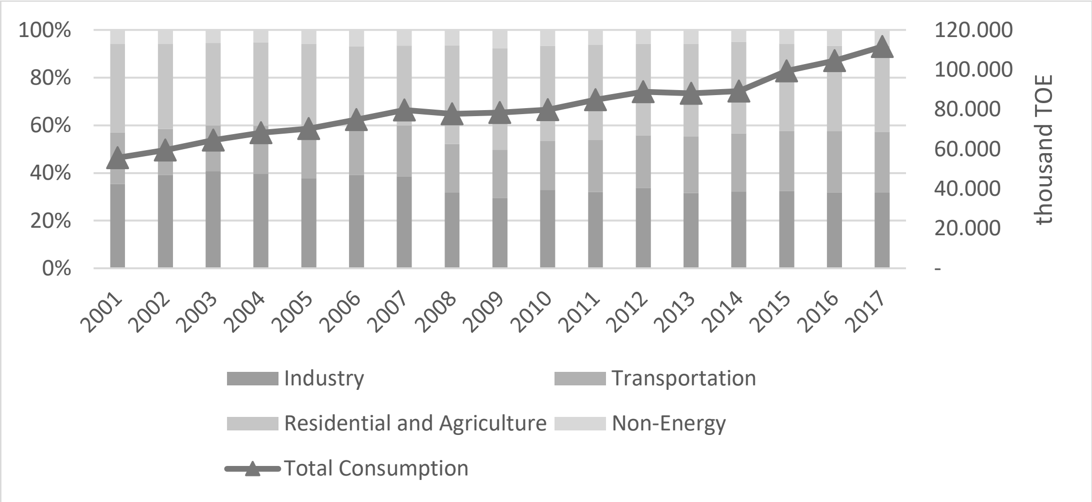


Figure 4.14 Total Final Primary Energy Consumption

Source: (MENR, 2018)

Turkey's energy intensity has been slightly decreasing since 2002. It was 0.14 in 2002 and decreased to 0.12 in 2017. Although, energy intensity of Turkey is well below the world average which is 0.18, it is higher than EU28 and Germany which are 0.08 and 0.09, respectively.

According to the 2018 Energy Efficiency Report of Turkey published by the General Directorate of Renewable Energy (now General Directorate of Energy Affairs) (MENR, 2017), the primary energy intensity of Turkey was 0.12 KEP/2010$ in 2016 while the World, OECD and EU-28 averages were 0.18, 0.11 and 0.09 KEP/2010$, respectively. Therefore, compared to the European countries Turkey's energy intensity remains to be high (Figure 4.15).

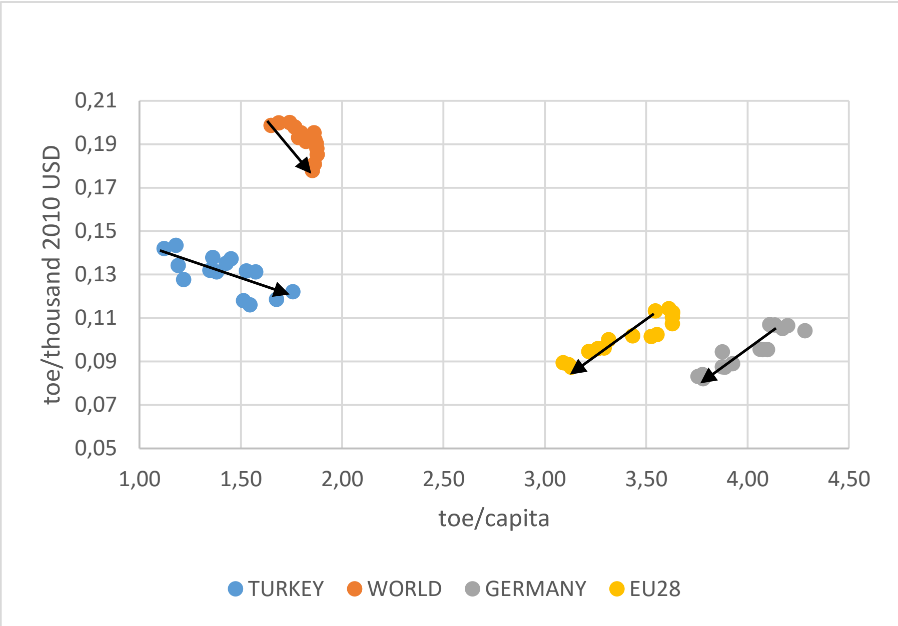


Figure 4.15 Energy Intensity vs. Consumption (2002-2016*)*

Source: (IEA, 2019)

In this regard, to decrease energy intensity Turkey has ambitious energy efficiency plans covered in the National Energy Efficiency Action Plan. "Turkey aims to invest around $11 billion for energy efficiency over the next five years, cut its primary energy consumption 14 %, and at the same time to reduce 66 million tons of CO2 emissions" (Anadolu Agency, 2019c). Turkey has recently reached an agreement with the World Bank for 200 million USD to fund public sector investment on energy efficiency (Anadolu Agency, 2018).

4.8. Review

Turkish energy markets have undergone a significant transition since 2002. This chapter focused on the transition experience of Turkish energy markets from different aspects. While the first part elaborated on the legal and regulatory framework, the second part focused on the policy and strategy papers defining the policy measures and targets by dividing the transition process into two periods: Transition 1.0 from 2002-2016 and Transition 2.0 since 2017. After discussing the policies, targets and strategies, the chapter covered the achievements of Turkish energy markets and discussed remaining challenges to be addressed.

Energy markets in Turkey can be described by two main characteristics: growing demand and increasing import dependency. Energy demand in Turkey rose 4.4% on average per annum from 2006 to 2016, much higher than the world average (BP, 2018). According to the IEA, Turkey will likely see the fastest medium to long-term growth in energy among member countries. Turkey depends on imported resources in almost 70% of its primary energy resources. To meet this growing demand while decreasing import dependency, Turkey decided to transform its energy markets and implemented major market reforms. These reforms were primarily based on several laws and regulations. Electricity sector in Turkey has shown significant transition after the enactment of the Electricity Market Law in 2001 and Renewable Energy Sources Law in 2005. Private sector participation in the power generation increased to 84% and all the distribution companies were privatized.

The objectives of the transition were significantly based on the relevant European Union (EU) acquis. According to the EU's Turkey 2018 Report, "Turkey has continued to align with the EU acquis. Regarding the internal energy market, good progress has been achieved on the electricity sector and good progress can be reported on renewable energy and energy efficiency." However, these developments bring their own difficulties such as utilizing systems and managing the grid while increasing the share of small and large-scale renewable (European Commission, 2018).

A survey by WEC Issues Monitor shows that, renewable energy, energy efficiency and nuclear energy have become top action priorities for Turkey's energy leaders (World Energy Council, 2019).

Increasing the share of domestic coal in power generation is an action priority for Turkey to reduce its high import dependency ratio. In 2004, when Turkey ratified UNFCCC, the share of coal (including hard coal, lignite and asphaltite) was 25.9% while renewables (solar, wind, geothermal and hydro) was 6.1%. In 2017, the share of coal rose and reached 28.2% but the renewables share more than doubled and reached 13.6%. In 2016, only 1.300 MW new coal capacity was added, while 3.850 MW additional renewable capacity was added to the total installed capacity.

Primary energy supply in Turkey relied on non-renewable energy sources with a 94.41% share in 2002 decreasing to 89.37% in 2016. From an energy transition perspective, it can be asserted that Turkey's primary energy supply composition has not changed significantly since 2002. Moreover, share of the energy consumption in total greenhouse gas emissions stood at 72%. The average increase in total greenhouse gas emissions was 4.19% between 2002 and 2016. It was 4.32% for the greenhouse gas emissions emitted by energy use for the same period. In 2002, non-renewable sources had 73.7% share in total electricity generation (Figure 4.16). While the total share of non-renewable sources remained 71.4% in 2017, individual shares switched among each other. The most dramatic change was observed in hard coal and lignite. Power generation from hard coal in total generation increased 19.1% in 2017 from 3.1% in 2002. Lignite's 21.7% share in 2002 decreased to 13.7% in 2017 (TEİAŞ, 2018). Although these figures do not address an energy transition towards a carbon free economy, a specific focus on electricity sector indicates a shift to low-carbon energy sources. Moreover, the policies and developments indicate a significant shift in these shares.

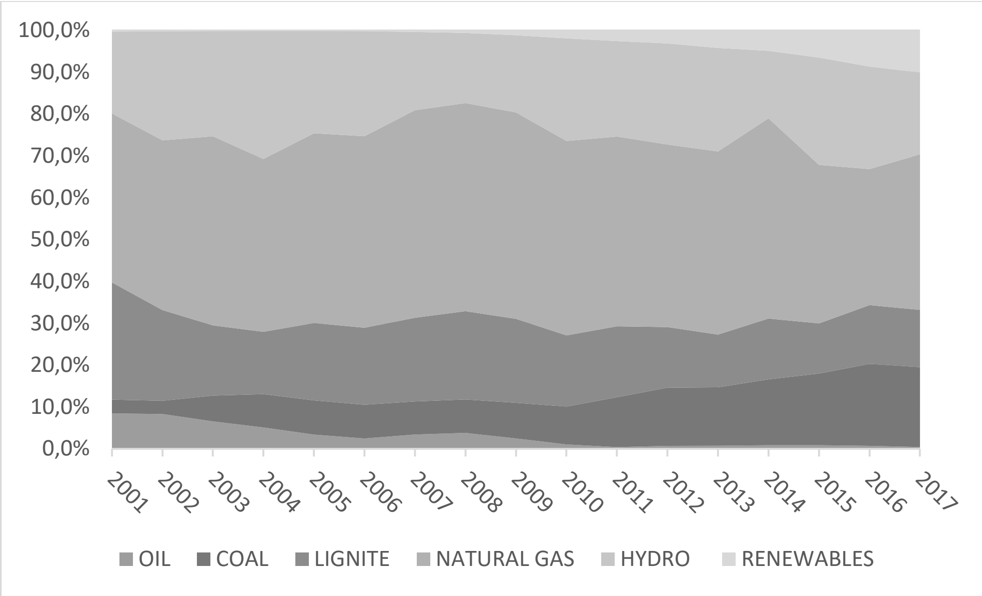


Figure 4.16 Shares of Sources in Electricity Generation

Source: (TEİAŞ, 2018)

As a developing country, Turkey's per capita energy consumption has been increasing every year but there still exists a significant gap with developed countries. Considering its commitments concerning climate change in challenge with its domestic coal policies and increasing energy demand; energy efficiency provides important opportunities to decrease import dependency and increase supply security. In addition to coal, nuclear and renewables, Turkey puts significant importance on energy efficiency. There are many benefits associated with the implementation energy efficiency policies for Turkey. Improvements in energy efficiency can reduce import dependency as well as supporting security of supply. Moreover, energy efficiency is very crucial for industry's competitiveness. Among the advantages are decreasing current account deficit and lowering the effects of external shocks (Bavbe, 2015). Considering all these benefits, Turkey has been taking intensive measures in energy efficiency.

Looking back to the last couple of years, mainly 2017 and 2018, Turkey made significant progress in energy transition to decrease import dependency and increase supply security while meeting increasing demand. The major developments are listed below;

- Two competitive tenders of 1000 MW for each of solar and onshore wind was completed in 2017.
- Second tender for wind was held in May 2019 for a total capacity of 1000 MW.
- An additional 8222 MW of capacity was added in 2017, almost 70% of which is from renewable resources, mainly solar and wind.
- An estimated 300 MW of new geothermal power capacity came online in 2017.
- Turkey granted the construction license for the country's first nuclear power plant, Akkuyu NPP in 2018.
- STAR Oil Refinery, aimed at reducing dependency on refined oil products, started its operations in 2018.
- The most important part of Southern Gas Corridor, TANAP, has become operational in 2018.
- TurkStream Natural Gas Pipeline is expected to become operational by the end of 2019.
- Turkey announced its National Energy Efficiency Action Plan in January 2018 which sets out actions to implement a reduction of 14 % of primary energy consumption by 2023.
- Turkey completed the purchase of two drilling vessels to continue exploration in the Mediterranean and Black Sea in 2018.

According to WEC Trilemma Index Report, Turkey reached good scores in energy equity and environmental sustainability. Moreover, in terms of supply security Turkey has shown some progress mainly due to supply diversity measures (Wyman, 2018).

To understand the progress of energy transition in Turkey, it is important to analyze the change in the shares of the primary energy sources in the power generation. Since

Turkey has been observing the results of its renewable energy policies very recently, cross correlation of power generation by source is considered to be a good indicator for the coming years. Table 4.22 below provides the cross correlation between primary energy sources for the period of 2001-2017.

Table 4.22 *Cross Correlation of Power Generation by Energy Sources (%)*

	Hard Coal	Lignite	Oil	Natural Gas	Thermal (Total)	Hydro	Geo +Wind +Solar	RE (Total)
Hard Coal	100							
Lignite	***-80.4***	100						
Oil	***-83.6***	73.9	100					
Natural Gas	-46.1	29.8	2.8	100				
Thermal (Total)	-55.6	71.5	33.3	78.7	100			
Hydro	-8.1	-33.9	12.2	-43.4	***-74.8***	100		
Geo+Wind+Solar	93.4	-65.8	-65.4	-64.4	-58.3	-10.3	100	
Renewable (Total)	55.6	***-71.5***	-33.3	***-78.7***	-100	74.8	58.3	100

Negative correlations in the Table 4.22 are primarily important because they indicate a correlated shift from one energy source to another. The most stunning result is the negative correlation between hard coal, lignite and oil exceeding 80%. Another significant result is that, renewables have strong negative correlation with natural gas. Considering the shares of oil, lignite and hard coal in the power generation has been decreasing; these figures indicate that in due course of time, hard coal would replace oil and lignite, and renewables would substitute natural gas.

The liberalization process of Turkish energy markets and the past accomplishments on renewable energy deployment indicate that success in shifting towards low-carbon sources and implementing adequate reforms looks inevitable. According to BloombergNEF, installed capacity of Turkey would triple by 2050 with renewables constituting the 68% of the total. Moreover, power generation is expected to become

88% zero-carbon by 2050. However, to achieve these, additional investment worth $ 276 million is required (BNEF, 2019). According to the IEA's latest report on renewables, Turkey is expected to increase its renewable energy capacity by 35% amounting to 14 GW. These capacity additions are expected to be mainly from solar, onshore wind and hydro (IEA, 2018b). Forecast on wind was decreased due to the shift in support mechanism from feed-in tariffs to RE-ZONE model (IEA, 2018b) Moreover, growth of solar PV is expected to be revised downwards due to regulatory changes and higher grid charges bringing additional burden on financing (IEA, 2018b). Turkey is already moving rapidly towards its renewable energy and energy efficiency targets from 2023. Turkey has passed its 30% share of renewable energy target, and yet, revised its target. Only in the first three quarters of 2018, Turkey has attracted $1.5 USD billion worth additional investment in clean energy resources (Shura, 2019b).

In sum, Turkey's energy transition experience has a long history with many achievements regarding liberalization of the markets and integration of renewables. Turkey's transition can be summed under 4 major categories: increasing energy security, reducing import dependency by increasing the use of domestic resources, increasing energy efficiency, increasing the share of renewables in power generation.

The policies and strategies driven for 15 years have transformed only the energy markets not the primary energy mix of the country. However, policies and strategies under the Transition 2.0 foresee a significant transition in the energy. The latest trends in the energy mix of the country towards renewable sources have already shown strong signals of which the policies are shifting towards. As the energy transition in Turkey is an ongoing process, it can learn from other country experiences and accelerate its progress through better measures.

CHAPTER 5

MULTIDIMENSIONAL ANALYSIS OF GERMAN AND TURKISH ENERGY TRANSITIONS

5.1. Introduction

Energy transition cannot simply be achieved by the efforts of a single country. A global, political and technological transition should be targeted. In this perspective, cooperation at international level is indispensable to meet the goals of energy transition towards low carbon. Therefore, adequate and comprehensive cross-country analysis is highly critical for strengthening multidimensional international cooperation. In this regard, this chapter conducts an analysis on Germany's and Turkey's energy transitions and seeks an answer to the question "Is German transition model applicable to Turkey?".

Chapter 2 analyzed the global energy transition and its implications in countries selected as case studies, namely, France, Brazil, United States and China. The chapter laid out how energy transition concept is realized differently depending on the country-specific circumstances. Following the second chapter, Chapter 3 elaborated on Germany's historic energy transition "Energiewende". Energiewende was evaluated in detail starting from its historical and legal background to its development over time and future predictions. While the third chapter covered German energy transition, Chapter 4 discussed the Turkish experience in transition towards low carbon energy.

There is a huge literature on the transition experiences of developed countries, but not so many studies on whether these experiences can be transferred to developing countries. In this regard, this chapter compares the German and Turkish energy transitions built upon the information in the previous chapters. Multidimensional analysis is an important area in understanding how ideas, interests and institutions shape the policymaker's actions (Steinberg & VanDeveer, 2012). Turkey and Germany have both shown significant growth in renewable electricity generating capacity over the last decade. However, a closer look at the development of the policies reveals both similarities and differences in the approach that the policymakers shaped the outcomes. It is possible that within similar political systems, same policy tools can develop in significantly different ways. This chapter analyzes the tools political interests become involved in the decision-making process. Moreover, relevant political institutions and their role in the policy formation are evaluated for both countries. The analysis points out that policy models can diverge or converge depending on the institutional framework of the relevant country.

This multidimensional analysis is comprised of 3 levels: energy security, environmental and economic aspects. Each of these aspects together constitute the baseline of all energy transitions with different weights depending on the priorities of a country. While energy security is the major motivator of transitions in both Germany and Turkey, environmental concerns rise as a global phenomenon. Economic aspect remains to be at the core of the transition since the transition is only possible when the economics hold up.

5.2. Main Indicators

Before delving into the multidimensional analysis, it is important to lay down the major indicators related to both energy and macroeconomics of Turkey and Germany as they form the foundation of energy transition strategies and provide information on where the countries stand at their energy transition process. As the multidimensional analysis focuses on energy security, environmental and economic aspects, this subchapter provides related indicators for each of these aspects as a reference point.

To make a proper comparison of the energy transitions from an energy security perspective, Table 5.1 presents main energy facts for Germany and Turkey. For most of the indicators, Turkey falls behind Germany. Electricity generation and primary energy supply of Germany is more than twofold of Turkey. Moreover, Germany has a greater advantage in energy security with its electricity storage capacity of which Turkey lacks. While electricity share in total final energy consumption is very close in two countries, Germany's per capita CO2 emissions is much higher than of Turkey's.

Table 5.1 *Quick Energy and Climate Facts*

		Germany	Turkey
Total Primary Energy Supply (2017)	Mtoe/yr	313,5	147,7
Electricity Generation	TWh/y	646,8	303,6
Electricity Consumption	TWh/y	595,6	233,6
Per Capita Primary Energy Supply	toe/cap	3,63	1,79
Per Capita Electricity Consumption	kWh/cap	6.375	3.063
Per Capita CO2 Emissions	tCO2/cap	8,84	4,68
Electricity Storage Capacity	MW	7.453	-
Electricity Share in TFEC (2017)	%	20,29%	19,03%

Source: (EnerData)

It is also essential to set out the main characteristics of Turkish and German energy policies at a broader scale before the detailed discussion. Figure 5.1 and Figure 5.2 provides the motivation, drivers as well as challenges and opportunities for German and Turkish energy policies. Increasing renewable share via incentive schemes rise as main drivers of energy policy in both countries. However, the motivations slightly differ from an environmental aspect. Climate protection is the major motivation for Germany while decreasing import dependency is prioritized in Turkey. Germany and Turkey's energy policies also diverge in opposite directions in nuclear and coal. For both countries, providing adequate investment is crucial for system flexibility when integrating variable renewable energy sources.

GERMANY

Selected Indicators

Parameter	2003	2018	CAGR
Total Final Energy Consumption	337,05 Mtoe	301,10 Mtoe	-0,7%
Final Energy Intensity	0,10 Tpes/GDP	0,07 Tpes/GDP	-2,3%
Electricity consumption per capita	6.439 kWh/cap	6.375 kWh/cap	-0,1%
Share of renewables in electricity	0,08%	0,36%	10,2%
Electricity price	17,00 € ct/kWh	29,47 € ct/kWh	3,7%
Motor fuel price	1,10 €/lt	1,39 €/lt	1,6%

Motivation & Objectives

- Climate protection and the loss of public acceptance of nuclear are chief motivators
- Focus on achieving renewables targets is shifting to system stabilization and cost control

Drivers & Governance

- Incentive schemes were the key enabler of very significant private investment in renewables
- Centralization of responsibilities to improve agility to ensure system stability

Challenges & Opportunities

- High penetration of volatile renewables poses challenge to investment in assured power supply
- Technical solutions and new business models are pioneered in Germany and have global potential

Figure 5.1. Main Characteristics of Germany's Energy Sector

TURKEY

Selected Indicators

Parameter	2003	2018	CAGR
Total Final Energy Consumption	77,79 Mtoe	147,70 Mtoe	4,4%
Final Energy Intensity	0,08 Tpes/GDP	0,07 Tpes/GDP	-1,2%
Electricity consumption per capita	1.691 kWh/cap	3.063 kWh/cap	4,0%
Share of renewables in electricity	0,25%	0,32%	1,7%
Electricity price	9,38 € ct/kWh	9,31 € ct/kWh	-0,8%
Motor fuel price	1,07 €/lt	0,94 €/lt	-0,9%

Motivation & Objectives

- Decreasing energy import dependency and improving energy industry are main motivators
- Government announced ambitious renewable, nuclear and domestic coal targets

Drivers & Governance

- Renewable tenders push private sector to invest on domestic renewable industry
- Financial/political sustainibility and inclusiveness are the key priorities

Challenges & Opportunities

- Economic fluctuations suppress private energy investments
- There are significant potential for renewables, energy efficiency and domestic coal

Figure 5.2. Main Characteristics of Turkey's Energy Sector

Environment is the next aspect of the multidimensional analysis. Both countries have ambitious policies on renewables and energy efficiency. Figure 5.3 and Figure 5.4, provides detailed statistics on renewable, energy efficiency as well as emission reductions of Turkey and Germany. It is evident from both tables that Turkey and Germany prioritize renewables and energy efficiency and have announced comprehensive policies to achieve their targets.

	2016	2017	2020	2030	2040	2050
Greenhouse gas emissions						
Greenhouse gas emissions (compared to 1990)	-27.3 %	-27.5 %	minimum -40 %	min -55 %	min -70 %	largely GHG-neutral -80 to 95 %
Increase in share of renewable energy in final energy consumption						
Share in gross final energy consumption	14.8 %	15.9 %	18 %	30 %	45 %	60 %
Share in gross power consumption	31.6 %	36 %	min 35 %	min 50 % (2025: 40-45 %)	min 65 % (2035: 55-60 %)	min 80 %
Share in heat consumption	13.5 %	13.4 %	14 %			
Share in transport sector	5.2 %	5.2 %	10 % (EU goal)			
Reduction of energy consumption and increase in energy efficiency						
Primary energy consumption (compared to 2008)	-6.5 %	-5.5 %	-20 %	→	→	-50 %
Final energy productivity	1.1 % per year (2008-2016)	1 % per year (2008-2017)	2.1 % per year (2008-2050)			
Gross electricity consumption (compared to 2008)	-3.6 %	-3.3 %	-10 %	→	→	-25 %
Primary energy demand buildings (compared to 2008)	-18.3 %	-18.8 %		→	→	around -80 %
Heat demand buildings (compared to 2008)	-6.3 %	-6.9 %	-20 %			
Final energy consumption transport (compared to 2005)	4.2 %	6.5 %	-10 %	→	→	-40 %

Source: CleanEnergyWire

Figure 5.3. CO2 Reduction, Renewables and Efficiency Targets of Germany

	2017	2018	2023	2030
Greenhouse gas emissions				
INDC (from BAU)	8%	-	15%	21%
Renewables and clean sources				
Renewables share in power generation	29,37%	32,38%	38,8%	
Solar Capacity	3.421 MW	5.100 MW	-	10.000 MW
Wind Capacity	6.516 MW	7.000 MW	-	16.000 MW
Hydro Capacity	27.273 MW	28.293 MW	-	max.
Nuclear Capacity	-	-	1.200 MW	4.800 MW
Reduction of energy consumption and increase in energy efficiency				
Primary energy demand	146,7 mtoe	148,0 mtoe	174,3 mtoe	-
Energy saving	-	-	23.901 ktoe	-
Gross electricity demand	296,7 TWh	303,3 TWh	375,8 TWh	-
Energy related plans and policies under INDC				
• Reducing electricity transmission and distribution losses to 15 percent at 2030 • Rehabilitation of public electricity generation power plants • Establishment of micro-generation, co-generation systems and production on site at electricity production Industry • Reducing emission intensity with the implementation of National Strategy and Action Plan on Energy Efficiency • Increasing energy efficiency in industrial installations and providing financial support to energy efficiency projects • Making studies to increase use of waste as an alternative fuel at the appropriate sectors				

Source: UNFCCC, TEİAŞ, MENR, TÜİK

Figure 5.4. CO2 Reduction, Renewables and Efficiency Targets of Turkey

Economic aspect is indispensable for any analysis. Therefore, the third aspect of the multidimensional analysis is the socioeconomic aspect. Laying down the macroeconomic indicators for both countries is well suited before the main analysis. In this regard, Table 5.2, compares main macroeconomic indicators for Turkey and Germany for the years 2003 and 2018. It is evident that Turkey suffers from a current account deficit while Germany experiences a surplus. Moreover, energy inflation is very high for Turkey compared to Germany. Unemployment rate is relatively higher as well. All these macroeconomic facts are in line with the facts discussed in the Figure 5.3 and Figure 5.4.

Table 5.2. *Main Macroeconomic Indicators*

Indicator	Year	Turkey	Germany
GDP (current billion US$)	2003	311,82	2.505,73
	2018	766,51	3.996,76
GDP (constant 2010 US$)	2003	550,63	3.154,32
	2018	1.236,99	3.939,23

Table 5.2 (continued)

Indicator	Year	Turkey	Germany
Inflation, CPI (annual %)	2003	21,60%	1,03%
	2018	16,33%	1,73%
Energy Inflation, CPI (annual %)	2003	18,20%	4,00%
	2017	10,50%	2,70%

5.2.1. Institutional and Regulatory Framework

A multidimensional analysis of energy transition policies is not only a useful tool for understanding how policy actions are taken but also for analyzing the institutional links between policy outcomes and the actors affected by them (Keppley, 2012). It is the institutions that shape the countries' actions while setting energy transition strategies. Therefore, Table 5.3 provides a list of institutions responsible for each area of interest to better understand the energy transition policies of Germany and Turkey. The table points out that while ministries in both countries serve for similar areas, in gas and electricity TSOs Germany has more players.

Table 5.3. *Authorities and Institutions in Turkey and Germany*

GERMANY Authority / Institution	Area of Interest	TURKEY Authority / Institution
Federal Ministry of Economics and Technology	Energy Policies	Ministry of Energy and Natural Resources

Table 5.3 (continued)

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety	Environmental Policies, RE Sources	Environmental Policies	Ministry of Environment and Urbanization
Federal Ministry of Transport, Building and Urban Development	Energy Savings	Energy Savings, Energy Efficiency	Ministry of Industry and Technology
Federal Ministry of Finance	Energy Taxation		Ministry of Treasury and Finance
Federal Network Agency	Regulatory		Energy Market Regulatory Authority Nuclear Regulatory Authority
Federal Office for Radiation Protection	Radiation Protection		Turkish Atomic Energy Institution
Federal Institute for Geosciences and Natural Resources	Natural Resources	Natural Resources and Licensing	General Directorate of Mining and Petroleum Affairs
15 Gas TSOs	TSO		Petroleum Pipeline Corporation
4 Electricity TSOs	TSO		Turkish Electricity Transmission Corporation
German Energy Agency	RE and energy efficiency	Energy Efficiency Measures	Coordination Committee of Energy Efficiency
Working Group on Energy Balances	Energy balances	Generation	Electricity Generation Corporation

Table 5.3 (continued)

German Emissions Trading Authority	GHG Licensing	Distribution	Turkish Electricity Distribution Corporation
Federal Cartel Office	Competition	Energy Investments Monitoring	Committee for Monitoring and Coordination of Energy Investments
Monopolies Commission	Competition Reporting Commission		

In addition, regulatory framework is essential for policy development. Table 5.4 and Table 5.5 lists all related laws and regulations on energy for Germany and Turkey in a chronological order by topic. It is evident from the list that Germany's laws and regulations dates long back compared to Turkey. As electricity sector is an integral part of the transition for both countries, legal and institutional framework leading to the transformation in the electricity sector is elaborated in detail. Figure 5.5 and Figure 5.6, presents a timeline on the developments in the electricity sectors of Turkey and Germany with a specific focus on the major regulatory developments. Turkey observes an increase in electricity generation from all sources after the enactment of market laws since 1997s. For renewables, there are two major turning points; the Renewables Law of 2005 and the introduction of feed-in-tariffs in 2011. For Germany, the dates are much sooner. First Feed-in-Tariff dates even back to 1991. While Germany experienced increase in power generation from renewables since 2000s with the enactment of Renewable Energy Act, coal, nuclear and natural gas stayed either stable or decreased. A sharp decrease in nuclear is observed right after the Fukushima accident in 2011.

Table 5.4. *Germany's Energy Laws and Regulations*

Law/Bylaw/Ordinance	Date	Purpose
Energy Industry Act	13.07.2005	Sets out the regulatory conditions for supply of electricity and natural gas.
Interruptible Loads Regulation	1.01.2013	Aims to develop demand side management potential in the interest of the security of the electricity supply system at transmission system level.
Incentive Regulation Ordinance	6.11.2017	Uses incentive-based regulation to stipulate the fees for access to the energy supply networks
High-Pressure Gas Pipeline Ordinance	18.05.2011	Specifies procedures and requirements for ensuring technical safety during the erection and operation of high-pressure gas pipelines
Gas Network Charges Ordinance	29.07.2005	Defines the methods to be used for calculating charges for access to gas pipelines and gas distribution networks
Gas Network Access Ordinance	9.09.2010	Defines the conditions under which grid operators shall provide access to their networks to those entitled to such access
Ordinance on the Connection of Power Stations to the Networks	27.06.2007	Lays down basic conditions under which facilities for the generation of electricity shall be connected to electricity supply grids
Low-Voltage-Connection Ordinance	8.11.2006	Comprises provisions governing the connection to the grid, the use of this connection, and the content of the grid connection contract
Electricity Network Access Ordinance	29.07.2006	Defines the conditions for feeding/take-off of electrical energy to/from the electricity grids as well as grid balancing and balancing-group management.
Ordinance on Grid System Stability	25.07.2012	Aims to prevent risks to system stability resulting from PV generation facilities

Table 5.4 (continued)

Low-Pressure-Connection Ordinance	8.11.2006	Lays down the conditions under which end consumers in the low-pressure range shall be connected to the general supply.
Electricity Default Supply Ordinance	8.11.2006	Stipulates the general conditions for the default supply of electricity to household customers in the low-voltage range.
Gas Default Supply Ordinance	8.11.2006	Stipulates the general conditions for the default supply of natural gas to household customers in the low-pressure range.
Electricity Network Charges Ordinance	29.07.2005	Specifies the methods to be used for calculating charges for access to the transmission and distribution grids.
Energy Security of Supply Act	20.12.1974	Defines how vital energy needs are to be met in the event of immediate threats or disruptions to the energy
Ordinance to Ensure the Supply of Electricity in a Supply Crisis	26.04.1982	Ensures that vital needs for electricity are met.
Grid Reserve Ordinance	6.07.2013	Specifies the procedure to be used to create the grid reserve as well as rules on decommissioning of electricity generation and storage installations
Ordinance to Ensure the Supply of Gas in a Supply Crisis	26.04.1982	Defines the powers of the Federal Network Agency and the Länder (as load distributors) that are necessary for ensuring that vital demand for natural gas is met
Power Grid Expansion Act	26.08.2009	Deals with the construction of extra-high voltage grids
Grid Expansion Acceleration Act	28.07.2011	Sets out procedural requirements for the construction of cross-regional and cross-border extra-high-voltage lines
Atomic Energy Act	23.12.1959	Defines basic rules for plant operation and for the structured phase-out of nuclear energy

Table 5.4 (continued)

Renewable Energy Sources Act	1.08.2014	Promotes the advancement of technologies that enable the production of energy from renewable sources
Renewable Energies Ordinance	17.02.2015	Sets out rules on how electricity for which funding has been disbursed pursuant to the Renewable Energy Sources Act (EEG) is to be marketed, on how the level of funding under the EEG is to be determined and published, and on certificates of origin, certificates of regional production and the relevant registers associated with these.
Biomass Electricity Sustainability Ordinance	24.07.2009	Applies to bioliquids used for electricity production under the Renewable Energy Sources Act
Biomass Ordinance	28.06.2001	Regulates which matters are deemed to be biomass under the RES Act, which technical procedures for the production of electricity from biomass fall under the scope of application of the act, and which environmental requirements must be complied with in the production of electricity from biomass.
System Service Ordinance	3.07.2009	Aims to improve the safety and stability of the electricity grids, even when there are high shares of electricity from wind energy in the networks
Cross-Border Renewable Energy Ordinance	16.08.2017	Defines the rules that apply for cross-border auctions for electricity from PV installations
Register-of-Facilities Ordinance	1.08.2014	Sets out requirements for the establishment and use of a register of facilities used to generate electricity from renewables and firedamp.
Offshore Wind Energy Act	1.01.2017	Encourages greater use of offshore wind energy
Combined-Heat-and-Power Act	1.01.2016	Regulates the funding for the low-carbon CHP installations.

Table 5.4 (continued)

Metering Act	29.08.2016	Sets out the rules on the introduction and use of smart meters
Energy Saving Act	22.07.1976	Sets out the basic legal requirements with regard to energy conservation in buildings.
Energy Saving Ordinance	24.07.2007	Aims to improve the energy performance of buildings
Heating Cost Ordinance	20.01.1989	Lays down the rules to be used to calculate energy costs based on the consumption of energy for heating and hot-water systems in buildings
Act on Energy Consumption Labelling	17.05.2012	Regulates the market supervision of product labelling.
Ordinance on Energy Consumption Labelling	17.05.2012	Regulates administrative offences relating to the obligations of manufacturers and sellers in the context of product labelling
Ordinance on the Energy Labelling Of Cars	1.11.2014	Introduces an energy label for cars that informs consumers about the car's carbon footprint
Greenhouse Gas Emission Trading Act	8.07.2004	Provides the basis for the trading of greenhouse gases emission allowances within a pan-EU emissions trading system
Carbon Capture and Storage (CCS) Act	17.08.2012	Provides the legal framework for the piloting and application of technologies used in the sequestration, transport, and storage of carbon dioxide found in deep geological strata
Energy and Climate Fund Act	8.12.2010	The Energy and Climate Fund was established in order to provide funding for the additional responsibilities associated with the Energy Concept of 28 September 2010.
Energy-Related Products Act	16.11.2011	Defines the energy-related requirements that apply to products entering the market and being used
Electric Mobility Act	12.06.2015	Regulates the preferential participation of electric vehicles in road traffic

Table 5.4 (continued)

Electricity Duty Act	24.03.1999	Lays down the rules on electricity taxation and specifies cases in which reduced tax rates or tax exemptions apply.
Energy Duty Act	16.06.2006	Lays down the rules regarding tax rates on heating and motor fuels
Energy Statistics Act	10.03.2017	Defines revision of energy statistics.

Table 5.5. *Turkey's Energy Laws and Regulations*

Law/Bylaw/Ordinance	Date	Aim
Electricity Market Law	14.03.2013	Establishes the electricity market and defines the market principles. All the electricity activities in Turkey are under the scope of this law.
Electricity Market Ordinance on Capacity Mechanism	20.01.2018	Regulates the capacity mechanism executed by the transmission system operator to ensure power supply security
Electricity Market Ordinance on Tariffs	22.08.2015	Stipulates the terms and conditions for the tariffs subject to regulation in the electricity market
Electricity Market Ordinance on Accession and System Use	28.01.2014	Regulates the connection of the entities to the power transmission system or distribution system.
Electricity Market Ordinance on Licence	2.11.2013	Defines the terms and conditions of pre-license application processes in the electricity market
Electricity Market Ordinance on Balancing and Reconciliation	14.04.2009	Sets out the balancing and reconciliation terms and conditions

Table 5.5 (continued)

Electricity Market Ordinance on Network	28.05.2014	Includes the provisions of planning, operation and stability of power transmission system as well as the conditions of supply security and quality
Electricity Market Ordinance on Import and Export	17.05.2014	Defines the terms and conditions for power import/export, capacity allocation of the international interconnections and usage of such interconnections for cross-border power trade
Electricity Market Ordinance on Distribution	2.01.2014	Defines the terms and conditions of planning and operation of distribution systems and system connections
Electricity Market Ordinance on Unlicenced Electricity Generation	12.05.2019	Stipulates the provisions of power generation without obtaining license or establishing corporation
Law Concerning the Use of Renewable Energy Sources For the Purpose of Electricity Generation	10.05.2005	Promotes the usage of the renewable energy sources for power generation as well as necessary industry
Ordinance Concerning Pre-Licence Applications For the Purpose of Establisment of Generation Facilities Based on Wind Or Solar Energy	13.05.2017	Defines the terms and conditions of the grid connection capacity competitions made by transmission system operator for the new solar and wind power plants.
Ordinance on the Certification and Promotion of Renewable Energy Sources	1.10.2013	Includes the provisions of the establishment and execution of the incentive mechanism for the renewable energy sources.

Table 5.5 (continued)

Ordinance Concerning Technical Evaluation of the Applications of Electricity Generation Based on Wind Source	20.10.2015	Defines the conditions of technical evaluation of the pre-licensed or unlicensed wind power plant applications
Ordinance Concerning Technical Evaluation of the Applications of Electricity Generation Based on Solar Source	30.06.2017	Defines the conditions of technical evaluation of the pre-licensed or unlicensed solar power plant applications
Ordinance on the Renewable Energy Source Zones	9.10.2016	Sets out the provisions of the allocation of large scale renewable energy source zones to the investors, promotion of the domestic manufacture of high technology equipment used for the renewable power plants and technology transfer.
Ordinance on the Promotion of Domestic Equipment Used At the Facilities That Are Generating Electricity From Renewable Energy Sources	24.06.2016	Establishes the terms and conditions for the assessment and audit of the premium to be granted to the renewable power plants installed by using domestic equipment.
Ordinance on Usage of the Geothermal Source Zones For Electricity Generation	14.10.2008	Sets out the provisions of usage of geothermal source zones that are suitable for power generation
Geothermal Sources and Natural Mineral Water Application Ordinance	11.12.2007	Regulates the licenses and activities for the exploration and operation of geothermal sources, mineral water and geothermal originated gases
Ordinance Concerning the Electricity Generation Facilities Based on Solar Energy	19.06.2011	Defines the standards to be used for the solar power plants as well as audit of solar originated power generation in the solar power plants and hybrid facilities that are using solar source

Table 5.5 (continued)

Natural Gas Market Law	18.04.2001	Establishes the natural gas market and defines the market principles. All the natural gas market activities in Turkey are under the scope of this law.
Natural Gas Market Distribution and Customer Services Ordinance	3.11.2002	Regulates the in-city natural gas distribution activities and customer services
Natural Gas Market Transmission Network Operation Ordinance	3.11.2002	Defines the rules of the operation of natural gas transmission system such as accessing, nomination, transmission planning, balancing, capacity allocation, delivery and metering.
Natural Gas Market License Ordinance	7.09.2002	Sets out the terms and conditions of licenses to be granted in the natural gas market
Natural Gas Market Ordinance on Determining the Base Terms and Conditions of the Use of Liquified Natural Gas Storage Facility	16.05.2009	Stipulates the basic rules of usage of liquefied natural gas storage facilities.
Natural Gas Market Tariffs Ordinance	13.10.2016	Regulates the natural gas market tariffs
Natural Gas Market Facilities Ordinance	26.10.2002	Sets out the terms for the conduct of natural gas market activities in accordance with the national and international standards
Natural Gas Market Ordinance on Determining the Base Terms and Conditions of the Use of the Underground Storage Facility	4.06.2011	Stipulates the basic rules of usage of underground natural gas storage facilities.

Table 5.5 (continued)

Law Concerning the Installation and Operation of Nuclear Power Plants and Energy Sale	21.11.2007	Regulates the installment, operation and power sale of nuclear power plants
Ordinance Concerning the Terms and Conditions of the Competition and Contract and Incentives Within the Scope of the Law Concerning the Installation and Operation of Nuclear Power Plants and Energy Sale	10.03.2008	Sets out the rules of the competition for the nuclear power plants such as conditions for applicants, land allocation, license fee, incentives, installed capacity, purchase guarantee and purchase price
Design Principles Ordinance For the Safety of Nuclear Power Plants	17.10.2008	Regulates the safety principles for the design of the nuclear power plants
Special Principles For the Safety of Nuclear Power Plants	17.10.2008	Regulates the special safety principles of the authorized person for the nuclear power plants
Ordinance Concerning the Nuclear Power Plant Fields	21.03.2009	Stipulates the safety rules for the installment of nuclear power plant on a land
Bylaw Concerning the Issue of License To the Nuclear Facilities	18.11.1983	Regulates the license granting of nuclear power plants
Radiation Safety Bylaw	24.07.1985	Sets out the rules applicable to whom obtaining, using, importing, exporting, transporting and storing ionizing radiation sources
Radiation Safety Ordinance	24.03.2000	Ensuring the safety of human and environment against ionizing radiation

Table 5.5 (continued)

Energy Efficiency Law	2.05.2007	Aims to increase energy efficiency for the effective use of energy, avoiding waste of energy, decreasing the burden of energy sources on economy and protecting environment
Buildings Energy Performance Ordinance	5.12.2008	Defines the terms and conditions of effective and efficient use of energy, avoiding waste of energy and protection of environment in the buildings
Turkish Atomic Energy Institution	9.07.1982	Establishes the Turkish Atomic Institution and defines its authorities
Management of Radioactive Waste Material	9.03.2013	Defines the terms and conditions for the management of radioactive waste arising out of nuclear power generation and ionizing radiation source use in order not to harm workers, society and environment.
Safe Transportation of Radioactive Matter Ordinance	8.07.2005	Ensuring the safety of human and environment from the transportation of radioactive materials
Environment Law	9.08.1983	Aims to protect environment in line with the principles of sustainable environment and sustainable development
Control of Industry Sourced Air Pollution Ordinance	3.07.2009	Aims to control emissions emitted by industrial facilities and power plants and to prevent and mitigate negative impacts
Ordinance Regarding Burn of Waste	6.10.2010	Aims to prevent negative impacts of waste burning on the environment and minimize the risks associated with waste burning

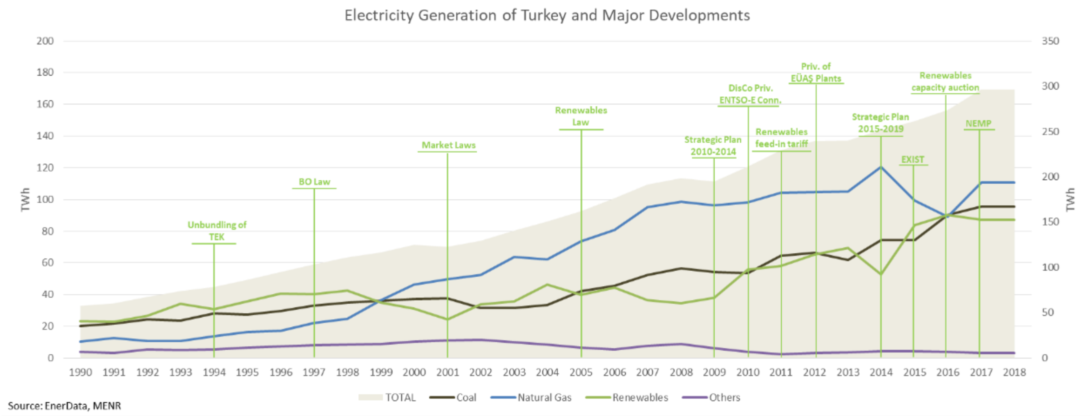


Figure 5.5 Electricity Generation of Turkey and Major Developments

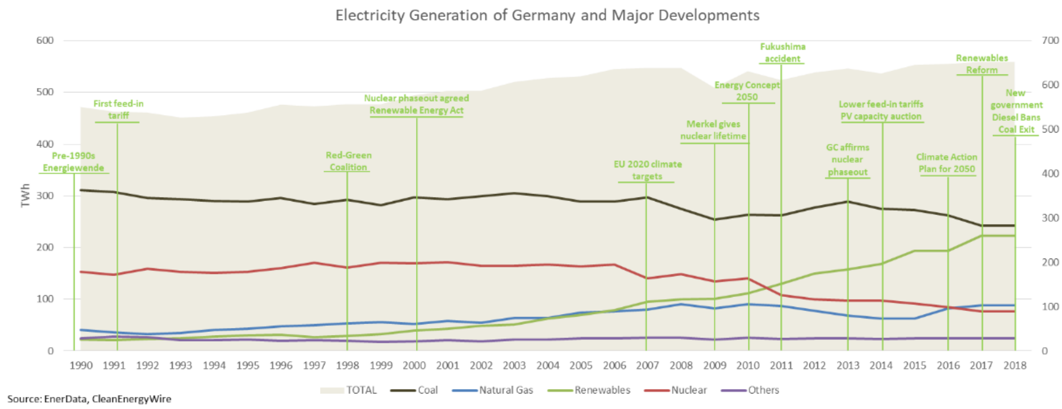


Figure 5.6. Electricity Generation of Germany and Major Developments

Main indicators as well as the institutional framework discussed in this subchapter would provide useful insights for the further discussions of this chapter. The framework would serve as a baseline for the multidimensional analysis.

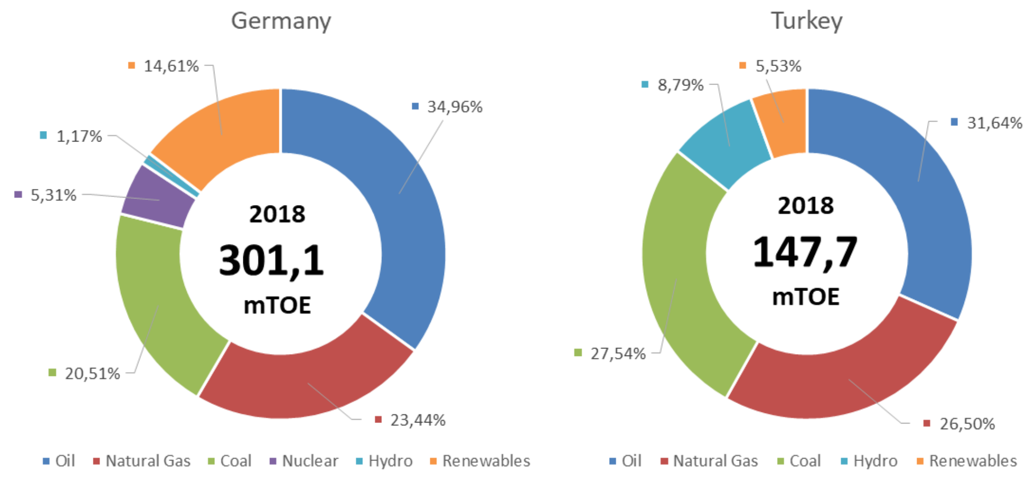
5.3. Energy Security Aspect

Energy security, defined as the "uninterrupted availability of energy sources at an affordable price" (IEA, 2020), lies at the center of energy policies of both Germany and Turkey. Especially with the rising trade-related geopolitical turmoil in the world and its effects on the energy sector have brought energy security into prominence, particularly for energy importing countries like Germany and Turkey (Bayraktar, 2018). Energy security is in particular critical for Turkey like most other developing countries. In developing countries, the challenge of meeting the demand of increasing population while dealing with rapid urbanization needs puts energy security above all energy policy priorities. In this regard, each country has their unique strategies that will be discussed further in this subchapter.

This subchapter is organized as follows; first, the energy mixes of both countries are compared. The discussion is followed by an analysis of the power sectors of both countries as electrification is the major driver of energy transition towards low carbon. Though less discussed, infrastructure is an integral part of energy security policies and remains to be highly critical for the success of energy transition. Both Germany and Turkey have their own infrastructure challenges, which will be discussed in the third part of this chapter.

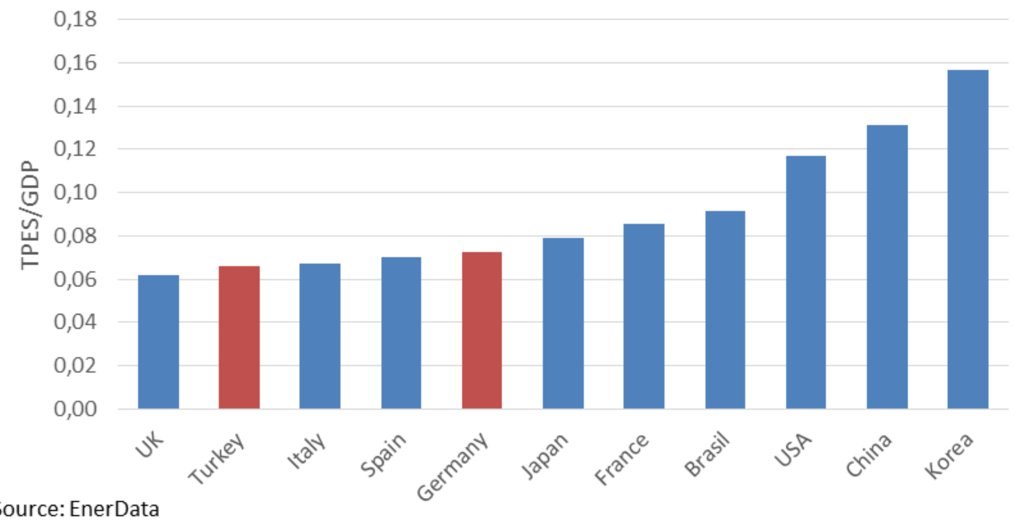
5.3.1. Energy Mix

It is crucial to understand the total numbers in energy systems as a whole to understand where a country stands in its energy transition. These numbers include energy supply mix, energy consumption and energy intensity. Both Turkey and Germany continue to rely on fossil fuels in their energy supply mixes. As shown in Figure 5.7 , oil, natural gas and coal represent the highest shares in energy supply mixes with a total of almost 80% and 87% for Germany and Turkey, respectively. Energy intensities of both countries are also very close in 2018 (Figure 5.8) with decreasing trends (sharper for Germany) since 2002 (Figure 5.9). While energy supply mixes and energy intensities are similar for Turkey and Germany, annual energy consumption in Germany is around twofold of Turkey’s (Figure 5.10).



Source: EnerData

Figure 5.7. Energy Supply Mix



Source: EnerData

Figure 5.8. Energy Intensity (2018)

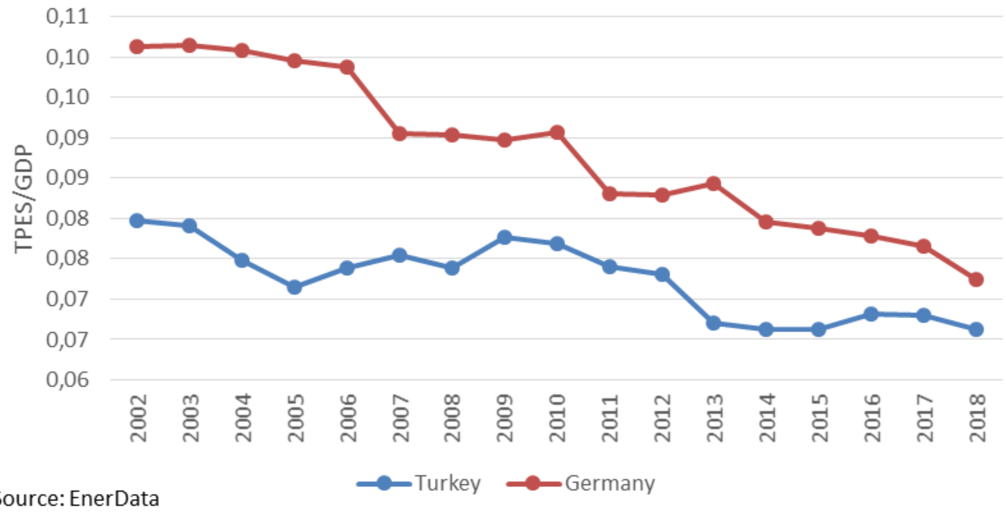


Figure 5.9. Energy Intensity Over Time

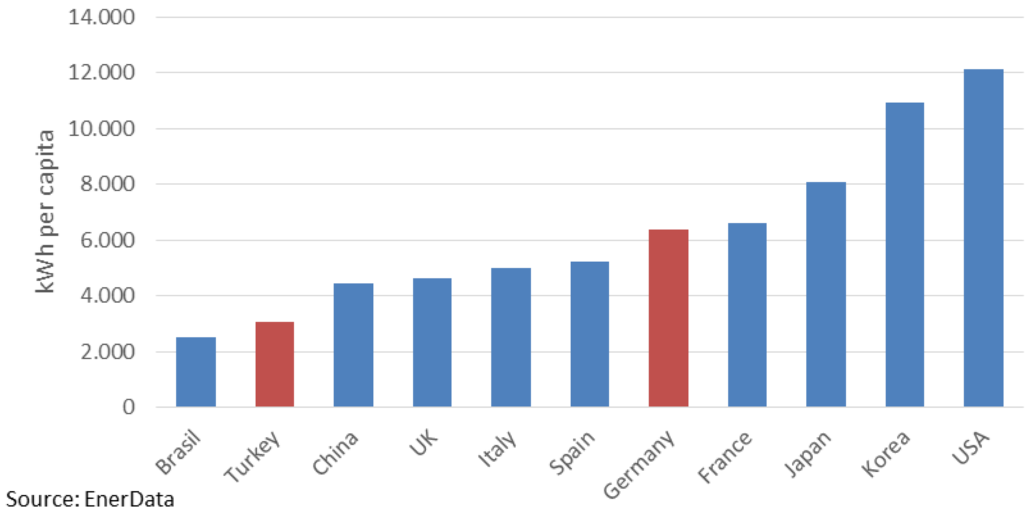


Figure 5.10 Annual Electricity Consumption (2018)

To further understand the similarities and differences in Turkey's and Germany's energy transitions, it is highly crucial to analyze the electricity sector as it lies at the heart of both countries transition processes. In this regard, next subchapter focuses on electricity generation with a specific focus on the system flexibility.

5.3.2. Electricity

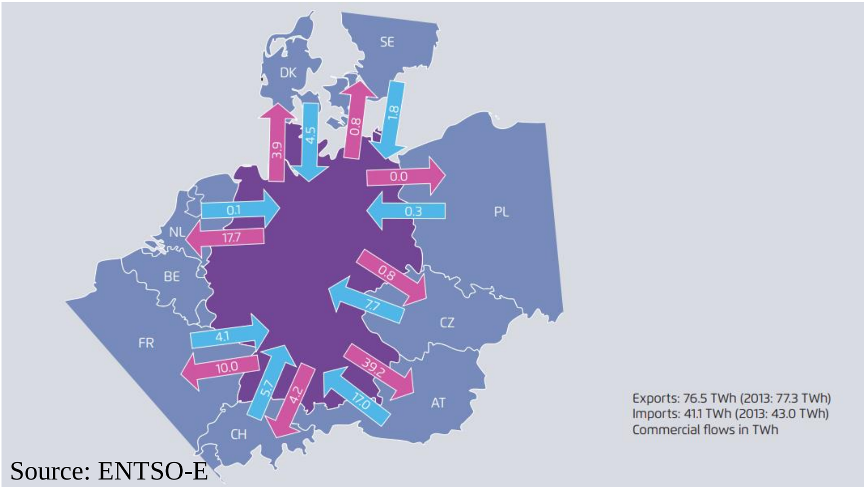
Transition to a new energy mix is only a portion of the entire story. A more immediate transformation is rather observed in the electricity markets. Transformation in the electricity sector is the key component of energy transitions for all countries. Power systems have already initiated the transition processes globally (IRENA, 2019) and the further success towards low carbon depends on the additional developments in the power sector. IEA has long been studying power system transformation. IEA describes the transformation as "creation of a policy and market environment that encourages innovative and sustainable technology solutions for electricity production, distribution and consumption" (IEA, 2018c).

An important step toward a comprehensive energy transition is decarbonizing the power sector by increasing renewable shares in electricity generation. However, integrating variable renewable energy sources into the existing power system remains to be a major concern. Therefore, system flexibility rises as an important factor for the success of the transitions. In this regard, this subchapter discusses the electricity generation dynamics in Turkey and Germany. As the expansion of variable energy sources remains to be a central pillar in the energy transition of Germany and Turkey, system flexibility in both countries is further elaborated. Detailed discussion on renewables is covered in the environmental aspect subchapter. Therefore, for further reading please refer to renewables section.

5.3.3. Grid Interconnections as a Source of System Flexibility

Many elements are required for a successful energy transition towards low carbon. System flexibility is getting integral to transition to low carbon sources as the share of variable energy sources in power generation are increasing. Global examples show that 25% of wind and solar can be successfully integrated without changing the grid system (Shura, 2018a). In this regard, among other countries Germany has developed flexibility options including increasing interconnection capacity and improving flexibility of plants using fossil fuels. According to many studies, increasing and strengthening interconnections reduces the cost of renewable integration (Shura, 2018a).

Among EU countries Germany has the highest annual electricity demand and its electricity system is interconnected with ten countries with a transfer capacity of more than 20 GW (Shura, 2018a). Germany benefits from a high level of interconnectivity with its neighboring countries. It is interconnected with Austria, Switzerland, the Czech Republic, Denmark, France, Luxembourg, the Netherlands, Poland, and Sweden (Figure 5.11).



Source: ENTSO-E

Figure 5.11 Commercial Electricity Exchange between Germany and It's Neighbors (2014)

Germany's per capita electricity consumption has not changed significantly since 2005 which was reflected by only a small change in total final electricity consumption (IEA, 2018a). The country is endowed with strong transmission networks. Power system of Germany is part of is part of the interconnected Central and Western European power networks. Due to abundant thermoelectric capacity, Germany is a net electricity exporter.

Since 1990s, Germany has been supporting renewable power generation. Renewables, in particular wind, contribute to the power flows from north towards south. Total renewable energy supply accounted for more than 37% of electricity generation in 2018 (Figure 5.12). The country has favorable wind sources but limited available land. Since 2015, Germany has been seeking opportunities in offshore wind. Germany has been supporting renewables through feed-in-tariffs with the enactment of EEG in 2000. In 2017, Germany switched from feed-in-tariffs to an auction mechanism. Since then, growth rate of renewables started to fluctuate. Within next year, a significant amount of renewable power plants would reach to 20-year period of the feed-in-tariff support mechanism. It is important to analyze the decommissioning effects of those renewable capacities. With the retiring power plants, higher installed renewable capacities are required to reach the renewable targets which would in turn cause transmission congestions from north to south. Due to congestion, around 2.9% of wind power was curtailed in 2017 (Weber & Tns, 2018) . Germany has plans to increase the transmission capacity from renewable rich north to south through three DC interconnectors.

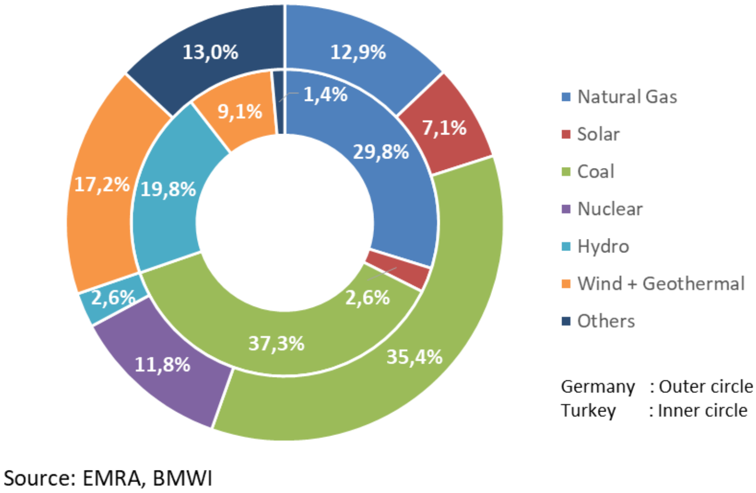


Figure 5.12. Electricity Generation by Source (2018)

In Turkey, the story is different. Unlike Germany, electricity consumption per capita raised from 2000 kWh per year to 3000 kWh per year from 2005 to 2016 (IEA, 2018a). Moreover, access to electricity increased around 15% during the same period (World Bank, 2019b). Therefore, different from Germany, demand growth, population growth and urbanization growth are important factors with significant effects on the energy transition.

On the other hand, Turkey has a much limited interconnection capacity compared to Germany with most of its interconnections not being in operation (Figure 5.13). Turkey achieved a major milestone in January 2016 when it became an observer member of ENTSO-E. The country is also planning new interconnections which would likely to increase the connectivity over the Black Sea. However, the efforts still remain to be limited. Turkey is a net exporter of electricity (IEA, 2018a) . Although Turkey has interconnection with Bulgaria and Greece since 2015, the system is still operated in isolation (EPDK, 2018). One advantage is that there is an abundant hydro resources of the country which enables flexibility in the system (Shura, 2018a). Flexibility through hydro has significant contributions on the growth of wind power.

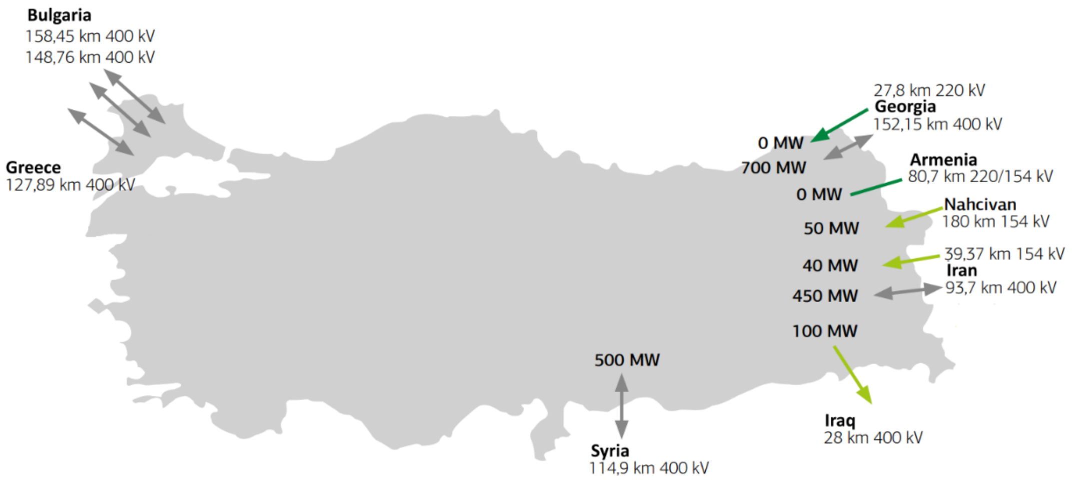


Figure 5.13. TEİAŞ Interconnections

In 2007, the government introduced a renewable support program which attracted many applications. However, the regions remained to be limited in terms of grid capacity. Some regulatory actions were taken during the process to enable the grid connection of wind power while keeping the system secure. The actions include:

- Determining the maximum connection capacity of a region by TEIAS (Transmission System Operator),
- Designing a bidding process in the connection requests exceed the maximum capacity of the substation,
- Planning of new substations to be able to increase renewable connection capacity.

Moreover, EMRA introduced a capacity remuneration mechanisms to secure enough capacity (Gedik & Gürgey, 2018). Additionally, complementing the hourly day ahead and balancing markets, Turkey introduced an intraday market to provide participants to trade close to real-time and balance their portfolios. All services together have significant contributions to the system security enabling more renewables to be integrated in the system.

Turkey started its renewable support mechanism much later than Germany, in 2007. Similar to Germany, Turkey also switched from feed-in-tariff to tendering mechanism. Until November 2019, Turkey finalized 2000 MW of wind tender and a 1000 MW of solar tender in various regions. System integration of these projects is important to follow once the projects are in operation.

According to IRENA, full penetration of renewable energy is challenging unless a system is appropriately interconnected (IRENA, 2018). Therefore, Turkey falls behind Germany in terms of system flexibility from power grid point of view. In order for successful energy transition in line with climate goals, it is important for Turkey to recognize the challenges regarding system flexibility and take measures in a timely manner.

The system reliability depends also on the developments in coal and nuclear. Coal and nuclear have been the major drivers of German power sector. Although there have been long discussions on the phase-out of both coal and nuclear, both resources continue to serve as a back-up for the variable renewable sources. For Turkey, the picture is quite different. While coal has a significant role in power generation, the focus shifted towards improving domestic coal to replace power generation form imported coal. As regards to nuclear, Turkey does not have any nuclear power plant, yet, the construction of the first nuclear power plant is ongoing.

Coal

Turkey and Germany rely on a high share of fossil fuels in their total energy supply Figure 5.7. Coal remains one of the largest energy source for electricity generation for both countries. In 2018, coal accounted for 35,4% and 37,3% in electricity generation, respectively for Turkey and Germany. Germany's coal-fired power generation has not been affected significantly from the growth in renewables. Instead, excess amount of generated power is exported to neighboring countries. Germany has established the Coal Commission in 2018. The Commission recommended to phase-out coal power plants by 2038, though the recommendation remains to be legally nonbinding (Schubert & Hauser, 2019)

In Turkey, domestic coal is an integral part of the National Energy and Mining Policy. Unlike Germany, new tenders are being held for new coalmines. According to the Ministry of Energy and Natural Resources, the installed coal capacity will be boosted as a part of the strategy to increase domestic resources (MENR, 2019). However, the realization rates of the projects have been low mostly due to financing issues (IEEFA, 2019).

Nuclear

Nuclear power is one of the major source of global energy supply and remains to be critical for energy security. Indeed, nuclear is still the dominant source of electricity in many countries like France and Belgium. According to IEA, "nuclear power and hydropower form the backbone of low-carbon electricity generation. Together, they provide three-quarters of global low-carbon generation" (IEA, 2019). 8 years after the Fukushima, countries still argue about the costs and benefits of possible denuclearization policies. Opinions about nuclear power have been divided into two polarized sides: increase nuclear power for energy security or phase-out nuclear completely.

Germany is one of the leading countries announcing to phase-out nuclear right after the Fukushima event. Following Fukushima in 2011, Germany has immediately shutdown 8 of its 17 nuclear power plants and the rest is planned to be closed by the end of 2022. Currently, there are 7 nuclear power plants that are still in operation. According to Energiewende targets, phasing out nuclear by 2022, will cause a 10 GW decrease in installed capacity which is mainly located in the south of the country. Therefore, more power transmission will be required from the north where the renewable generation is in the rise towards the south where the nuclear capacity is in a fall.

The role of nuclear power is one of the fundamental difference between the energy policies of Germany and Turkey. While Germany still generates 23% of its electricity from nuclear with ambitious plans to phase out nuclear, Turkey does not have any nuclear power plants, yet, has firm plans to add nuclear to its power mix. First nuclear power plant of Turkey is expected to become operational in 2023 and expected to supply 10% of electricity generation once it is fully completed. Additionally, there are intentions to further develop two more nuclear power plants.

Turkey sees nuclear energy as an important element of energy security. Turkey's energy policy considers nuclear energy and renewable energy under the same umbrella as a way to transition towards low carbon while increasing energy security. Turkey has published its National Energy and Mining Policy in 2016, which includes an ambitious target of generating 10% of electricity from nuclear by 2023 as part of the localization in the energy systems. The Policy Paper sees nuclear as an important element of energy security, power source and a tool for environmental protection.

5.3.4. Infrastructure

Another important energy security challenge is aging infrastructure. According to IEA, until 2035 around 2000 GW of power plants will be retired with two thirds being fossil-fueled power plants globally (International Energy Agency, 2018b) . Moreover, nuclear capacity is also in decline especially with increasing number of countries putting moratorium on nuclear power plants including Germany. This declining installed capacity from fossil fuels and nuclear have to be replaced by other sources to meet the required demand and remains to be highly critical for energy security of many countries. To achieve low-carbon energy transition the reduced amount of capacity must be met by low carbon capacity sources like renewables. However, when it comes to numbers this is a challenging target. In terms of replacing the power plants required additional capacity amounts to around 450 Fukushima power plants (Goldthau & Sovacool, 2012). Meeting this amount of reduced capacity by additional renewables requires a vast amount of investment. For Germany, while the infrastructure to export the excess electricity to its neighboring countries is adequate as discussed previously, the national infrastructure that needs to integrate variable energy sources to the electricity grid is inadequate.

Germany and Turkey face challenges in their energy infrastructure as discussed in the previous chapters. Therefore, both countries need to tackle with technical and economic consequences of infrastructure needs to achieve their energy transition goals.

5.4. Environmental Aspect

There are many definitions of energy transition. Although the definitions slightly differ, one thing is common. The global energy transition is towards low carbon energy sources. According to IRENA, “the energy transition is a pathway toward transformation of the global energy sector from fossil-based to zero-carbon by the second half of this century” (IRENA, 2018). Decreasing C02 emissions lies at the heart of energy transition. According to the same study by IRENA, "Renewable energy and energy efficiency measures can potentially achieve 90% of the required carbon reductions." (IRENA, 2018). Therefore, it is a common understanding that energy transition towards low-carbon can only be achieved by replacing fossil fuels with renewables accompanied by reducing energy consumption through energy efficiency measures.

In line with this global phenomenon, Turkey and Germany has comprehensive policies regarding both renewables and energy efficiency put forth in the numerous policy papers. Although CO2 emissions of the two countries are distinctively far from each other, both Germany and Turkey have firm plans to increase renewables and energy efficiency that will be discussed in the next subchapters.

5.4.1. CO2 Emissions

Global energy supply accounts for almost two thirds of global carbon emissions (World Energy Outlook, 2016). According to IEA, "Global energy-related CO2 emissions grew 1.7% in 2018 to reach a historic high of 33.1 Gt CO2. It was the highest rate of growth since 2013, and 70% higher than the average increase since 2010." (International Energy Agency, 2019). In this regard, tracking CO2 emissions is one of the most critical measures that shows the progress of energy transition towards low carbon. There is also an important role for policy in prioritizing the reduction of CO2 emissions.

Germany has been a leading actor in climate change discussions since the first election of Angela Merkel in 2005 who was later known as the "climate chancellor". In 2007, Germany has pledged to decrease emissions by 40% by 2020 compared to 1990 levels. Later, the target was revised to decrease CO2 emissions by 55% by 2030. To achieve these targets many measures were announced. The German government has initiated those measures in the form of two major action plans; "Climate Action Programme 2020" and the "Climate Action Plan 2050". Climate Action Plan was adopted in November 2016, which sets out the long term goal of

Germany's Paris Agreement pledge. According to this plan, Germany is set to become CO2 neutral by 2050. Although Germany has set ambitious targets for 2020 and 2030, the government has admitted that the 2020 targets were to be missed by 8% (Deutsche Welle, 2018). In November 2019, German Parliament has passed a law to ensure reaching the medium-term goal of 2030. According to this law, each ministry must make predetermined emission reductions in their field of interest. Additionally, a national carbon pricing is to be adopted (Eddy, 2020).

Germany's climate goals has long been debated. According to figures, the country's carbon emissions are not declining in line with its climate pledges, despite the sharp increase in renewable power generation. On the contrary, Germany's carbon emissions per capita rose slightly in 2013 and 2015. It is claimed that due to variability of renewables, enough energy is not supplied to meet all the power needs. To meet the required demand, the country might have to keep coal-fired power plants running which would in turn have negative environmental impacts. Hence, the effects of coal as well as nuclear phase-out are to be followed to better understand the environmental aspect of Energiewende.

Turkey has a different story in its climate history. Although the country has a much lower per capita CO2 emissions compared to Germany, Turkey's emissions are set to increase. The main reason behind that is, Turkey has a growing economy and population with expanding energy needs. However, the country has outlined many efforts in its emission reduction. According to Turkey's Paris Agreement pledge, the country is set to cut emissions by up to 21% by 2030. Turkey has not set any targeted date for peak emissions. The Paris Agreement pledge of the country has been criticized for being unrealistically high. In this regard, based on national circumstances, Turkey has long sought a special status at the UNFCCC. As an Annex II listed country, Turkey was obliged to reduce its emissions and to help developing countries some of which are economically wealthier and more developed than Turkey. In 2001, Turkey was removed from Annex II and UNFCCC invited all parties to recognize the special circumstances of Turkey, meaning Turkey was not obliged to provide climate finance. Additionally, the country has requested further differentiation with the claim that the special circumstances are not clearly defined. Currently, Turkey argues that access to climate finance is crucial for reducing its CO_2 emissions. The country has not ratified Paris Agreement, yet, the ratification of the Paris Agreement remains to be conditional on access to the Green Climate Fund. As Germany and Turkey differ in their climate policies, the realizations of the emission reductions are to be followed in order to track their energy transition progress.

5.4.2. Renewables

The rapid expansion of renewables is indispensable to reach the global emission reduction target and achieve successful transition towards low carbon. Good implementation of renewable energy policies provide great opportunities for increasing energy security, economic activity and decreasing CO_2 levels and in turn achieving energy transition goals. On the other hand, bad implementation can lead to high energy surcharges for consumers and industry, perverse support mechanisms causing economic harms and public opposition. Numerous policy mechanisms have evolved over time aiming to increase renewable capacity while keeping the costs in a moderate level. These mechanisms include feed-in-tariffs, feed-in-premiums and auctions. In this subchapter, the policy mechanisms of Turkey and Germany are compared and their reflections are discussed.

Renewables is at the center of energy transition of both countries. Renewable deployment is the key pillar of Energiewende (Agora Energiewende, 2017) as well as Turkish energy transition (Saygin et al., 2018). However, as a first mover, Germany is far ahead of Turkey in terms of installed renewable capacity. Table 5.6 presents some major facts related to renewable generation for Turkey and Germany. Although renewable share in total electricity generation looks similar for 2018, in terms of variable renewable sources like solar and wind, Turkey is behind Germany.

Table 5.6. *Renewable Electricity Generation*

		Germany	Turkey
RE Share in Total Generation	%	36,0%	32,4%
Variable RE Share in Total Generation	%	24,4%	9,2%
Variable RE Capacity Additions (2003-2018)	MW	89.445	12.074
Total RE Capacity	MW	119.388	42.215
Total Variable RE Capacity	MW	104.261	30.245

Sources: AG Energiebilanzen (Energy Balance 2017), MENR (Energy Balance 2017)

Both countries have ambitious targets regarding renewable deployment (Table 5.7). In Germany, renewable deployment has accelerated rapidly since 2000. From 2000 to 2018, share of renewables in electricity consumption has increased 9.6% reaching 36% in total share (Figure 5.14). Compared to other countries and world average, increase in Germany's renewable share is much higher (Figure 5.14). There are major milestones leading to high deployment of renewables. Before any other country, Germany started the implementation of support mechanisms for renewables in 1991 (Figure 5.6). In 2000, the Red-Green coalition has announced a climate protection programme which aimed to increase power generation from renewables to 10% by 2010. In 2002, the target was further raised to 12.5% by 2010 and 60% by 2050 (Lauber & Jacobsson, 2016). The government introduced the landmark Renewable Energy Sources Act (EEG) to achieve these targets. EEG guaranteed a certain amount of payment for renewable electricity for 20 years. In the following years, the EEG was amended several times to take into account the complaints of the industry (Hoppmann et al., 2014). However, with the new amendments the EEG surcharges were to be paid by the households. Later, the increasing energy bills of caused a discussion among the opponents of the EEG. Starting from 2008, cost reduction attempts were carried. It is important to mention that, no matter how high the costs are, the public opinion on increasing renewables has remained high in Germany which became the greatest support of the government.

Table 5.7. *Renewable Electricity Targets*

		Germany (2030)	Turkey (2023)
RE Share in Total Final Energy Consumption	%	30%	-
RE Share in Total Generation	%	50%	38,8%
Nuclear Share in Electricity Generation	%	0%	10%
Hydro	MW	-	34.000
Biomass	MW	-	1.000
Wind	MW	-	20.000
Geothermal	MW	-	1.000
Solar PV	MW	-	10.000

Sources: MENR, BMWi

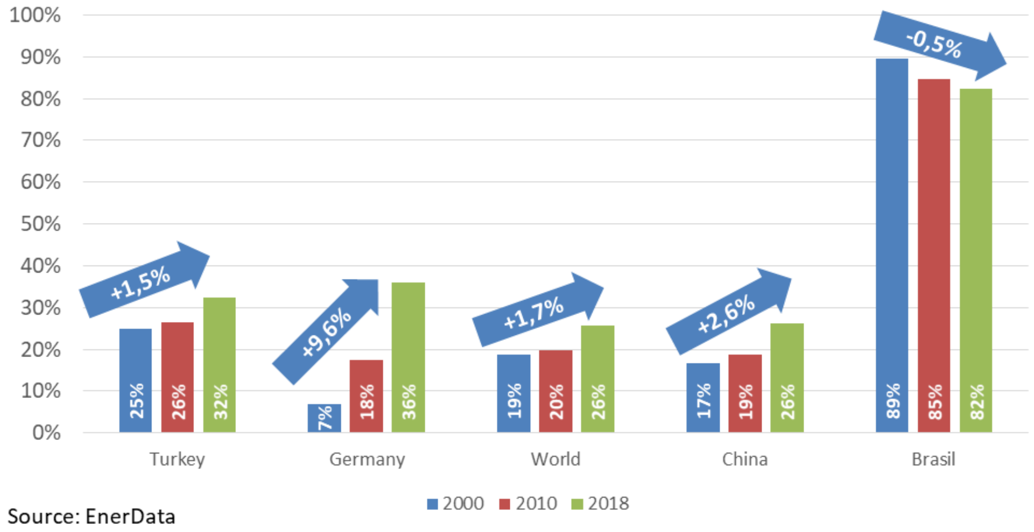


Figure 5.14. Share of Renewables in Total Electricity Generation (%)

In 2010, Germany enacted its Energy Concept setting official targets for renewable energy deployment. Later, Renewable Energy Act was further amended in 2014 increasing the target for renewable energy share in electricity generation. According to the latest action plan of Germany announced in 2019, the Climate Action Programme, “The German government aims to see renewables account for 65 % of electric power consumed in Germany by 2030" (The German Federal Government, 2019). With these policies in place, Germany has been the frontrunner in renewable deployment and remains to be a critical player globally.

Although Germany is a significant international pioneer in the field of renewables, the country is not alone in its efforts. Experiences of Germany in renewables extends not only to Europe but has a more global impact. EEG has been emulated by many countries one of which is Turkey. Turkey supplied more than 40% of electricity from renewables in 2018, mainly from hydro (29.8%) followed by wind (9.1%) (Figure 5.12). In Germany while wind and solar power takes the lead in the acceleration of renewables, in Turkey hydro plays a crucial role for the expansion dynamics. Solar power constituted only 2,6% of the total electricity generation in 2018. Solar power is only starting to increase in Turkey; however, there has been a significant growth in wind power generation. Due to demand growth and availability of flexible sources like hydropower more than 7,5 GW of wind capacity was added.

In renewables, both Turkey and Germany prioritizes renewables as a key driver of their energy transitions. However, the motivation is slightly different in Turkey. Turkey sees renewables essential for increasing energy security as well as decreasing import dependency on fossil fuels. In this regard, the government of Turkey has announced a number of plans and policies to increase renewables in its energy mix. The National Renewable Energy Action Plan of 2014 provides the renewable energy targets for each technology by 2023 (MENR, 2014). Moreover, the Strategic Plans for 2010-2014 includes objectives regarding increasing the share of hydro, geothermal and wind power plants. Complementarily, the 2015-2019 Strategic Plan builds on the targets of the previous plans and prioritizes increasing the share of renewables in electricity generation as well as in the energy supply. National Energy and Mining Policy of the country announced in 2016 also supports renewable targets. This Policy Paper analyzes renewables under the "localization" concept that integrates increasing renewable power generation through local manufacturers.

In both Germany and Turkey, the expansion of renewables has been supported by renewable targets and some type of a support mechanism in particularly for solar and wind. Since the introduction of EEG, feed-in-tariffs have become a widely used instrument for the acceleration of renewables across the globe and Turkey. Setting long-term goals by the governments together with a fixed feed-in-tariff has triggered the private investment on renewable manufacturing. However, the high cost of feed-in-tariffs has raised questions among the consumers. In this regard, support mechanisms started to shift towards auction mechanisms. In Germany, with a reform in EEG, more than 80% of the support began to be allocated through an auction-based mechanism. Similarly, during the same period, Renewable Energy Resource Areas (YEKA) auctions were introduced in Turkey. Moreover, Germany has simultaneously implemented R&D support measures that supported the technological development to reach the targeted levels. In terms of R&D investment in renewables, Turkey followed Germany with a significant time gap.

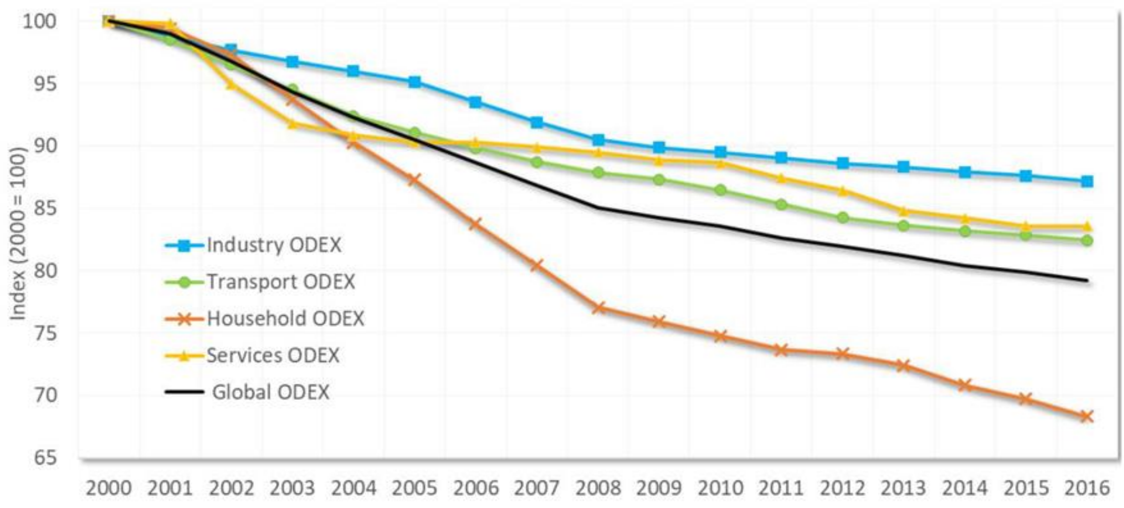
Public support on renewables is an important aspect that Turkey and Germany falls apart in renewables development. In Germany, despite the high electricity surcharges, there exists a high-level support from the public (Hirsch, 2015). In Turkey, the citizen participation and public opinion on renewables remains to be limited especially during times of economic difficulties.

5.4.3. Energy Efficiency

Energy efficiency lies at the core of energy security policies and hence energy transition. Energy efficiency is a critical enabler of the energy transition towards low-carbon system. Alongside increasing renewable energy deployment, improved energy efficiency is essential to reach emission reduction targets. In this regard, both Germany and Turkey have ambitious targets to improve energy efficiency. As discussed in Chapter 3.3, any policy since 2007 includes a target for energy efficiency in Germany. Similarly for Turkey, energy efficiency is a backbone of the transition towards low carbon economy covered in each strategic plan and policy paper.

There are several indicators to measure energy efficiency. Primary energy intensity is a widely accepted proxy to measure energy efficiency performance of a country, which is equal to the ratio of total primary energy use to GDP. Put differently, primary energy intensity measures how much energy is required to generate one unit of GDP (Bethel Afework et al., 2015). The numbers for energy intensity is very similar for Turkey and Germany in 2018 and much lower than major economies namely, the USA, China and Korea (Figure 5.8). When the same numbers are compared over time, energy intensity of Germany has substantially decreased since 2002 and converged to the level of Turkey (Figure 5.9).

Energy intensity can be decreased by measures covering all end-use sectors, mainly households, industry and transport. Industry is responsible for almost 40% of final energy demand (IEA, 2017a). Moreover, "transport accounts for just below 30% of final energy demand today and almost two-thirds of direct oil use in end-use sectors" (IEA, 2017a). Therefore, sector specific policies are crucial in achieving energy efficiency targets. A common index used to measure energy efficiency by sector (industry, transport, household and services) is ODEX index, which is an index prepared for the Odyssee-Mure project to measure the energy efficiency progress by main sectors (Odyssee-Mure, 2010). The technical ODEX indicator shows that energy efficiency in Germany has improved by 21% between 2000 and 2016, mainly driven by household and transport sectors (*Figure 5.15*). The same index for Turkey reveals that the energy efficiency improvements were mostly observed in the transport sector while households followed a linear pattern over the same period (*Figure 5.16*).



Source: ODYSSEE database

Figure 5.15. Development of the Technical Energy Efficiency Index of Germany (ODEX)

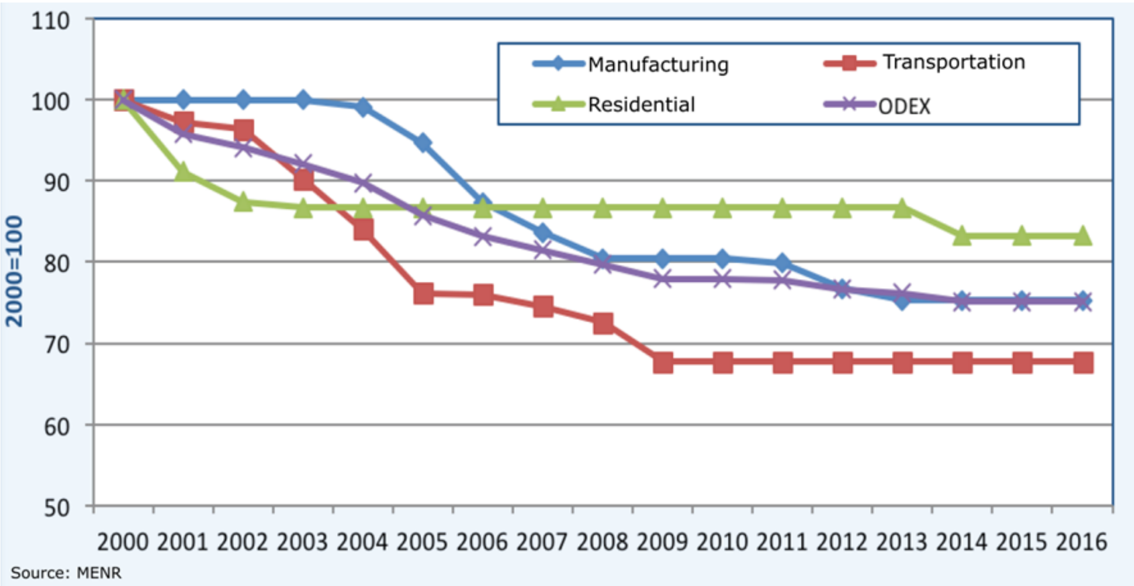


Figure 5.16. Development of the Technical Energy Efficiency Index of Turkey (ODEX)

Further progress on energy efficiency is crucial as the economies and populations grow. In this regard, both Germany and Turkey's policies are in line. Both countries prioritize energy efficiency in their policy papers. Increase in renewable energy accompanied by a concurrent increase in energy efficiency not only brings environmental benefits but its potential extends far beyond. Expansion of renewables and energy efficiency has important potential concerning socioeconomic dynamics.

5.5. Economic Aspect

So far, energy security and environmental aspects of energy transition were discussed throughout the chapter. However, future progress of the energy transitions in Turkey and Germany depends also on the economic aspect. As decision makers decides on a policy, understanding the socioeconomic consequences of energy transition is of vital importance. According to IRENA, “Accelerating the deployment of renewable energy will fuel economic growth, create new employment opportunities, enhance human welfare, and contribute to a climate safe future.” (Ferroukhi et al., 2016)

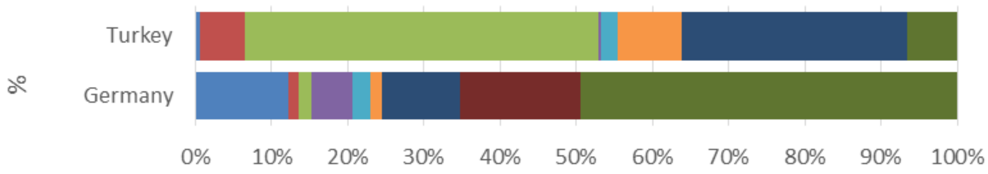
Energy transition has both economic benefits as well as challenges. While it is claimed that the energy transitions bring additional burdens on the countries mainly related to energy costs, low-carbon energy transition also plays crucial role as a driver of job creation triggering economic growth. However, it is important to analyze the net benefits. Increased investments might have direct economic benefits creating employment opportunities, but the net effect could be negative if energy prices experience a sharp increase. This subchapter discusses major socioeconomic factors such as employment, trade and energy prices that have substantial impacts on the energy transitions of Turkey and Germany.

5.5.1. Employment

Creating additional employment opportunities for the citizens is without any exception one of the main policy concerns of all governments. Generating employment over the duration of global energy transition is an important issue to understand, which in turn could have policy consequences globally. Especially for low-carbon energy transition, planning employment opportunities is a key consideration. Most of the governments prioritize low-carbon transition to reduce GHG emissions while seeking for additional socioeconomic benefits. According to IRENA's latest report on renewable employment, the sector employed 11 million people at the end of 2018 globally (International Renewable Energy Agency, 2014). There are numerous studies in the literature analyzing the employment effects of low-carbon energy transition.

- According to IEA's scenarios, a global economy in line with low-carbon energy transition will have 0,3% more employment compared to business as usual case by 2030 (International Energy Agency, 2015).
- According to IRENA, "doubling the share of renewables increases direct and indirect employment in the sector to 24.4 million by 2030" (Ferroukhi et al., 2016).
- A study compares how many full-time equivalent jobs are created from 1 million US$ spending on fossil fuels and renewables. The study finds out that 2.65 jobs are created from $1 million spending in fossil fuels, while the same number is equal to 7.49 jobs in renewables. A net increase of 5 jobs can be created by shifting a 1 million US$ investment from fossil fuels to renewables (Giberson & Kiesling, 2019).
- Another study reveals that energy transition will inevitably cause job losses of around 6 million while creating around 24 million jobs. (International Labor Organization, 2018).

The above-mentioned numbers reveal that renewables provide great opportunities for employment. Comparing the current employment numbers for Germany and Turkey Figure 5.17 shows that, most people employed in renewables are in wind, biomass, solar PV and biogas sectors in Germany, while in Turkey people are mostly employed in hydropower and solar PV sectors. Turkey remains behind Germany in most of the renewable sectors, mainly wind and biogas.



	Germany	Turkey
Biogas	35.000	700
Geothermal	3.917	5.960
Hydropower	4.600	47.730
Liquid Biofuels	15.500	500
Muni./Ind. Waste	6.300	2.200
Solar Heat./Cool.	4.500	8.660
Solar Photovoltaic	29.300	30.450
Solid Biomass	44.900	-
Wind	140.800	6.700

Source: Irena

Figure 5.17. Employment in Renewable Energy Sector (2017)

While most of the related literature discusses that transition towards low-carbon generates employment opportunities. It is important to mention that job losses will be experienced in sectors closely related to fossil fuel extraction and the generation of electricity from fossil fuels (International Labor Organization, 2018).This effects are expected to be more prevalent for emerging countries like Turkey. For emerging countries, International Labor Organization asserts that new job creation is only possible if adequate amount of skilled workers can be found (International Labor Organization, 2018).

5.5.2. Trade

Energy transition would inevitably bring changes in the trade patterns. Global trend of increasing renewable deployment provides opportunities for energy equipment exporter economies. However, it also presents challenges for economies which rely on fossil fuel exports. Therefore, the shifts in the trade would significantly impact national and global economies.

Increasing renewable deployment in line with low-carbon energy transition, will reduce the fossil fuel trade volume since renewable sources do not require any fuels. According to IRENA, doubling the share of renewable energy by 2030, will reduce coal imports more than half and reduce other fossil fuels imports by 7% globally (Ferroukhi et al., 2016). On the other hand, renewable sector is very capital intensive. Therefore, demand for renewable equipment as well as services would increase. As industrial capacity of countries varies, the sign of the trade effect varies as well. While the effect of fossil fuel trade is straightforward, effect of a demand increase in renewable equipment is not as clear. New markets would eventually emerge providing opportunities for economies with experience in different segments of related sectors. The countries who are already exporters of renewable equipment and services would have a comparative advantage.

The global boom in renewable technology demand offers a great potential for the mature German industry. The "Export Initiative Renewable Energies" also known as "Renewables – Made in Germany" (Exportinitiative Erneuerbare Energien) was founded by the German Ministry for Economic Affairs and Energy in 2003 to support German renewable energy companies that want to position themselves in the international arena (Haas, 2017). For Germany, those opportunities would have significant positive impacts as the exports of the country increases (Edler, 2012). Figure 5.18 presents share of global exports in the wind and solar PV sectors for Turkey and Germany. While Germany is net exporter in both wind and solar with significant global shares (29% in wind and 5% in solar PV).

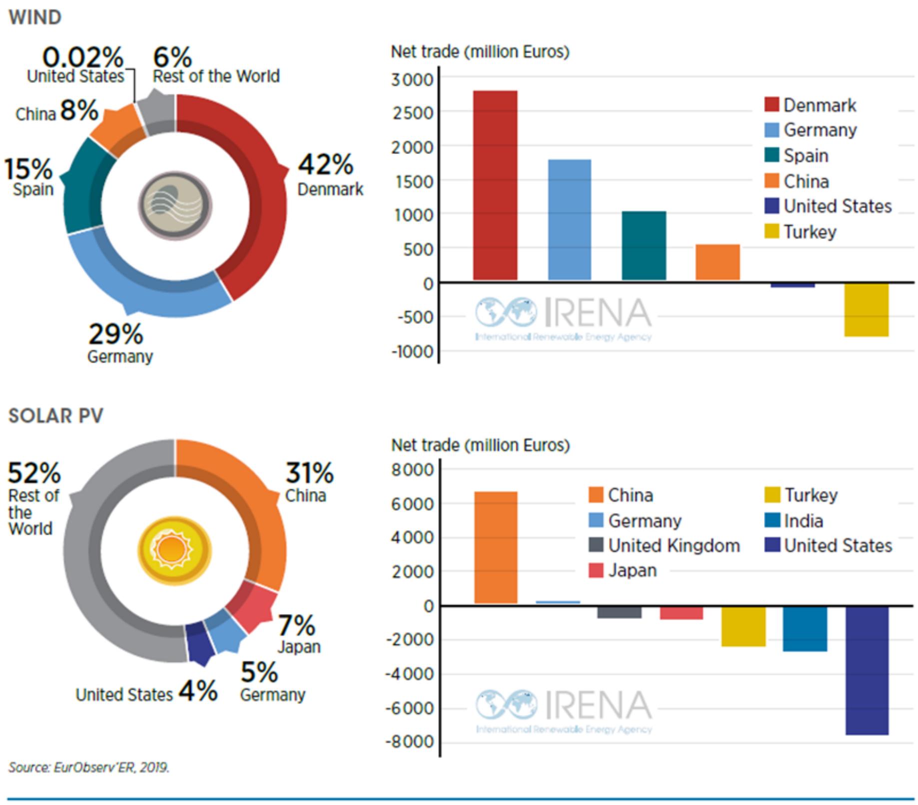


Figure 5.18. Share of Global Exports and Net Trade Values in the Wind and Solar PV Sectors for Selected Countries (2016)

Unlike Germany, Turkey is a net importer of energy related machinery. In 2015, imported energy supply equipment amounted to 2.8 billion US$ (TEPAV, 2017). The major component of this amount is due to rising imports of renewable equipment. Although Turkey is a net importer of solar PV equipment, the country has been exporting wind equipment worth around 1 billion US$ per year, which is by far outweighed by other exported energy-related equipment (TEPAV, 2017). One advantage of renewable technologies is that they are transferrable across countries providing opportunities to the developing countries. Turkey, in this regard, has been investing in developing renewable manufacturing technologies locally. Once the RE-ZONE projects, enforcing domestic production of renewable equipment, are realized the net imported amount would decrease while renewable generation capacity increases.

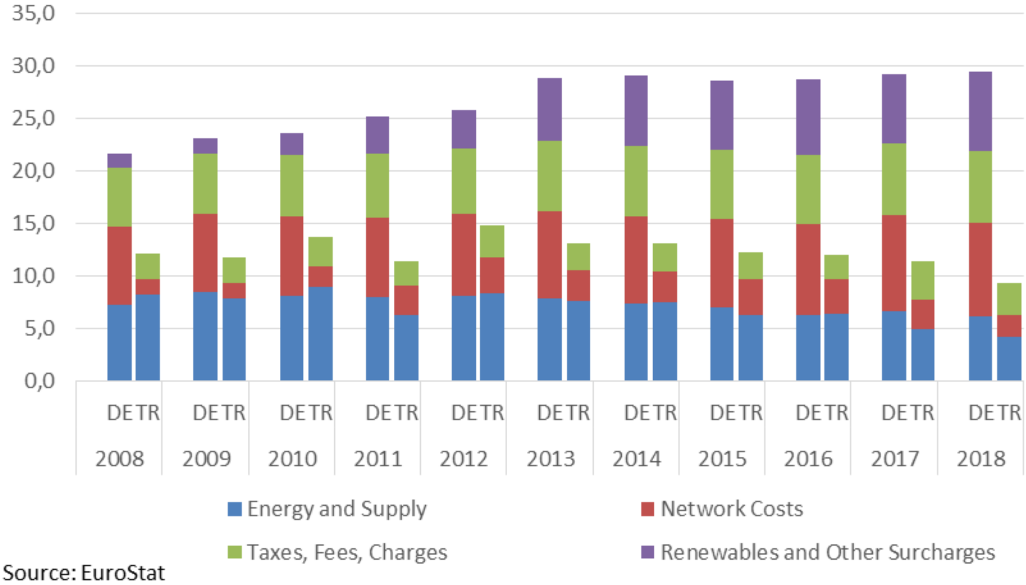
Import dependency on fossil fuels is a crucial problem for both Turkey and Germany. Almost 75% of Turkey's energy supply is imported, approximately 100% of natural gas and oil and 65% of coal (IEA, 2017b). In total, the country paid 42,99 billion US$ for energy imports in 2018 a 15,6% increase compared to 2017 (TÜİK, 2020). Germany imports 63,4% of its total energy supply (Schmid, 2020). The number is lower compared to Turkey because Germany is self-sufficient in renewables and the country has nuclear energy as a power source. However, similar to Turkey, dependence of oil, natural gas and hard coal of Germany was around 95% in 2017 (BGR, 2020). Therefore, reducing fossil fuel imports is on the priority list of both countries. One critical difference between two countries is that, Turkey's strong trade relations with its neighbors rely on the political stability of the region and the bilateral ties. However, as Germany imports oil from 33 countries mainly from Russia, Norway and United Kingdom, Middle East dynamics is less of a concern (BGR, 2018). Ties with Russia remains to be critical for both countries as Germany and Turkey imports a significant amount of oil and natural gas from Russia. Therefore, driving the transition from imported fossil fuels towards renewables rises as an important priority for both countries as it contributes to the current account balance and reduce political dependence on energy imports.

5.5.3. Energy Prices

"Factors such as energy productivity, cost and job creation must be analyzed as a whole to produce the best effect." (World Economic Forum, 2012). Moderate level of energy prices have major economic contributions. First, it helps to stimulate the economy. Moreover, consumers and businesses decrease their expenses that can be spent in other ways. Lastly, lower energy prices increases competitiveness of the industry by reducing input costs of many goods and services. Therefore, any country with ambitious transition targets takes into account energy prices as a major determinant during policymaking.

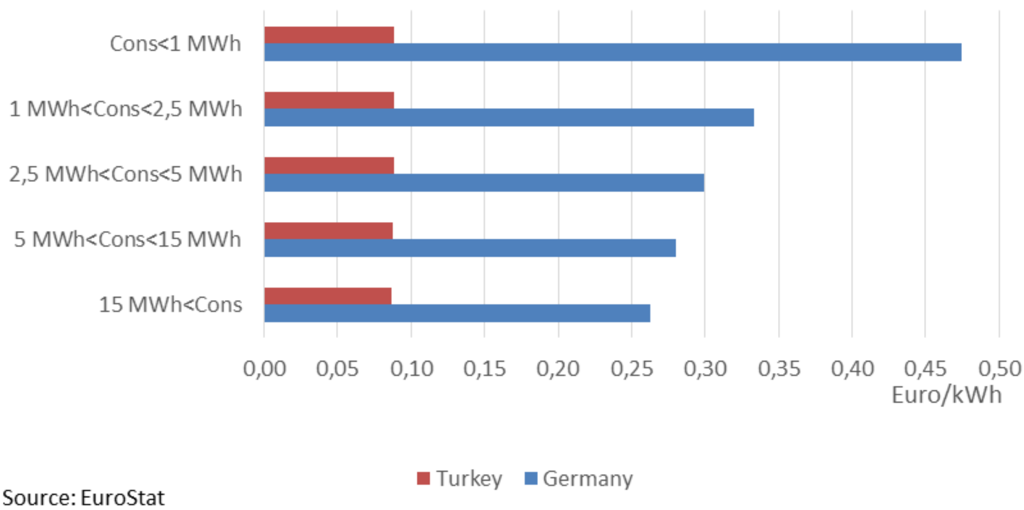
Energy pricing choice of countries is among the factors that has significant effects on the success of energy transition policies. Germany, in this regard, experienced major challenges. The high surcharges for consumers were discussed as a major challenge in German Energiewende in Chapter 2. This subchapter laid out the cost effect of feed-in-tariffs and increasing renewable capacities. Between the years 2000 and 2015, German consumers paid 125 million Euros through higher electricity bills (Bdew, 2016). A recent report by McKinsey also draws significant conclusions. According to this report, German electricity prices are 45% higher than the European average. Within the household electricity bill, 54% is due to green taxes (McKinsey & Company, 2020). Moreover, the costs do not arise only to increase renewables but also a significant amount of conventional power plants has to be sustained as a backup source (Frondel et al., 2015)

Additional investment on the power grids to integrate volatile renewable also brings additional costs. In Germany, wind power is produced in the north and east of the country. The power generated in the north and east must be transported to the industrialized west and south through expanded power grids. Due to these factors, it is expected that electricity prices would further increase if Germany reaches its renewable targets. The McKinsey report also projects that the prices are likely to increase through 2030 with higher prices having significant impacts on the German industry especially energy-intensive sectors (McKinsey & Company, 2020). Compared to Turkey, cost of electricity in Germany is more than twofold with an increasing gap (Figure 5.19). As illustrated in Figure 5.20 and Figure 5.21, electricity prices for household consumers and non-household consumers are much higher for Germany.



Source: EuroStat

Figure 5.19. Cost of Electricity



Source: EuroStat

Figure 5.20. Electricity Prices for Household Consumers (2018)

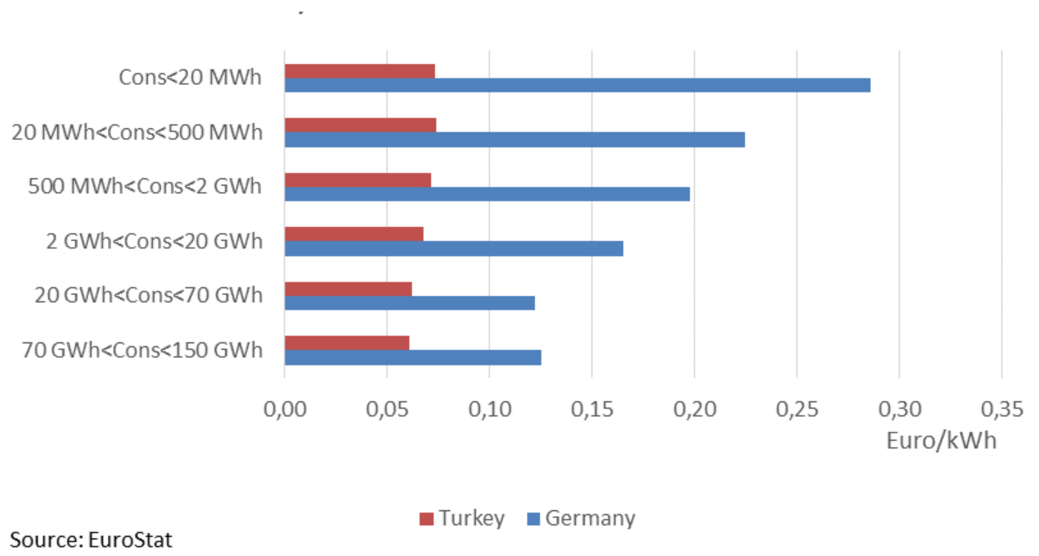


Figure 5.21. Electricity Prices for Non-Household Consumers (2018)

In the energy transition of both Germany and Turkey, incentive and support mechanisms continue to play critical roles especially in the electricity sector. In Turkey, there exists numerous forms of supports in the form of tax incentives, land accession and grid connection priority. However, the most important one is the feed-in-tariff for renewables. According to an estimation, "US $3.2 billion, was paid for low carbon energy transition, of which US$2.4 billion was for electricity generated from renewable energy under the feed-in tariff" (Taranto & Saygın, 2019). During the same period fossil fuels are estimated to receive US $1.6 billion of annual support. In 2018, the average wholesale market price in Turkey was approximately US $4.5 cents/kWh. During the same period, around US $8.1 cents/ kWh weighted average price was paid for renewables under the feed-in-tariff. Hence, the net subsidies for renewables in Turkey is estimated to be US $2.4 billion in 2018. If we look at the last 3 years total, this number reaches to US $5.8 billion. It is important to mention that this amount is directly paid by the end-user consumers.

As discussed in the previous subchapters Turkey's renewable energy sector has been growing with wind and solar reaching 9% of total power generation in 2018. This rapid increase was triggered by the feed-in-tariff mechanism that has been in its current form since 2011. The feed-in-tariff mechanism is to expire by the end of

2020. In addition to the feed-in-tariff, since 2017 auction mechanism was introduced to create a renewables market in the country. Once the feed-in-tariff expires, a more market-based and cost-efficient approach is expected to replace the existing mechanism in addition to the auctions. Moreover, with increasing share of renewables additional support might be required for the flexibility of the system as Turkey does not have nuclear or adequate interconnection capacity like Germany. Similarly, support for R&D capacity development that exists in Germany could also help the acceleration of the energy transition of Turkey.

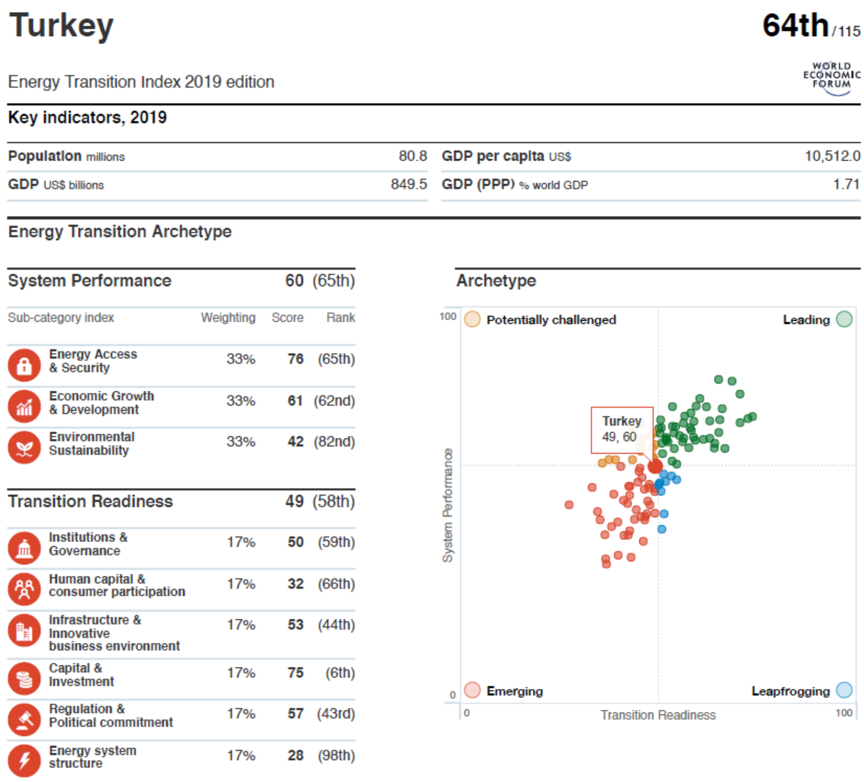
5.6. Review

For a successful energy transition exchange of best practices remains to be key in line with cooperation in policymaking (Hager & Stefes, 2016). In this regard, Germany, a leading example in energy transition, can provide an example for many countries, mainly countries with more factors in common. Turkey, a developing country with increasing renewable energy sources, can benefit from the German experience and take lessons from the challenges the country has experienced throughout the Energiewende.

Germany has been successful in numerous aspects with its landmark Energiewende. Moreover, Turkey's energy transition experience has a long history with many achievements regarding liberalization of the markets and integration of renewables. On the Energy Transition Index (ETI), Germany ranks the 17th among 115 surveyed countries while Turkey ranks the 64th (Figure 5.22 and Figure 5.23).

For the ETI, the World Economic Forum (WEF), surveys 115 countries from different regions each year on the basis of their energy transition status. The countries are ordered based on two performance indicators with equal weights: transition readiness and system performance which are reported in percentages. In terms of system performance, which considers energy access and security, economic growth and development and environmental sustainability, Germany and Turkey achieved

66% and 60%, respectively. On the other hand, the difference in the ranking of these countries stems mainly from transition readiness ranking. While Germany achieved 64% (ranks 11th) in transition readiness index, Turkey falls much behind with 49% (ranks 65th).


Turkey — **64th**/115

Energy Transition Index 2019 edition

WORLD ECONOMIC FORUM

Key indicators, 2019

Population millions	80.8	**GDP per capita** US$	10,512.0
GDP US$ billions	849.5	**GDP (PPP)** % world GDP	1.71

Energy Transition Archetype

System Performance		60	(65th)
Sub-category index	Weighting	Score	Rank
Energy Access & Security	33%	76	(65th)
Economic Growth & Development	33%	61	(62nd)
Environmental Sustainability	33%	42	(82nd)

Transition Readiness		49	(58th)
Institutions & Governance	17%	50	(59th)
Human capital & consumer participation	17%	32	(66th)
Infrastructure & Innovative business environment	17%	53	(44th)
Capital & Investment	17%	75	(6th)
Regulation & Political commitment	17%	57	(43rd)
Energy system structure	17%	28	(98th)

Figure 5.22 Energy Transition Index

Germany

17th/115

Energy Transition Index 2019 edition

WORLD ECONOMIC FORUM

Key indicators, 2019

Population millions	82.7	**GDP per capita** US$	44,549.7
GDP US$ billions	3,684.8	**GDP (PPP)** % world GDP	3.28

Energy Transition Archetype

System Performance		66	(46th)
Sub-category index	Weighting	Score	Rank
Energy Access & Security	33%	92	(5th)
Economic Growth & Development	33%	53	(90th)
Environmental Sustainability	33%	52	(57th)

Transition Readiness		64	(11th)
Institutions & Governance	17%	84	(8th)
Human capital & consumer participation	17%	62	(11th)
Infrastructure & Innovative business environment	17%	83	(4th)
Capital & Investment	17%	75	(5th)
Regulation & Political commitment	17%	72	(4th)
Energy system structure	17%	11	(111th)

Archetype

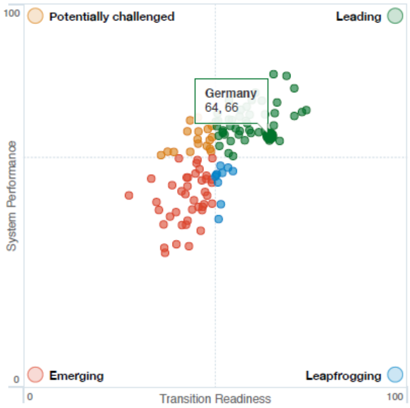


Figure 5.23 Germany – Energy Transition Index

In a general sense, energy transitions of Turkey and Germany have similarities as well as differences. Two countries share two similar goals: increasing renewable deployment and energy efficiency. In addition, improving energy security and reducing import dependency are clearly shared goals for both countries. Turkey has been confronting the energy transition challenges and prepared its market to benefit from the existing opportunities to achieve its energy transition targets. In this regard, Turkey can draw on Germany's energy transition experience. Germany has already uncovered major hurdles that Turkey is no longer need to discover. Therefore, Turkish policymakers in wary of the positive and negative aspects of Energiewende could utilize tremendous opportunities in the energy markets.

Energy transitions are driven by several major goals, including improving energy security, reducing import dependency, diversifying economy and mitigating climate change, simultaneously. While these goals are common for all countries, the concerns are starker for Germany and Turkey. In this regard, this chapter has discussed all these goals with a specific focus on Turkey and Germany. The chapter thoroughly elaborated on the differences and similarities in the energy transitions of Turkey and Germany from three important aspects: energy security, environment and economic. Based on these multidimensional comparisons, the analysis sheds light to the areas in which Turkey follows the German experience with many similarities. Additionally, the multidimensional analysis highlights the major differences between the German and Turkish experiences. While Germany has its own challenges in its transition story, the discussed differences remains to be key challenges for the success of energy transition towards low carbon in Turkey.

For a successful energy transition Turkey has ambitious plans and strategies set under various action plans and strategy papers. However, it is crucial to point out that most of the targets are set for 2023, very shortsighted compared to Germany's targets. German example demonstrates the need for a longer-term policy setting for investor confidence. Increasing the market certainty for private sector players remain to be an important challenge for the energy transition in Turkey. In addition, there are some overlapping and contradicting targets included in the strategic plans and policy papers which should be clarified.

Security of supply is a very critical concern especially for import dependent countries like Germany and Turkey. These countries differ when it comes to energy import sources. Germany is highly interlinked with the EU Framework. As Germany imports energy from its neighbouring countries, European energy network play a critical role in supply security. Therefore, the support of EU should always be kept in mind when making an analysis from a security perspective for Germany. On the other hand, while both countries mainly import their energy needs from neighbouring countries, Turkey is prone to geopolitical risks due to its geographical location. Political relationships with neighbouring countries are significant determinants of the uninterrupted energy supply for Turkey.

Transition towards low carbon also raises questions regarding the structuring of the electricity supply system. Germany's shift from nuclear and fossil fuel based supply system to variable renewable resources attracts international attention. For renewable integration Germany took several precautionary measures including grid infrastructure investments and increasing interconnections with the neighboring countries. Moreover, more flexible conventional power plants were used as well as specific grid code requirements were applied for renewable power plants. In addition to these measures, Germany also utilizes smart grid and metering measures. Germany's geographic location and its position in the EU electricity markets provides important flexibility options. However, Turkey does not enjoy favourable conditions when it comes to interconnection capacity. Therefore, increasing this capacity to the extent that market permits is critical to renewable integration.

Natural gas is a controversial issue for both Germany and Turkey. Although natural gas has been treated as a transition fuel, in terms of energy security and reliance on source countries it raises questions among the policymakers and citizens. Both Germany and Turkey have high reliance on Russian gas. With the ongoing natural gas pipeline projects NordStream 2 and TurkStream connecting additional Russian gas to Germany and Turkey respectively, questions on source country dependency increases.

Nuclear and coal are the fundamental differences between Energiewende and energy transition in Turkey. Turkey regards nuclear and coal as important sources in reducing import dependency. Turkey's energy policy considers nuclear and renewables under the same umbrella as a low carbon non-fossil fuel source. On the contrary, nuclear phase-out is one of the major pillars of Energiewende. As of 2018, Germany generates 23% of its electricity from NPPs with an ambitious phase-out plan by 2022. Turkey does not have any nuclear power plants, yet, has firm plans to add nuclear into its power mix. First NPP of Turkey is expected to become operational in 2023 and expected to supply 10% of electricity generation once it is completed.

Another integral part of Energiewende is coal phase-out. Germany has traditionally been a coal burner. The country supported coal with high government subsidies reaching several hundred billion euros. Coal policy of Germany has totally reversed with the raising public protests. In line with Energiewende, Germany declared that it aims for a coal phase-out by 2038. Although phase-out plans were taking place, lignite remained to constitute around a quarter of Germany's total power generation, yet, at a decreasing trend. In January 2019, Germany appointed a coal commission to enable the closure of coal-fired power plants by 2038. The Commission offered a 40 billion euros aid plan to help the regions that would get the most harm out of the phase-out. On the contrary, in line with increasing domestic energy supply policies, Turkey has firm plans to increase the share of coal in power generation.

Another aspect of the multidimensional analysis is environmental. Turkey and Germany have comprehensive policies in line with rising environmental awareness. Although CO2 emissions of the two countries are distinctively far from each other, both Germany and Turkey have firm plans to increase renewables and energy efficiency included in various policy papers.

Renewable energy deployment is the key driver of energy transitions of Germany and Turkey. Energy transition practices show that policy instruments can be effectively used in steering the investments in right direction in both countries. Among the policy instruments, regulatory changes, taxation and feed-in-tariffs are widely used by many countries including Germany and Turkey in encouraging new energy resources. The EEG is one of the most influential instruments that has been exported to many other countries which guaranteed reliable investment conditions for renewable power generation through a fixed feed in tariff. Since 2017, there has been legislative changes shifting from feed in tariffs towards an auction mechanism to boost up renewable expansion. Turkey has followed a similar pattern in its laws and regulations regarding renewables. Similar to Germany, Turkey's legislative framework played an essential role in the rapid deployment of renewables especially wind and solar.

Increasing renewables in Turkey addresses many of the problems that the country is being faced. First, it improves energy security by increasing the share of domestic power generation. Second, it reduces the current account deficit. Third, it creates a new industry generating economic opportunities as well as new jobs. Lastly, renewable deployment reduces carbon emissions which is gaining importance in the energy policies of the country. Therefore, in further progress of energy transition renewable energy deployment remains to be valuable for energy security of Turkey.

Carbon pricing mechanisms are expected to play an increasingly important role in the transition towards low carbon. Germany has been a part of the EU ETS for more than 12 years. On the other hand, Turkey does not have a national carbon market, yet several attempts were initiated none of which were implemented.

Energy transition in Germany and Turkey prioritize transition towards low carbon sources while ensuring energy security as well as maintaining economic competitiveness. Therefore, in addition to the security and environment aspects, economic aspect lies at the center of the multidimensional analysis.

The German experience draws importance on the economic value of a long-term policy mechanism. Moreover, for most of the developing countries including Turkey, maximizing the impact of transition policies on employment and economic value creation is crucial. In this regard, renewable deployment provides important opportunities for both countries. In Germany and Turkey, increasing renewables created new industries generating economic opportunities as well as new jobs. However, the experiences differ from a trade perspective. While Germany is net exporter in both wind and solar with significant global shares, Turkey is a net importer of energy related machinery. In this regard, Turkey included terms related to local manufacturing in its auction design for renewables. However, the maturity of these projects remains to be a critical concern.

It is also important to draw attention to some critical issues that needs to be addressed for further achievements in renewables. In Turkey, most of the solar PV was developed under unlicensed capacity. However, unlicensed capacity allocations were postponed until further notice which creates uncertainty in the market especially for smaller players. Some regulatory changes must be done to attract investment from small-scale investors. There are several uncertainties in how the FiT mechanism and auction mechanism would work. The design of the future auctions remains to be question. There is no official announcement on the dates, locations and model of the upcoming auctions.

Turkey, with high import dependency ratio, is vulnerable to changes in global energy prices with significant current account and inflationary impacts. Energy imports contributes the most to the large current account deficit of the country. Current account deficit problem not only stems from fossil fuel imports but also machinery and equipment imports. Turkey is only a net exporter of wind equipment but the numbers are far outweighing by solar PV and coal equipment imports. Therefore, investment in R&D is crucial for future success of energy transition in Turkey.

In Germany, the government played a critical role in increasing the public participation throughout the process. Citizen participation is an integral part of German energy transition and the major motivator of the entire process. Energiewende is characterized by public support for nuclear phase out and renewable expansion. Therefore, strengthening public side remains to be an issue for the Turkish transition experience.

Energy transition in the transport, industry and agriculture sectors are critical to become a frontrunner in the energy transition towards low carbon. Similar to Germany, Turkey's energy transition mostly focuses on the electricity sector. However, ambitions beyond the power sector should be prioritized in Germany and Turkey for further achievements in their energy transitions. Germany has pledged to shift its focus towards heating and transport sectors. Turkey also has some targets related to heating, yet, developments in the transport and industry sectors remain to be scarce.

The multidimensional analysis of Chapter 5 reveals that Energiewende and Turkish energy transition has numerous similarities as well as differences. While Turkey has already implemented major policies based on the German experience, much remains to be learned for further progress of efficient transition towards low carbon.

Energiewende can be characterized by long-term policy mechanisms, market design and public support. Energiewende forms a model for Turkey by presenting an energy transition through long-term targets and stable policy measures. In sum, Energiewende should not be considered as a model but rather an experience that must be continuously developed through international exchange of information. International partnerships not only provide an “exporting” opportunity for Energiewende but also provides opportunity for “importing” international practices. To develop further exchanges of experiences both ways, any international policy should incorporate mechanisms that bring together international experiences into their national discussions.

CHAPTER 6

CONCLUSION

There are several frontrunner countries in energy transition towards low carbon. Their transition experiences differ in terms of motivation, aim, drivers as well as governance methods. Each of these unique transition models provide different sets of challenges and opportunities that serve fruitful lessons for other countries. Among major economies, Germany is commonly regarded as a pioneer in the field of energy transition. Germany has started its energy transition dating back to late 1970s, with a significant global influence. Even the word "Energiewende" itself has been adopted by many other languages. Through Energiewende, Germany has laid down a comprehensive plan to reform its energy sector and presented valuable transition practices to serve as an example at a global scale.

This thesis sought an answer for the question "Is German Energiewende a unique model applicable to all countries?". In that sense, Turkey was selected as a developing country with many shared as well as different characteristics compared to the German energy markets. With a comprehensive analysis, the thesis showed that Energiewende is not a unique model, yet, has many aspects that many countries can take lessons from. The thesis highlights, above all, the importance of building own energy transition narratives to enhance the governance of the transition process. Especially for countries experiencing challenges in governing intertwined energy system shifts like Turkey, a new narrative would prove to be fruitful both nationally and internationally.

6.1. Objective and Argument

This thesis contributes to the literature in many aspects. There is ample literature on energy transition towards low carbon. The literature on energy transition spans a variety of countries from different regions and development levels. Among many countries, there exists a growing amount of literature on Energiewende. Most of this work on the German Energiewende is cited throughout this thesis and yet many remains to be restricted to German speakers. In this perspective, this thesis is crucial that it belongs to a scarce, yet, growing literature.

In addition, the literature on energy transitions is mostly policy oriented. Most of the published papers and reports on energy transition stem from public institutions, NGOs, think tanks and international organizations such as IRENA, IEA etc. The literature lacks peer-reviewed articles. Therefore, this thesis adds to the literature by adding an academic perspective to the literature.

Existing literature focuses on the transition analyses from economic, historical or technological perspectives. However, current energy transitions are mainly motivated by political goals. Therefore, it would be beneficial to conduct the analysis from a political economy approach. The focus of this thesis is on multidimensional analysis of energy transitions of Turkey and Germany, which is relatively a fertile area in the study of the political economy. Therefore, the analysis fills a missing portion of the political economy literature.

Another branch of literature exists on multidimensional analysis. This branch of the literature consists mostly of cross-country analysis. As energy transition experiences draw attention to international cooperation and lesson drawing, the importance of multidimensional analyses increases. However, multidimensional analyses remain to be scare. In the literature, there are numerous papers on comparison of Energiewende with other economies, yet, the comparisons remain limited in terms of the countries they cover and mostly focus on developed countries. In this regard, this thesis proves to be important by providing a cross-country analysis of Energiewende with Turkey, a developing country.

It is evident that there is a growing but still a limited amount of research on global energy transitions. Within this context, to my knowledge, no published articles on Turkey's energy transition exists. There are only some reports by national and international organizations and a few government publications. It is important to draw attention that Turkey's energy transition experience has a long history with many achievements regarding liberalization of the markets and integration of renewables. Hence, the experience itself can serve as an important example for developing countries. However, the transition of Turkey has not received the attention it deserves by neither the analysts nor the academics. To fill this missing element in the literature, this thesis delves into the energy transition experience of Turkey from various aspects and provides a detailed analysis.

The thesis not only provides details of energy transition in Turkey but it also examines the Energiewende and energy transition of Turkey from a multidimensional perspective. Additionally, it suggests possible fields of cooperation areas for further progress in the transition of both countries. To my knowledge, there is no multidimensional research on the energy transition experiences of Germany and Turkey so far. Thus, this thesis fills in a critical gap in the literature by providing a detailed multidimensional comprehensive analysis.

6.2. Scope

This thesis is comprised of six chapters including the introduction and conclusion. The thesis started by presenting different understandings behind energy transitions and the time factor behind the concept. Energy transitions are defined in various ways as definitions evolved over time. In this perspective, Chapter 2 discusses varying definitions in the literature to build a baseline for the main analysis of the thesis.

When we say energy transition, it commonly refers to transition towards low carbon energy sources. Therefore, in addition to various definitions, the chapter focused on the evolution of rising environmental awareness leading to climate change negotiations and discussed how it shaped the understanding of contemporary transition towards low carbon.

It is evident that each country has a different cause for undergoing an energy transition. There are endogenous as well as exogenous factors affecting their decision-making process. Among varying energy transitions, some countries rise as leading examples with their unique experiences. In that sense, Chapter 2 provided case studies of energy transitions of selected major economies to further elaborate on different examples based on country-specific circumstances. Throughout this chapter, four countries are selected as case studies, namely, France, the United States, China and Brazil.

The case studies of Chapter 2 analyzed four different energy transition experiences. As all case studies indicate, the most common driver of energy transitions is securing energy supply. For instance, reducing import dependency in the US and France, meeting increasing demand in growing economies like China are major motivations behind their transitions. Although the motivations are similar, the path that each country chose varies significantly depending on their national circumstances. In most countries, increasing energy security is often combined by minimizing the cost and preserving the competitiveness of the industry. While these are the major drivers in energy transitions of most leading countries, Germany has a contrasting starting point. The main motivation behind the landmark Energiewende appears to be stemming from environmental concerns and rising anti-nuclear movement across the country. After going through four different energy transition experiences, the next chapter took the analysis to a further step and elaborated on the energy transition of Germany.

Following Chapter 2, Chapter 3 analyzed Energiewende from various aspects. After laying out basic indicators and figures related to German energy and economy, historical background and legislative framework of the energy sector development of Germany was elaborated in a chronological order. Moreover, energy policies leading to the evolution of Energiewende is focused in detail. The major motivators and challenges of the transition path were analyzed to understand the baseline for Energiewende. Energiewende can be summarized as an integrated policy scheme covering various sectors including energy, economy and environment. The comprehensive policy set includes phasing out nuclear by 2022, improving energy efficiency, increasing the share of renewables in power generation as well as policies to reduce CO2 emissions.

After a detailed analysis on Energiewende, Chapter 4 analyzed Turkish energy transition from a similar perspective to make a healthy multidimensional analysis. Turkey's energy system has experienced a significant transformation over the last 20 years. With the establishment of EMRA and the enactment of laws for electricity and natural gas markets, the liberalization process of energy markets has started. During this period, numerous measures were taken to liberalize the electricity markets, attract investments and improve the system efficiency. Altogether, Turkey's energy transition can be summed under four major categories: increasing energy security, reducing import dependency through domestic resources, increasing energy efficiency and increasing share of renewables in power generation. The energy transition experience of the country has a long history with many achievements regarding liberalization of the markets and integration of renewables. However, the transition is still far from complete and critical issues need to be addressed.

Detailed evaluation of the energy transitions of Germany and Turkey in Chapters 3 and 4 provided the groundwork for the major analysis of this thesis. Chapter 5 brought all related information and conducted a multidimensional analysis of German and Turkish energy transitions. As Chapter 2 discussed, energy transitions include objectives in terms of increased energy security, increased energy efficiency and decarbonization of the energy system while maintaining economic competitiveness. In this regard, the multidimensional analysis was based on three aspects: security of supply, environment and economy.

6.3. Lessons Learned and Recommendations

There are six major questions that this thesis sought answers for which were mentioned in the introduction. These questions that were answered throughout the thesis are stated below.

1. Energy transition is a highly debated concept across the world. There are different understandings when it comes to defining this concept. This thesis aims to answer what is the definition of energy transition and how it evolves over time?
2. What are the motivations behind the energy transitions occurring globally? Given the unique circumstances of selected countries as case studies, what drives their energy transitions? The thesis also uncovers the specific policy targets as well as the tools for each of these case studies.
3. More specifically, what makes the prominent German experience "Energiewende" different from others? The thesis would like to explore the drivers of Energiewende. What are the roles of the government, other stakeholders as well as technological innovation? Moreover, the thesis aims to discover the decision-making process and the policy tools that the German government implements.
4. In tandem with the developments in energy transition, what is the position of Turkey? What motivates the energy transition of Turkey? How far the country has achieved so far? Among numerous policies, plans and implementations spanning a period of almost 20 years, what are the challenges the country is facing and what needs to be done to overcome these challenges?
5. Through a comprehensive multidimensional analysis of Energiewende and energy transition in Turkey, what are the possible takeaways from the German experience that Turkey can benefit? Beyond Turkey, what possible spillover effects can Energiewende have on other countries, especially developing ones?

6. Given all the answers to the questions above, is there a unique energy transition model applicable globally, such as Energiewende, or several models suitable for different countries?

Energy transition towards low-carbon is prioritized among long-term energy strategies for many countries. Germany has a first-mover advantage in energy transition with its Energiewende vision and serves as an example for other countries. Primarily, the experience itself shows other countries that an energy transition is feasible and it can bring additional economic benefits. The German experience underlines the importance of a comprehensive plan and an inclusive strategy.

The international signaling effect of Energiewende is directly and most rapidly observed in renewable developments around the world. Germany has implemented several regulatory tools to increase renewable expansion. Most notable among them is the EEG. The EEG played a critical role in reducing the renewable costs globally by reducing investor risk through guaranteeing grid connection, grid access and a feed-in. There are more than 70 countries implementing a FiT mechanism to increase the share of renewables in electricity generation. Moreover, Energiewende had major impacts on the price reductions in the solar and wind industries which triggered renewable energy expansion globally.

For Turkey, the strengths as well as challenges of Energiewende provide a benchmark in shaping its own energy transition. Germany is an example, drawing attention to the important role of governments in enabling a successful energy transition. In Energiewende, the German government implemented long-term policy measures to enable secure and reliable supply through private sector investments. While Turkey has firm energy transition plans, most of the targets are set until 2023. German example demonstrates the need for a longer-term policy setting for investor confidence. Increasing the market certainty for private sector players remain to be an important challenge for the energy transition in Turkey.

One of the major drivers of energy transitions is the participation of all stakeholders in the process. In this regard, in Germany, an increasing level of actors have been taking place at different levels. For example, in the production of renewable power the number of players has been increasing starting from a local level. Moreover, citizen participation has a critical role in the energy transition of Germany. Energiewende has a strong support among German citizens. For instance, the major pillars of Energiewende, nuclear phase-out and coal phase-out decisions were mainly triggered by strong public support whereas in Turkey, decisions are rather influenced by political forces. Therefore, increasing public participation in the decision-making process would serve as an opportunity for the progress of the energy transition in Turkey.

Transition from fossil fuels towards renewables brought together issues related to the structuring of the electricity supply system. It is worth mentioning that Germany's renewable sources are mainly wind and solar, not hydro. Thus, integration raises as an important issue. In this regard, Germany relies on its interconnections with the neighbouring countries. As the interconnection capacity increases, flexibility of renewables increases accordingly. Therefore, Germany's geographic location and its position in the EU electricity markets provides important flexibility options. Integrating variable sources like renewables remain to be an important issue for Turkey as the share of renewables in electricity generation. Although abundant hydro provides opportunities for renewable integration in Turkey, developing adequate plans and increasing interconnection capacity is crucial for further developments.

Renewable expansion of Germany had another advantage compared to other country examples. In Germany, the expansion enabled the development of a new manufacturing sector. The FiT model together with the long-term goals created a secure investment environment through a stable market support mechanism. While this model had significant contribution on the development of renewable energy sources, it also increased R&D that further contributed to the development of renewable technologies. With these developments, Germany became a net equipment exporter in renewables. On the other hand, Turkey remains to be an importer with exporting capacity of wind equipment. The auction scheme implemented in 2017 includes local equipment requirements that is expected to contribute local equipment manufacturing. However, these projects remain to be underdeveloped. To become a manufacturing hub for renewables, Turkey needs additional R&D investments.

Beyond the significant achievements of Energiewende, the challenges that Germany faced are equally helpful for the development of energy transition in Turkey. Among these challenges, high EEG surcharges come the first. Cost burden of the EEG on consumers caused many debates among the German society. Due to its first-mover position, Germany started developing renewables when the costs were high. However, the feed-in tariffs were not adjusted in line with the sharp cost reduction in wind and solar systems. Turkey, in this regard, could take into account the German experience in planning the support mechanisms for renewables which is due to expire in late 2020 as well as the new auction designs.

Germany also faced challenges related to integration in the transmission and distribution networks. The challenge was boosted by the rapid increase in the number of prosumers who consume and produce electricity at the same time. To integrate prosumers to the system, the existing grid design which aimed to transmit electricity from large power plants needs to be adjusted. The adjustments require higher investment in smart meters, local substations and better grid management software. Insufficient grid capacity also posed a problem while transmitting the electricity generated from wind power plants in the north to the south where there is high energy demand. Similar to Germany, demand in Turkey is centered around the west while power is mainly generated around the east. Therefore, Turkey should anticipate similar challenges and revise its plans accordingly.

Another major challenge of Energiewende is reliance on fossil fuels. Germany still relies heavily on fossil fuels with a high share of coal use. Germany is a net coal importer and lignite producer. Similarly, Turkish energy composition has a significant share of fossil fuels. In this regard, high share of fossil fuels raise questions on emissions of Turkey and Germany. German Energiewende has ambitious targets on reducing CO2 emissions. In this regard, Germany's Climate Action Plan 2050 which was published during COP22 received great attention. However, due to high fossil fuel use, Germany announced that it is to miss its emission reduction targets.

Following the withdrawal of the US from the Paris Agreement in 2016, Germany has been acting more actively to take the leadership in energy transition as well as setting the climate agenda. It could also become a leading actor in the climate talks globally and provide a credible model for other countries only if it can achieve the goals it has set. On the other hand, Turkey's position in climate talks is unusual. Turkey's INDC relies heavily on increasing the share of renewables and energy efficiency in various sectors. However, a closer look at the export industry indicates that these sectors are high energy-intensive making it difficult for Turkey to reach its emission reduction targets.

In Germany, while share of renewables increased significantly, much remains to be done in bringing energy transition to other sectors mainly heating and transport. Similar to Germany, Turkey's energy transition mainly focuses on the electricity sector. For further achievements, transition in other sectors especially industry, transport and agriculture is indispensable.

In sum, Germany offers beneficial takeaways for Turkey as both countries continue their energy transitions. Overall, renewable energy transition in the power sector provides essential lessons. First, it demonstrates the importance of optimal deployment of solar and wind power. Additionally, the experience shows how important is to collaborate with the neighbouring countries as well as making adequate grid investments. Moreover, cost-efficiency of the investments and public participation in the decision-making process are lessons to be learned from Energiewende. The Energiewende experience underlines the importance of grid management and flexibility, role of the government in preparing the necessary environment for the investors and promoting R&D in new technologies, energy efficiency measures and role of renewables and efficiency in other sectors beyond power generation.

Developments from now on would focus on new technologies, financing mechanisms and business models. In this regard, experiences of Germany would help Turkey to accelerate its energy transition. Based on the Energiewende experience there are 6 aspects that Turkey should prepare itself.

1. In addition to the targets set for 2023, setting longer-term goals in line with the predictable market pillar of the energy policy.
2. Increasing small-scale players while keeping large players in the game.
3. Making adequate investments for grid flexibility and reliability as increasing renewable plants are added to the system.
4. Increasing investment in R&D in new technologies to increase local manufacturing and to become a manufacturing base of the region.
5. Shifting the existing experience in renewable energy and energy efficiency to the sectors beyond electricity to heating, cooling and transportation.
6. Planning the support mechanism and the auction mechanism for renewables in a cost-effective manner.

Therefore, Energiewende is not a unique model that each country must follow. Rather a country-specific approach needs to be determined based on the lessons learned from other country experiences. Energy transition is a continuous process. Each country has their ongoing transition experience based on their unique circumstances. As discussed in the case studies of Chapter 2, China’s main target was to tackle with air pollution. The severe consequences of air quality related issues led the country to shift its entire energy system. In addition, comparative advantage in manufacturing is a critical driver of Chinese energy transition as well as their leading role in fighting climate change. While China is the main manufacturer and exporter of renewable equipment, the country is also the main supplier of rare earth materials essential for renewable equipment manufacturing. China is also investing significantly on electric vehicles to better compete in this new segment. In France, the transition was rather nuclear driven. In the US, shale gas revolution enabled the coal to gas transition. It is evident from these case studies that transitions are only possible and successful if it fits the economic model as well the respective capabilities of the country. Moreover, beyond national targets there is a global pressure to deal with climate change. In this regard, Energiewende takes climate change at the center of its national transition narrative in line with the global shift. In this perspective, Turkey should follow a similar approach and build a new energy transition narrative, this new version which can be described as Transition 2.1, with climate change at the core of the strategy. Similar to German experience, this new narrative could increase the knowledge and participation of civil society which would ease the adaptation of new policy tools. Increasing public acceptance is critical in this new national narrative and transition to be successful.

Turkey has already come a long way in its energy transition. In the new narrative, the developments discussed in Chapter 4 should be restated in a different language prioritizing climate change related goals at the center. Moreover, a new possible field would be implementing a suitable type of carbon pricing mechanism which is already being indirectly enforced by the New European Green Deal. Beyond all, developments in the natural gas and oil exploration should be closely followed. Sufficient amount of discovery can play a major role in Turkish energy transition since gas is also referred as the transition fuel. Turkey, a country with high import dependency, needs to discover and use its own gas in order to tackle with the criticisms related to coal like the US example. Technically, availability of natural gas would allow the system to integrate more climate friendly, yet intermittent renewable energy resources without jeopardizing system reliability and flexibility. Economically, producing domestic gas would help Turkey to reduce current account deficit, mitigate global price volatility and provide more affordable gas to consumers which would enhance public support for energy transition.

Coming up with a new model to address energy and climate issues, provides an opportunity for setting the standards for other countries. Beyond this point, any new model should prove its benefits for the economy, society as well as the environment.

Along the way, there will be mistakes or shortcomings. It is essential to improve these through adequate policy interventions that provide predictable investment environment for the investors and all other stakeholders. Setting proper targets and building strategies to achieve these targets are important. However, the implementation is equally important, if not more. Therefore, the progress of energy transition would require regulatory changes, implementation of new policy tools and application of new financing and business models.

Having reviewed the arguments, objectives and lessons learned, it is also essential to give some prospective points for potential future research. Since this thesis fits into a broad literature, yet a very limited number of researches exists, this thesis can lead to many fruitful further analyses. I would suggest a number of possible research areas that I find missing in the literature which can largely be extended.

Firstly, as the title of the thesis suggests this is a multidimensional study which analyses energy transitions from 3 different dimensions. However, urban research has taken another approach realizing the importance of linkages between cities, regions even towns with their environment. It is crucial to realize that new energy paradigm has emerged at a local level emphasizing the critical role of local entities in shaping the national and global energy transitions. In this regard, there are some studies on the EU focusing primarily on the role of cities in adapting the inevitable smart and sustainable systems transition. However, this area remains to be open for future work.

Another possible field of study would be the two-way interaction of geopolitics and energy transitions. In this thesis, the role of geopolitics has been left out for the future work on purpose, however, the interaction remains to be critical. The global developments in renewable technologies and their rapid deployment is having indispensable long run impacts on geopolitical dynamics shifting the conventional understanding. With the new technological developments, disruptive innovations and their widespread use, the shift would become more severe. Therefore, for future work on energy transition geopolitics will play a more critical role.

Last but not least, it is inevitable that technological developments would be at the center of any energy transition dicsussion in the near future. The rapid developments in information technology and smart technology would enable a new area in energy transitions globally. The technological developments would require countries to rethink their understanding and force the implementation of new policy and market mechanisms. In this regard, a whole new research could focus on adding an extra "technological dimension" to the multidimentional analysis of this thesis.

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Zhu, T., & Wang, L. (2020). *State Energy Transition*.

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: Bayraktar, Alparslan
Nationality: Turkish (TC)
Date and Place of Birth:
Marital Status:
Phone:
email:

EDUCATION

Degree	Institution	Year of Graduation
LLM	Bilkent University	2013
MA	Fletcher School of Law & Diplomacy	2006
BS	Istanbul Technical University	1995

WORK EXPERIENCE

Year	Place	Enrollment
2019-Present	MENR	Deputy Minister
2018-2019	MENR	Deputy Undersecretary
2016-2018	MENR	Director General
2010-2016	EMRA	Commissioner

FOREIGN LANGUAGES

Advanced English

PUBLICATIONS

1. Bayraktar, A. (2018a). Energy transition in Turkey. *Turkish Policy Quarterly*. Retrieved from http://turkishpolicy.com/article/929/energy-transition-in-turkey
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