KADİR HAS UNIVERSITY
SCHOOL OF GRADUATE STUDIES
ENERGY AND SUSTAINABLE DEVELOPMENT PROGRAM

THE RENEWABLE ENERGY TRANSITION IN TURKEY

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MASTER’S THESIS

ISTANBUL, MAY, 2019

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Submitted to the School of Graduate Studies of Kadir Has University in partial fulfillment of the requirements for the degree of Master's in the Program of Energy and Sustainable Development.

ISTANBUL, MAY, 2019

DECLARATION OF RESEARCH ETHICS /

METHODS OF DISSEMINATION

I, MESUT CAN YILMAZ, hereby declare that;

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This work entitled **THE RENEWABLE ENERGY TRANSITION IN TURKEY** prepared by **MESUT CAN YILMAZ** has been judged to be successful at the defense exam held on **29/05/2019** and accepted by our jury as **MASTER'S THESIS**.

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ABSTRACT

Energy is an integral part of human life. The energy demand has been increasing for many years. The primary energy source differed over time. Fossil fuels dominated the energy market since 19th century. Overuse of fossil fuels has created serious problems such as climate change. In order to tackle these problems renewable energy source (RES) utilization gained importance in the recent years. With the help of economic and technological improvements, the transition from fossil fuels to renewables has accelerated in recent decades. Many countries have already started to invest in RES instead of fossil fuels. Germany and China have some unique characteristics that can help to reshape Turkey's roadmap to the renewables. Turkey is a developing country with a population of about 80 million. Turkey's energy import dependency is 77%. According to the experts, Turkey has a good potential for RES. Due to its geographical position there is adequate potential of solar, wind, hydro and geothermal. Turkey has an opportunity to utilize its RES potential. If the important steps are taken, RES can become the primary source of Turkey's energy demand and would have positive effects on both the economy and sustainability.

Keywords: Renewable Energy Transition, Sustainability, Solar, Wind, Climate Change, Carbon Emissions

TÜRKİYE'DE YENİLENEBİLİR ENERJİ GEÇİŞİ

ÖZET

Enerji insan yaşamının ayrılmaz bir parçasıdır. Enerjiye olan talep her geçen gün artmaktadır. Birincil enerji kaynağı zaman içerisinde bir takım değişikliklere uğramıştır. Yakacak odunla başlayıp kömürle devam eden bu süreç şimdilerde doğalgaz veya elektrik olarak ilerlemesini sürdürmektedir. Geçmişten günümüze fosil yakıtların kullanımı başta iklim değişikliği olmak üzere önemli bazı sorunlara neden olmuştur. Bu sorunlarla mücadele etmek adına son yıllarda yenilenebilir enerji kaynaklarına bir yönelim olmuş ve bu yönelim hızı artarak devam etmiştir. Almanya ve Çin yenilenebilir enerjiye geçişte önemli bir yere sahip olan iki ülkedir. Son yıllardaki politikalarıyla hem yenilenebilir enerji kapasitesi hem de elektrik üretiminde iyi göstergelere sahip olan bu iki ülkenin geçiş süreçleri incelenmiş olup Türkiye için nasıl örnek teşkil edebilecekleri açıklanmıştır.

Türkiye enerjide 77% oranında dışarıya bağlı, gelişmekte olan bir ülkedir. Türkiye artan nüfüsunun ve gelişen ekonomisinin enerji talebini yüksek oranda fosil kaynaklardan karşılamaktadır. Yenilenebilir enerji potansiyeli açısından zengin bir ülke sayılan Türkiye'nin yenilenebilir enerjiye geçiş süreci bu çalışmada detaylıca incelenmiş olup, bir takım değerlendirmelerde bulunulmuştur. Küresel ısınma ve çevre sorunlarıyla mücadele edilen dünyamızda yenilenebilir enerji sürdürülebilir bir geleceğe sahip olmak adına önemli bir yer tutmaktadır. Bu geçişi hızlandırabilmek adına başarılı olmuş politikalar örnek alınmalı ve daha iyilerinin oluşturulabilmesi için ortak hareket edilmelidir.

Anahtar Sözcükler: Yenilenebilir Enerjiye Geçiş, Sürdürülebilirlik, İklim Değişikliği

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LIST OF ABBREVIATIONS

°C	Degree Celsius
BMBF	German Federal Ministry of Education and Research
BMEL	German Federal Ministry of Food and Agriculture
BMU	German Federal Ministry for the Environment, Nature Conversation and Nuclear Safety
BMWi	German Federal Ministry of Economics and Technology
BP	British Petroleum
CO_2	Carbon Dioxide
EIA	U.S Energy Information Administration
EIGM	General Directorate of Energy Affairs
EMRA	Energy Market Regulatory Authority
EU	European Union
EUAS	Electricity Generation Corporation
EXIST	Energy Exchange Istanbul
FIT	Feed-in Tariff
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GW	Gigawatt
IEA	International Energy Agency
IMF	International Monetary Fund
IRENA	International Renewable Energy Agency
KWh	Kilowatt hour
MW	Megawatt
MWe	Megawatt electric

MWh	Megawatt hour
MTOE	Million Tons of Oil Equivalent
MENR	Republic of Turkey Ministry of Energy and Natural Resources
NDC	Nationally Determined Contribution
NDRC	National Development and Reform Commission
R&D	Research and Development
REN21	Renewable Energy Policy Network for 21th Century
OAPEC	Organization of Arab Petroleum Exporting Countries
TWh	Terawatt hour
TEDAS	Turkish Electricity Distribution Corporation
TEIAS	Turkish Electricity Distribution Corporation
TETAS	Turkish Electricity Trade and Contracting Corporation
UNFCCC	The United Nations Framework Convention Climate Change
YEGM	General Directorate of Renewable Energy

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INTRODUCTION

Energy is an integral part of human life. It has been used for many purposes, including lightning, heating, cooling, manufacturing, transportation and more. Economic growth and energy are deeply connected. Demand for energy has increased alongside population and life expectancy. The world population grew rapidly in the last two centuries. It took roughly 200 years for the world's population to increase from 1 billion to 7.5 billion. There is also a positive correlation between population, economic growth and energy demand. Since the populations and economies are growing daily, energy demand is rising in a commensurate fashion.

Humanity's energy sources have changed over time. These sources have included wood, coal, oil and natural gas. People have tended to switch from one energy source to another if the new one was better than the current one (Solomon and Krishna, 2011). Three characteristics made one source better: higher calorific value, greater practicability in use and lower environmental impact. Wood fuels were the primary energy resources for most of humanity's history, but coal replaced wood in the first half of the nineteenth century because of its higher calorific value and its suitability for industrial use (Fouquet, 2010). Coal became widely used, especially for the steam engines during the Industrial Revolution. With the help of technological improvements, petroleum products became the dominant energy source from coal in twentieth century (Fouquet, 2010). Oil was better than coal in terms of calorific value, practicability and cleanliness. When natural gas became available for large-scale use in the 1950s, it became preferred as an energy source along with oil because of its advantages over coal and other sources. The energy transition is a dynamic, ongoing process and is still advancing towards better sources.

Fossil fuels - oil, natural gas and coal - dominate today's energy markets. According to BP (2018), most of the world's primary energy consumption comes from fossil fuels with a share of 85.2%. The share of renewables including hydro is 10.4%. However, fossil fuel dominated energy systems are unsustainable. Firstly, all fossil sources are finite by nature, and their reserves are diminishing year by year. Another major problem is environmental.

The burning of fossil fuels has resulted in significant damage to the environment. The world's average temperature has risen due to the release of carbon emissions into the atmosphere. If the world's average temperature exceeds 2 °C level, the consequences could be catastrophic for humankind. Renewable energy sources (RES) can therefore play an important role in helping mitigate the adverse effects of climate change. First of all, RES are considered infinite and abundant. Secondly, they are environmentally friendly. They offer an economic, environmental and social sustainability and it is possible that they dominate the energy sector in the near future (IEA, 2016; EIA, 2019).

Turkey is a developing country with a population of about 80 million. Its economy is the 18^{th} largest in the world and is expected to grow in the coming years (IMF, 2018). Since energy is needed for economic development, energy demand is also expected to increase. Turkey's energy mix consists of 87% fossil fuels. However, the net import dependency is 77% (Ministry of Energy and Natural Resources, 2017). At the same time, Turkey has good potential for RES. Due to its geographical position there is adequate potential of solar, wind and geothermal (Ediger and Kentel, 1999; Balat, 2005; Özgür, 2008; Serpen et al, 2009; Kırtay, 2010; Melikoğlu, 2017; Kılıçkaplan et al., 2017). Biomass potential is also comparatively sufficient (Erdil and Erbıyık, 2015; Toklu, 2017). Turkey should use its renewable energy potential for its sustainable development by switching from fossil fuels to renewables.

The main purpose of this thesis is to harness knowledge about renewable energy transitions in the world and in other specific countries and to arrive at insights and guidelines that will be beneficial for Turkey to hasten its own transition. In the thesis, I tried to answer the following question: "what should Turkey do to hasten its own renewable energy transition?". Sub-questions include: "which countries have had the best practices of in hastening a renewable energy transition?; "which countries should Turkey emulate in order to achieve a successful transition"; "what obstacles do countries face in the transition?"; "what kind of policies should be implemented to change the renewable energy future in a better way?"; and "what are the basic strategies Turkey that should follow?". The study takes Germany and China models because of their unique characteristics that can be compared with Turkey. All these three countries have one common point: energy import dependency. The share of domestic production in consumption of Germany (20.2%), China

(70.1%) and Turkey (21.6%) can be increased with the help of enhancing renewable energy share in their energy mix (BP, 2018). Turkey (56%) and Germany (35%) are both importing natural gas from Russia to meet their energy demand (EIA, 2017; Forbes, 2018). Germany is a pioneering country, having launched its renewable transition and implemented efficient policies during the process. Also, the populations of Germany and Turkey are similar, which makes for a helpful for comparison. China, meanwhile, is the global leader of the renewable energy transition in terms of installed capacity and growth rate although it started to the RE transition later than Germany. However, the eagerness of change and domestic manufacturing power has helped China to accomplish its RE targets and made them world leader in a short period.

There are numerous papers analyzing the global renewable energy transition. While these studies generally focus on the political aspects of the energy transition, others focus more on economics. For instance, Fouquet (2010) analyzed the historical background of energy transitions. Smil (2016) examined the energy transition briefly and identified 12 different aspects. Kelsey and Meckling (2018) discussed the policies that led to the renewable energy transition and provided related evidence. Yanfang and Wei (2012) studied the legislation and incentives behind the renewable energy transition in China, which has implemented a considerable amount of RES into its energy system in recent years. Conolly et al. (2016) examined the impacts of renewable energy on the European Union (EU). Pacesila et al. (2017) analyzed the renewable energy sector in the EU and grouped similar states by their renewable energy usage. Strunz et al. (2016) analyzed the policies of both the EU and Germany. Renn and Marshall (2016) investigated the details of renewable policy since the 1950s.

There are also several publications on renewable energy transition in Turkey. Ediger and Kentel (1999), Balat (2005), Özgür (2008), Serpen et al. (2009), Kırtay (2010) and Kılıçkaplan (2017) assessed the current and future renewable energy situation of Turkey. Özturk et al. (2007) and Erdoğdu (2011) studied on hydropower in Turkey. Melikoğlu (2017) focused on Turkey’s geothermal energy, and analysed the country’s future targets for 2023. Şekercioğlu and Mustafa (2012) examined the renewable energy policies of EU and Turkey. Greenpeace (2015) prepared a very informative and detailed report that examined the past, present and future of the transition in Turkey. Meanwhile Mete and

Heffron (2015) reviewed the Turkey's renewable energy policies and legislation. Kılıçkaplan et al. (2017) investigated the renewable energy transition of Turkey by 2050 with a two different scenario simulations. All of these works were informative and inspiring.

The data used in this study was obtained from the International Energy Agency (IEA), the International Renewable Energy Agency (IRENA), BP (British Petroleum), the Renewable Energy Policy Network for 21st century (REN21), Greenpeace and other international organizations. Turkey's domestic data were obtained from the Energy Market Regulatory Authority (EMRA), the Ministry of Energy and Natural Resources (MENR), the Turkish Electricity Transmission Corporation (TEIAS), the Turkish Statistical Institute (TÜİK) and other related local organizations. The data was collected and interpreted to give information about the current situation and to make future predictions.

This thesis has four parts. The first provides a brief introduction to the global renewable energy transition. The second assesses how other countries, including Germany and China, have undertaken their own transitions. It then moves to the third part to investigate the energy transition in Turkey by giving specific background about Turkey's renewable energy potential, its installed capacities, its electricity generation and the possible future status of renewables. The economy of renewables, such as affordability and feasibility, will be an important component as will analyzing the obstacles that Turkey faces for its renewable energy transition. It will also suggest ways for the country to identify a roadmap to increase its share of RES. Finally, in the fifth part, it will conclude by offering recommendations.

1. THE GLOBAL RENEWABLE ENERGY TRANSITION

This section provides detailed information about the renewable energy transition process, including historical background and the reasons that it began and that sustain its momentum. In addition, countries that have enacted successful renewable energy transitions, including Germany and China, are analyzed in further detail.

1.1. The Global Renewable Energy Transition

Energy types have changed over time, and primary energy resources have differed throughout history. It took many centuries to transition from wood to natural gas. Fossil fuels remain the main sources of today's energy consumption. However, these sources are unsustainable because of their environmental impact and depleting reserves. When all of these reasons are taken into consideration, RES are a better option. They are eco-friendly and considered infinite. They offer new potential to solve substantial problems.

Renewable energy is not a new concept. Solar, wind, biomass and geothermal energy have been used in elementary forms for centuries. Water and windmills were widely used in agriculture and transportation while geothermal for heating. With the help of technological developments RES become more sophisticated. Their usage area and efficiency levels have changed in a considerable extent. Solar, wind, biomass or geothermal energy can be easily transformed into electricity and are used in a large scale.

The importance of the renewable energy has grown in recent decades. After the oil crises of the 1970s, countries sought new alternatives. Price fluctuations of fossil fuels greatly affected energy demand, especially in developing countries (El-Ashry, 2012). Securing energy that was sustainable and that could make states more energy independent became important issues. Renewable energy gained prominence in this context and affected governmental policies (Hache, 2018). States started to plan more independent systems in order to cope with their energy problems. However, the technology and cost of renewables were too high, making it difficult to compete with fossil fuels. The conventional technologies have had political and financial support for many years, and such support is essential for RES to compete with fossil fuels (Greenpeace, 2015). Governments can incentivize RES investment through instruments such as VAT exemption, tax deduction, land allocation, or financial support. These investments can stimulate the economy and contribute to society by enhancing technological development and global competitiveness. Also, from an economic perspective, renewable energy can help create high-quality jobs and encourage the development of micro-industries and mini industrial zones (Conolly et al., 2016).

Climate change is another critical factor that has accelerated the renewable energy transition because it forced governments to think about cleaner energy resources. Many countries signed the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 and accepted the Kyoto Protocol in 1997. The protocol pledged the signatory countries to decrease their greenhouse gas emissions and use more renewable energy into their systems. The EU pledged to double its renewable energy proportion by 2010. The countries also signed the Paris Agreement in 2015, the main goal of which was to mitigate the global adverse effects of climate change and keep the global rise in temperature below 1.5°C (UNFCCC, 2015). The signatory countries should make a serious effort to reach their nationally determined contributions (NDCs) according to the agreement.

There is an external factor that changed the world's perspective about renewables and shaped future energy policies: the nuclear disasters at Chernobyl and Fukushima (Verplanken, 1991; Jacobsson and Labuer, 2006; Khatib and Difiglio, 2016). In 1986, a major accident occurred at the Chernobyl nuclear power plant in Ukraine, in which the reactors exploded and radiation released into the atmosphere. Radioactive clouds spread all over Europe and neighbor countries including Turkey. The radiation caused many deaths and serious illnesses; the impacts of the accident are still felt (Baverstock and Williams, 2006). The plant area is unusable, as radiation levels at Chernobyl are not at normal levels and are not expected to be in the near future. In 2011, the Great East Japan Earthquake created a tsunami that inflicted heavy damage to the Fukushima Daiichi nuclear power station. A meltdown occurred in the reactors, and thousands of people were evacuated. Radioactive materials leaked into ocean, causing radioactive fallout. The reliance on fossil fuels and nuclear was shattered. After the disaster, countries changed their future energy plans (Kan, 2018). France, for example, generated its electricity mostly from nuclear power, but decided to close 14 nuclear reactors by 2035 (France24, 2018). Germany also decided to shut down its nuclear plants by 2022 (BBC, 2011). The common aim was to replace nuclear with wind and solar power.

The technology of renewables is also changing rapidly. Costs have fallen significantly in recent years, and governments have started to support RES with greater seriousness and urgency. With the help of technological and economic developments, the global installed capacity of renewables has risen dramatically (Table 1.1), doubling over the last ten years with an average growth rate of 8.3% (IRENA, 2019a).

Table 1.1 Global Installed Capacity of Renewable Energy

Years	Total Capacity (MW)	Growth Rate
2009	1,136,226	7.4%
2010	1,224,050	7.7%
2011	1,329,202	8.6%
2012	1,441,393	8.4%
2013	1,563,122	8.4%
2014	1,693,254	8.3%
2015	1,848,157	9.1%
2016	2,007,996	8.6%
2017	2,179,448	8.5%
2018	2,350,755	7.9%

Source: IRENA, 2019a

Likewise, the global consumption of renewable energy grown at a rate of 16.6% annually, bringing to market around 500 Mtoe (BP, 2018). After tepid development until 2006, RE consumption doubled from 2012 to 2017. The market continued its growth, with many regions of the world contributing to RE development. In 2017, electricity generation from renewables increased by 17% and accounted for 8.4% of the world’s total consumption (BP, 2018).

In 2018, solar power capacity grew by 24.2%, wind power capacity by 9.5%, geothermal power capacity by 4.22% and hydropower capacity by 1.67% (IRENA, 2019a). Figure 1.1 shows the global energy consumption of the world between the years of 1965 and 2017. It can be clearly seen that the RE consumption has increased rapidly since 2000s.

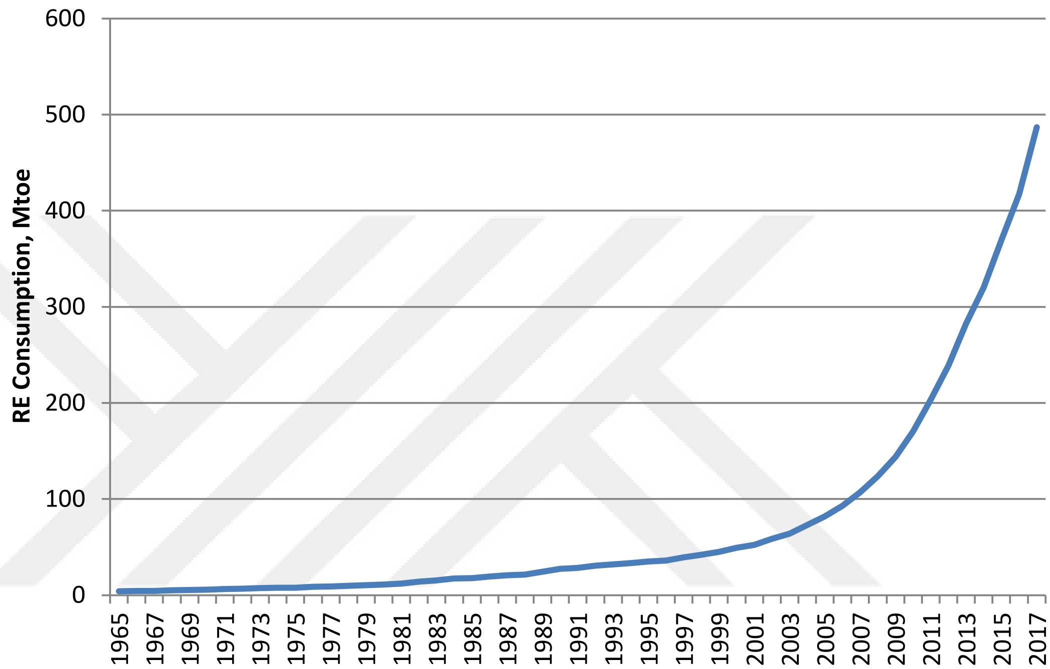


Figure 1.1 Global Renewable Energy Consumption, 1965-2017
Source: BP, 2018

Many countries, especially EU countries, are increasing their investments in renewable energy as an alternative to fossil fuels. Portugal (14.2%), Germany (13.4%), Finland (13.4%), Sweden (12.4%), Spain (11.3%), and United Kingdom (11.0%) have a good share of renewable energy in their energy mixes (BP, 2018). In addition to these countries, Asian markets are eager to deploy renewable energy. China (695.865 MW) is the leader in total installed capacity as well as total added power both in solar and wind. China (695.865 MW), USA (245.245 MW), Brazil (135.674), Germany (120.014 MW), India (117.919 MW), and Japan (90.154 MW) have a significant amount of installed RE capacity (IRENA, 2019a).

Germany and China are the two countries considered the most successful in terms of enacting a renewable energy transition. Germany started its transition earlier than anyone and regulated its energy structures and laws accordingly. China started its transition later than Germany but has pursued a more aggressive policy to catch up. China is now leading the world in global investment in RES-based generation and invests in every kind of RES. I will examine these two different countries in the following section.

1.1.1 Germany

Germany's *Energiewende* pioneered the renewable energy transition. *Energiewende*, first introduced by Kraus et al. (1980), described a path for economic growth and prosperity without uranium and petroleum. Germany had long been a coal-dominated country. When world preferences started to change, they decided to switch to green energy to secure its energy supplies and create a more sustainable system. Today renewable energy is one of its most important sources of energy consumption, constituting a 13.2% share (Figure 1.2).

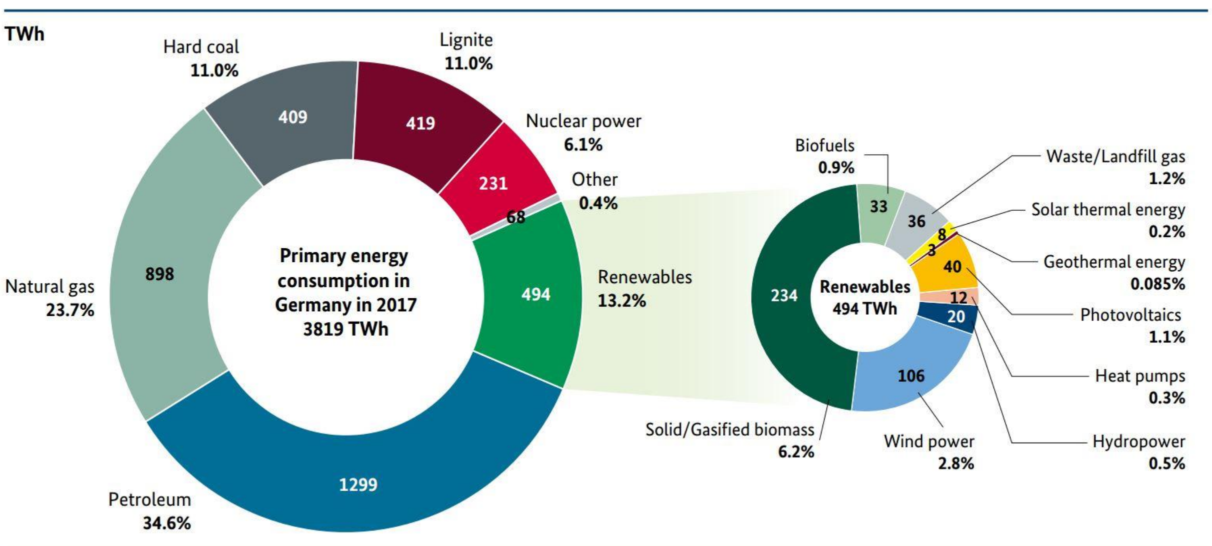


Figure 1.2 Primary Energy Consumption in Germany (TWh)
Source: BMWi, 2017

Germany's transition began several decades ago. The Ruhr basin in North Rhine-Westphalia was rich in coalmines; thus the coal industry was located there (Marx, 2014). The coal industry very dominated the market for many years. Then, nuclear power began to be phased in during the 1950s, and it became an important source of domestic supply (Hake et al., 2015). Governmental support for coal and nuclear increased especially after the Organization of Arab Petroleum Exporting Countries (OAPEC) crisis in the 1970s (Hager, 2015). The Ministry of Research and Technology organized a program and invested 10 million DM in research and development (R&D) for renewables (Hake et al., 2015). In order to ensure energy-supply security, solar and wind technologies were supported. A new political movement formed around the anti-nuclear movement, which later became the Green Party. The Greens were environmental activists who pursued a more environmentalist and transparent brand of politics (Hake et al., 2015). They entered parliament in 1983 and tried to achieve better environmental and transparent policies (Hager, 2015).

The past reveals that predetermined policies are likely to change when there is an unexpected incident, and it was the Chernobyl disaster in 1986 that reshaped the Germany's energy policy (Kunz and Weigt, 2014; Strunz, 2014; Renn and Marshall, 2016). Later Fukushima disaster occurred in 2011. Intended projects were cancelled due to great public opposition against nuclear. Instead of nuclear, new alternatives such as solar and wind were evaluated. In 2011, Germany made a bold decision that clearly indicated its exit from nuclear, which was one of the most extreme reactions among countries to the Fukushima disaster (Grossi et al., 2017).

Before that, the environmental impacts of climate change started to gain more attention in the 1990s, which led countries to initiate policies that supported renewable energy (Strunz, 2014). Germany signed the UNFCCC in 1992. In 2010, the government announced new energy strategies that sought to achieve ambitious targets for climate protection. It targeted to reduce carbon emissions by 55% and increase the share of RES in electricity consumption to 50% by 2030. These targets were later extended to an 80% emissions decrease compared to 1990 and an 80% increase in RE electricity (Hake et al, 2015). Other energy concepts such as green transportation, energy efficient buildings, and better energy-storage systems were also given priority.

EU countries adopted feed-in tariff (FIT) mechanisms after the acceptance of the UNFCCC. These mechanisms guaranteed the sale of electricity for renewables producers, who could their generated electricity at a fixed price for a fixed period of time. Germany was one of the first countries to implement FITs, and additional legislation supporting electricity generation from RES was concurrently pursued. The policies started in 1990s and were expanded in the following years. In 1991, the Electricity Feed Act (EFA) was passed. In 1998, the Green Party and Democrats won the elections and formed a coalition agreement that promised to exit nuclear, reduce carbon emissions, and accelerate the renewable energy transition (Hake et al., 2015). At the same time, electricity and natural gas markets were liberalized in the same year, which led to the liberalization of energy markets and a more decentralized energy generation regime. This had the benefit of being more competitive than the previous regime (Strunz, 2014).

In 2000, Germany adopted the Renewable Energy Sources ACT (EEG) as an extended version of the EFA in order to accelerate the implementation of renewables and to decentralize energy production (Strunz, 2014). FITs were also restructured with the EEG so that other countries could benefit from them (Buchholz et al., 2019). They had a chance to create their own systems in order to stimulate the market. Germany's FIT mechanism had three main characteristics: long-term guarantees (20 years) for the sale of RE electricity at a higher price than the market price, priority of electricity sales at the market (merit order), and obligatory grid connection by the grid operator (Matschoss et al., 2019). In order to attract potential investors, the FIT support premium was higher than the market price. For example, wind power was being sold at 9.1 cent/kWh and solar power at 50.6 cents/Kwh (Borosso and Iniesta, 2014). The EEG helped the solar and wind energy market grow substantially; the photovoltaics (PV) market grew at an average rate of 30 percent since 2000s (German Federal Ministry of Economics and Technology, 2018). It can be stated that improvements in FITs significantly contributed to the proliferation of RES, whose consumption increased from 2.1 Mtoe in 1999 to 44.8 in 2017, a nearly 22-fold increase, within 18 years (BP, 2018).

In order to understand the success behind *Energiewende*, the Germany's government structure for energy should be carefully examined. The main institutions are the Federal Ministry of Economics and Technology (BMWi), the Federal Ministry of Education and Research (BMBF), the Federal Ministry for the Environment, Nature Conversation and Nuclear Safety (BMU), the Federal Ministry of Food and Agriculture (BMEL), German Energy Agency (DENA), Arbeitgemeinschaft Energiebilanzen (AGEB) and Federal Cartel office (FCO). The BMWi is responsible for the energy policy and R&D in general. The BMU was established in order to take part in the nuclear sector in 1982 (Hake et al., 2015). However, the BMU is now responsible for the environmental policies such as climate change, nuclear safety and fossil fuel usage. The BMWi, BMBF and BMEL are working together to implement supportive programs. The BMWi and BMBF are dealing with projects related to the efficiency of renewable energy, nuclear systems and waste disposal. The BMEL is funding bioenergy projects. The FCO regulates energy and electricity markets. AGEB is responsible for the preparation and evaluation of energy-balance statistics from all sectors of the energy industry. In 2000, the government also founded the German Energy Agency (DENA) in order to bring various energy sector players together, help develop energy-efficient policies for both climate change and sustainable development (Jacobs, 2012; Strunz, 2014; Renn and Marshall, 2016). In 2006, the German Solar Industry Association (BSW) was founded in order to stimulate growth in the solar market.

In the transition period, Germany became interested in two RES: wind and solar. It is mainly because the potential success of these sources is relatively greater than others. However, these technologies were implemented around 1990s (Erge et al., 2001; Jacobsson and Lauber, 2006).

The government invested in projects such as “Growian” (big-wind turbine) in order gain experience with RES (Hake et al., 2015). The Growian failed due to technical difficulties, which pleased coal and nuclear supporters (Hake et al., 2015). However, Germany did not stop seeking alternatives. In 1989, the government presented a support program for wind power that aimed to install 100 MW of wind power with a guaranteed payment of €0.04 cent/kWh (Jacobsson and Lauber, 2006). The first rooftop PV system that had a grid connection was used in Munich (Erge et al., 2001). This led to the development of small-scale solar.

In 1991, the government initiated “the German 1000-Roofs Program” in order to accelerate this technology. One of the main objectives was to popularize the small-grid connected installations. After the program, more than 2000 grid-connected PV systems were established and public awareness increased (Erge et al., 2001). The 1000-Roofs program was a good start for solar power, and the program was expanded in 1999 to the 100,000-Roofs-Solar Programme by the BMU. This program provided subsidies, such as low interest loans and easy terms of payment, for investors (Jacobsson and Lauber, 2006). PV systems larger than 1 kW could also benefit from these subsidies. The program sought to develop 300 MW of additional capacity and ended in 2003 with 55,000 rooftop installations and 261 MW of additional capacity (IEA, 2012). Together, these developments contributed to the renewable energy transition (Table 1.2, Table 1.3).

Table 1.2 Total RE Consumption of Germany, 1999-2017

Year	Mtoe	Annual Variation
1999	2.1	17.5%
2001	3.6	10.5%
2003	6.3	26.7%
2005	9.7	17.3%
2007	15.2	30.1%
2009	17.2	4.3%
2011	24.1	26.3%
2013	29.3	6.6%
2015	38.4	18.8%
2017	44.8	17.1%

Source: BP, 2018

Table 1.3 Share of Primary Energy Consumption in Germany by Carrier

%	1990	2000	2005	2010	2015
Hard coal	15.5	14.0	12.4	12.1	13.0
Lignite	21.5	10.8	11.0	10.6	11.8
Petroleum	35.1	38.2	35.5	32.9	33.9
Gases	15.5	20.8	22.4	22.4	21.0
Nuclear Energy	11.2	12.9	12.2	10.8	7.6
Renewable Energy	1.3	2.9	5.3	9.9	12.4
Other Energy Carriers	0.0	0.4	1.4	1.7	1.7
Net import of electricity	0.0	0.1	-0.2	-0.4	-1.3
Total	**100**	**100**	**100**	**100**	**100**

Source: AGEB, 2018b

Energy regulations also affected the carbon dioxide (CO_2) emissions negatively. The total amount of CO_2 emission was greater than 1000 million tons (mt) between the years of 1965-1988. In 1989, the emissions went down below the 1000 mt (998,8 mt) for the first time. This downtrend has been continuing since 1990. Between the years of 1990 and 2017, total amount reduced from 1003,2 mt to 765,4 mt (BP, 2018). In order to contribute to the international climate protection, the reduction target for 2050 was set to 50% (Hake et al., 2015).

Energiewende regulations had had a notable effect on energy supply and consumption (Renn and Marshall, 2016; Strunz et al., 2016; Hansen et al., 2019). RES increased its share of production by 9% from 2011 to 2017 (BP, 2018). Germany has seen one of the highest increases in RES generation worldwide. In 2017, it installed 7,295 GW in total new capacity and most of the increase took place in solar (8.5%) and wind (6.6%), while hydropower and bioenergy capacities remained stable (IRENA, 2019a). According to the REN21 (2018), Germany ranked first in per-capita PV capacity in 2017. With the help of supporting mechanisms, PV and wind played an important role in the electricity market between 2000-2015 (Table 1.4), where the share of renewables grew while coal and nuclear declined.

Table 1.4 Primary Energy Consumption in Germany in 2016-2017

Energy Carrier	2016	2017	Change from 2017 to 2016		Share %	
	Mtoe		Mtoe	%	2016	2017
Mineral Oil	155.3	159.5	4.2	2.7	33.9	34.5
Natural Gas	103.8	110.2	6.4	6.2	22.7	23.8
Hard Coal	56.7	50.3	-6.4	-11.3	12.4	10.9
Lignite	51.8	51.5	-0.3	-6.0	11.3	11.1
Nuclear Energy	31.5	28.4	-3.1	-9.8	6.9	6.1
Renewable Energy	57.2	60.7	3.5	6.1	12.5	13.1
Electricity Exchange Balance	-6.6	-6.7	-0.2	-	-1.4	-1.5
Other	8.4	8.4	-0.1	-0.8	1.8	1.8
Total	458.1	462.3	4.1	0.9	100	100

Source: AGEB, 2018a

The increase of solar and wind did come at a cost. There was a price reduction in solar energy generation after the Renewable Energy Sources Act in 2001 (Buchholz et al., 2019). In 2011, more than 80% of electricity from RES (RES-E) generation received additional payments as specified within the Renewable Energy Sources Act, with total payments to RES operators amounting to more than €16 billion (Kreuz and Müsgenz, 2018). The FIT mechanism was amended several times in order to accommodate these price realities. Germany pursued policies that decreased financial support after the determined level; payment were always higher at first, but gradually declined over time.

Energy Research programs played a critical role. The 1st Energy Research Programme was initiated by the government to fund non-nuclear research projects with a budget of 12 billion DMs in 1977 (BMWi, 2018). Thanks to this program, different actors from business, academia, and society got involved in the energy transition. In 2010, the BMWi and BMBF started an R&D program in order to stimulate the solar industry with a budget of €100 million. Funding of RE has helped create a more efficient, sustainable and cleaner energy system. Also it helped universities, institutes and firms gain experience with RES at an early stage (Hager, 2015). R&D activities opened the new door for greater technological advancement in solar and wind. Programs funded a wide range of sectors, as shown in Table 1.5. General energy researches, energy saving, energy storage and photovoltaics have a greater share than others.

Table 1.5 Expenditures of German States on Non-Nuclear Research by Sector

Sector (€ million)	2010	2011	2012	2013	2014	2015
Biomass	15.90	18.73	18.71	22.44	20.56	21.53
Fuel cells and Hydrogen	15.14	8.11	5.40	12.29	9.82	11.46
Carbon Storage	0.24	0.07	0.21		0.02	2.77
Energy saving	23.74	31.66	51.35	45.58	34.73	46.10
General energy research	12.97	14.96	21.01	72.81	61.73	73.03
Energy systems, modeling	7.87	2.46	5.37	4.53	4.33	3.13
Renewables, general	18.09	28.28	35.83	13.50	15.34	15.96
Geothermal	8.86	11.27	12.52	8.43	8.09	2.09
Power plant technology/ CCS	4.84	6.09	11.35	7.12	4.25	5.52
Photovoltaics	19.62	20.84	26.95	21.85	21.31	24.81
Wind power	8.26	11.61	14.48	18.60	27.29	12.25
E-mobility / power storage / grids	21.58	20.31	49.61			
E-mobility				54.19	22.54	15.88
Energy Storage				25.84	24.16	28.12
Grids				4.58	2.40	4.33
Total	**157.11**	**174.39**	**252.79**	**311.76**	**256.57**	**266.98**

Source: BMWi, 2017

In September 2018, the Federal cabinet adopted the 7th Energy Research Programme (BMWi, 2018). The program had a €7 billion budget for projects advancing innovative ideas, technological readiness, and energy efficiency. The energy research programs provided opportunities to test innovative ideas, in which start-ups would play a critical role. Coordination with the EU and other international organizations also became possible, as their scope was extended to the international level.

Energy efficiency and RES were the main targets of these programs, but also included research on fusion and nuclear safety (Figure 1.3). The funding helped build more affordable, efficient, and environmentally friendly solutions for the RE transition.

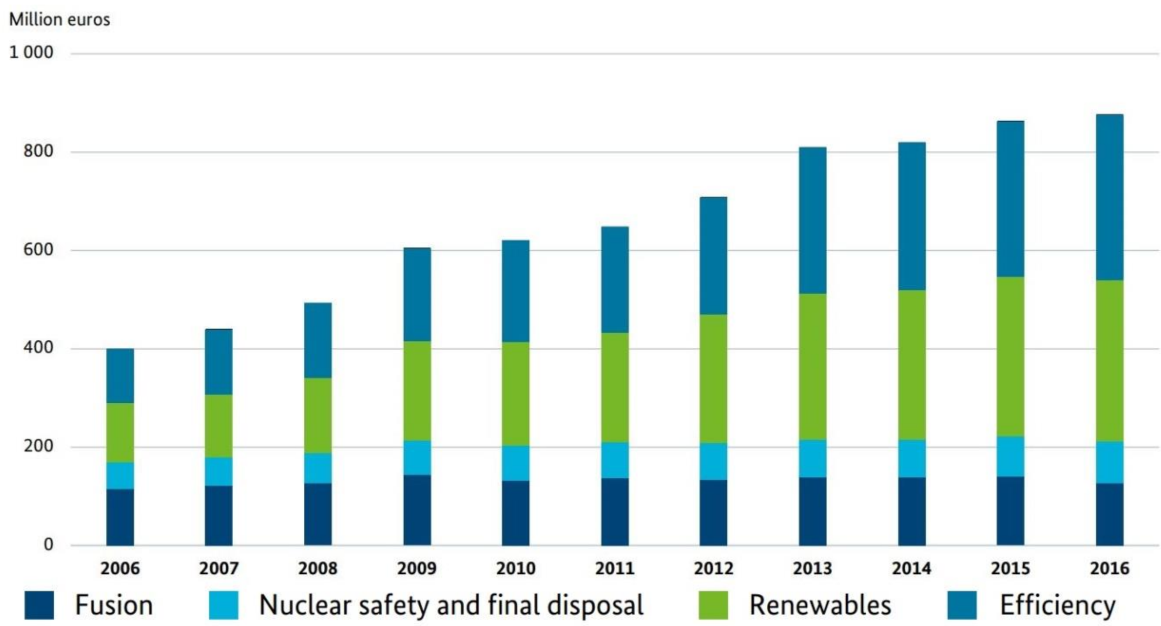


Figure 1.3 Federal Energy Research Programme Funding by Topic in Germany

Source: BMWi, 2017

Domestic production and intellectual property rights are also important in Germany. There are more than 1000 company that are actively manufacturing RE component, equipment and final products especially in solar and wind sector (Jacobsson and Lauber, 2006; Rogge and Scheleich, 2018). There is a remarkable increase in the number of patents in the RE technology. According to IRENA (2018), number of total RE patents increased from 1,493 to 30,696 since 2000. With the help of technological improvements and supporting instruments, the cost of solar power fell from €50 cents/kWh to €6 cents/kWh (BMWi, 2018). In order to maintain development in the transition period, government has continued to fund institutions and projects (Table 1.6).

Table 1.6 Federal Government's 7th Energy Research Programme in Germany

€, thousands	Target	Government draft	Plan Data		
	2018	**2019**	**2020**	**2021**	**2022**
BMWi	639,700	725,205	725.778	723,800	723,745
Project funding	595,596	682,980	682,980	682,980	682,980
Institutional Funding	44,104	42,225	42,798	40,820	40,765
BMEL					
Project Funding	46,803	46,803	46,803	46,803	46,803
BMBF	506,613	515,601	528,018	521,819	521,809
Project Funding	133,427	133,261	133,355	133,355	133,355
Institutional Funding	373,186	382,340	394,663	388,464	388,454
Total	**1,193,116**	**1,287,609**	**1,300,599**	**1,292,422**	**1,292,357**

Source: BMWi, 2018

As part of the renewable energy transition process, Germany also promoted electric vehicles, while taking actions to curtail the use of conventional cars. In 2009, the BMU introduced the National Electro-Mobility Development Plan, whose target was to decrease vehicle-related emissions and invest in R&D facilities (BMU, 2009). Later, in 2015, the BMWi and BMU initiated the Electric Mobility Act, which gave privileges to electric vehicles, such as purchase grants or free parking (BMWi, 2018). The government is planning to expand its charging infrastructure by providing €300 million (BMWi, 2018). It has also started to exclude diesel cars from roads. As a beginning, old diesel vehicles were banned from roads in Bonn and Cologne in order to have better air quality (DW, 2018). As of 2017, Germany had 110,000 electric vehicles with a market share of 1.6% (IEA, 2018). The goal is to reach 1 million electric vehicles by 2022 (Reuters, 2018).

Germany started its renewable energy transition several decades ago. When we look at Germany today, it can be stated that all its investments and political decisions served the purpose very well (Figure 1.4). The transition continues for Germany. Its target is to reach to high levels in RE production and consumption.

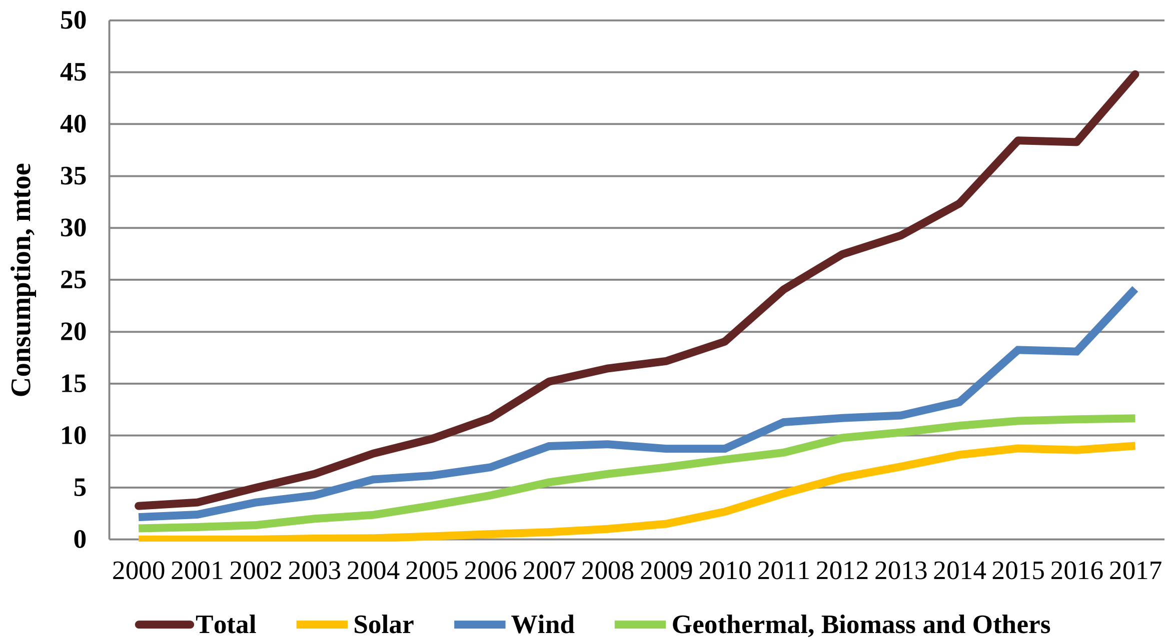


Figure 1.4 Development of Renewable Energy in Germany, 2000-2017

Source: BP, 2018

The major factors that underlie the success of the renewable energy transition in Germany can be summarized as follows:

- Early starter of transition;
- Economic and political support from the government;
- Strong feed-in tariff (FIT) mechanism;
- Public awareness.

The early phases of renewable energy transition have been completed, having passed through many stages already (Table 1.7). RE consumption increased in the transitional phase (Table 1.8).

Table 1.7 Milestones of Renewable Energy Transition in Germany

1980	*Energiewende* concept introduced
1990	Government-initiated 1000-Roofs PV Program
1991	Electricity Feed Act introduced
1997	The Kyoto Protocol adopted
1998	Electricity and gas markets liberalized
1999	Government-initiated 100,000-Roofs PV Program
2000	Renewable Energy Sources Act (EEG)
2004	Renewable energy sector employed 160,000 people
2011	Government phase out of nuclear by 2022 after Fukushima
2015	Paris Agreement signed

Table 1.8 Renewable Energy Consumption in Germany by Sector, 2003-2017

	Solar	**Wind**	**Geothermal, Biomass and Others**	**Total**
2003	0.1	4.2	2.0	6.3
2004	0.1	5.8	2.4	8.3
2005	0.3	6.2	3.2	9.7
2006	0.5	6.9	4.2	11.7
2007	0.7	9.0	5.5	15.2
2008	1.0	9.2	6.3	16.5
2009	1.5	8.7	6.9	17.2
2010	2.7	8.7	7.7	19.1
2011	4.4	11.3	8.4	24.1
2012	6.0	11.7	9.8	27.4
2013	7.0	11.9	10.3	29.3
2014	8.2	13.2	11.0	32.3
2015	8.8	18.2	11.4	38.4
2016	8.6	18.1	11.6	38.3
2017	9.0	24.1	11.7	44.8

Source: BP, 2018

The speed of the transitional is increasing in virtue of its experience and multi-directional development. There is a consensus that FIT mechanisms have made important contributions in stimulating and popularizing RE (Couture, 2010; El-Ashry, 2012; REN21, 2018). Germany has adequate economic power to promote FIT mechanisms and to subsidize R&D

and other facilities. Germany is a powerful economic country. It has the fourth largest economy in the world, and its economic indicators are strong. In 2018, Germany's budget surplus was about €58 billion (DW, 2019). In this transition period, they set realistic targets and followed them unambiguously. Also the role of Green Party is undeniable. It started a movement, acted as a legislator, and tried to change policies after entering the parliament (Hake et al, 2015; Hager, 2015). Most RE experts agree that climate change and nuclear disasters also had a big influence on the transitional process (Renn and Marshall, 2016; Hake et al, 2015, Jacobsson and Lauber, 2006; Hache, 2018). The decisive attitude of Germany towards renewable energy transitions, in short, should be model for other countries.

1.1.2. China

China is the world's largest energy consumer. In 2017, its primary energy consumption was 3,132.2 Mtoe with an increase of 3.1%. This constituted nearly 25% of the world's total consumption (BP, 2018). China's energy demand and economic growth are interconnected. It has the world's second largest economy with a growth rate that has averaged 6% over the last 30 years (IMF, 2017). It is following a rigorous strategy towards securing energy supplies and is consuming every type of energy source in order to maintain its economic growth. However, the Chinese energy market has been dominated by fossil fuels, mainly coal and oil, for a long time. China wanted to create a more diverse energy structure than its current coal-dominated one (Lin et al., 2013). Also, air pollution has been a serious problem that has shortened the life expectancy of people in northern China by about 5.5 years (Chen et al., 2013). Air quality is thus a major driver of China's transition, as the overconsumption of fossil fuels has caused a large amount of CO_2 emissions. China's fossil fuel-related CO_2 emissions reached 9,232.6 million tons, accounting for 26.6% of global emissions (BP, 2018). In order to reduce its CO_2 emissions, China made commitments at the UN Climate Conference in 2015. The 2030 target is to increase the share of renewables to 20% and decrease emissions by 60% (IEA, 2016).

Meanwhile, the share of electricity in China's energy consumption is expected to grow. The IEA (2016) estimates that 40% of final energy consumption will be met by electricity, 60%

of which will be generated by RES in 2040. Since electricity generation from renewables will grow in importance, China is positioning itself for the future and has made huge investments in its electricity infrastructure.

China’s investments in renewables have made it one of the most successful transitional countries in terms of acceleration and capacity. According to the REN21 (2018) China ranks first in installed capacity and annual investment in most RES, including solar PV, wind, bioenergy, and hydropower (Table 1.9).

Table 1.9 Top 5 Countries in Annual Investment and Net Capacity Additions in 2017

Rank	**1**	**2**	**3**	**4**	**5**
Investment in renewable power and fuels (hydro over 50 MW not included)	**China**	US	Japan	India	Germany
Geothermal power capacity	**Indonesia**	Turkey	Chile	Iceland	Honduras
Hydropower capacity	**China**	Brazil	India	Angola	Turkey
Solar PV capacity	**China**	US	India	Japan	Turkey
Wind power capacity	**China**	US	Germany	UK	India
Solar water heating Capacity	**China**	Turkey	India	Brazil	US

Source: REN21, 2018

Renewable energy was considered a supplementary source, something to use when there was a shortage of conventional fuels in rural areas (Liu, 2019). The transition from fossil fuels to renewables became more popular, however, in recent decades. The main reasons were an increase in demand and the attractiveness of RE market, climate change and carbon emissions, and economic developments (Lahiani et al., 2017).

One of the main reasons for China’s renewable investments is climate change. The excessive consumption of low-efficiency fossil fuels, especially coals has created an ecological problem. In 2017, China becomes the world’s largest carbon emitter. Its use of coal is responsible for 13% of global annual emissions (He et al., 2017). The most important target of previous Chinese five-year plans was increasing coal, petroleum and electric power usage (Lanfang and Wei, 2012). After China became a member of the UNFCCC and Kyoto Protocol, it took major steps towards creating a lower carbon energy system. It committed to decrease emissions by 60% and increase the share of renewables to

20% by 2030 (IEA, 2016). It also attached these targets to its five-year plans in order to demonstrate its determination (Lanfang and Wei, 2012).

China is making investments in both fossil fuels and renewables. Its total energy supply investments share increased to 20% as a consequence of spending on electricity infrastructure and coal power in 2015 (IRENA, 2017). Generally, these investments focused on capacity expansion, energy infrastructure, and system integration (He et al., 2017). With governmental support, China became the world leader in terms of installed capacity and generation (Table 1.10).

Table 1.10 Top 5 Countries in Total Capacity or Generation as of December 2017

	1	**2**	**3**
Renewable power capacity (including hydropower)	**China**	United States	Brazil
Renewable power capacity (not including hydropower)	**China**	United States	Germany
Bio-power generation	**China**	United States	Brazil
Hydropower capacity/ generation	**China**	United States	Canada
Solar PV capacity	**China**	United States	Japan
Wind power capacity	**China**	United States	Germany

Source: REN21, 2018

Conventional energy development was the primary goal of Chinese energy policy from 1949 to 1992 (Lanfang and Wei, 2012). China started to implement renewable energy into its energy system in the 2000s. It enacted the Renewable Energy Law (REL) in 2006 and revised it in 2009 (IEA, 2017b). Before REL, feed-in tariffs prices were determined by negotiation and were thus different every time. However, this arrangement caused some price speculations, which were harmful in the long run (Jiang, 2017). Renewable energy generators were signing FIT agreements with the state grid. Details for wind power FITs were determined by the REL and prices by the government, which differed from province to province (Jiang, 2017). The premium for wind was CNY0.51-0.61/kWh ($0.075-0.090/ kWh) in 2009 and planned to fall by 4.9%-13.7% by 2018 (Yang et al., 2016). In 2016, the government revised the wind tariffs and divided them into four classes; CNY 0.4/kWh, CNY0.45/kWh, CNY0.49/kWh and CNY0.57/kWh. For solar power it was CNY0.65/kWh, CNY0.75/kWh, and CNY0.85/kWh plus fixed CNY0.42/kWh (Jiang, 2017). Figure 1.5 shows the latest tariffs for different regions (Yang et al, 2016). In addition to price premiums, the government paid the initial investment in small scale-off grid solar PV systems (IEA, 2017a). After the promulgation of the REL with the FIT, installations of RES including wind and solar peaked (Zhang, 2006). Renewable electricity became more competitive with the governmental-support mechanisms (Yang et al., 2016). Electricity generated from wind rose from 1.3 TWh in 2004 to 13.1 TWh in 2008, nearly ten-fold growth in four years (BP, 2018).

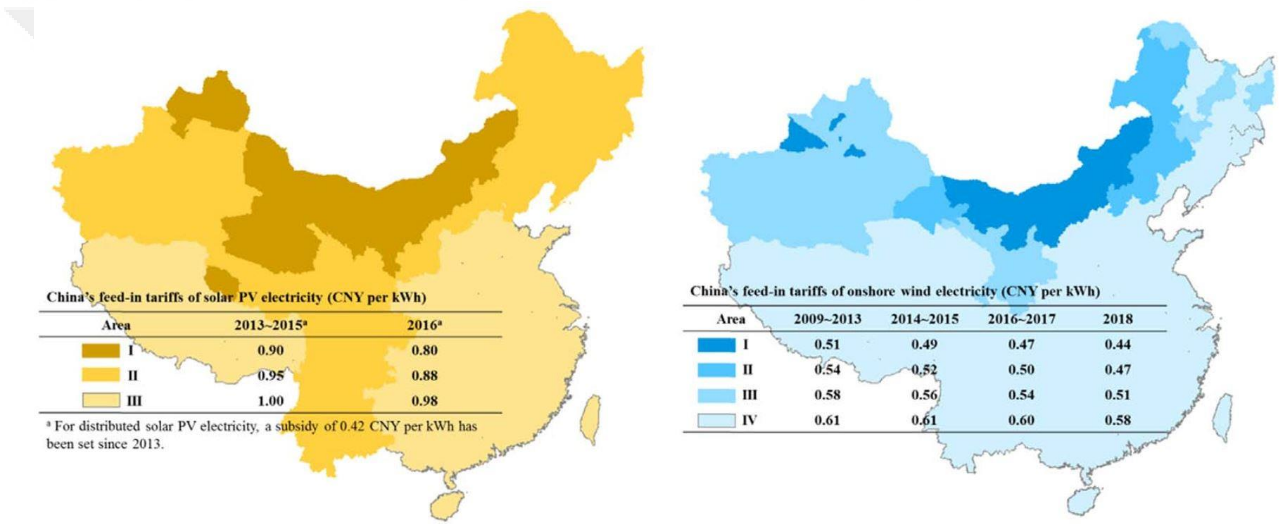


Figure 1.5 Feed-in Tariffs for Solar and Wind in China
Source: Yang et al., 2016

In 2014, the state council announced the Strategic Action Plan for Energy Development (2014-2020). Future coal consumption was limited to 4.2 billion tons in order to reduce the share of coal in primary consumption (IEA, 2015). The plan also targeted to reach a total capacity 100 GW in solar PV, 200 GW in wind, and 350 GW in hydropower by 2020 (Lin et al, 2015). According to the IRENA (2019), China, as of 2018, had 175,032 MW of total solar PV installed capacity, 184,696 MW of wind, and 352,261 MW of hydropower.

Of these, the greatest potential lies in hydropower. It is estimated that China has 694 GW of theoretical hydropower potential, which is 16% of the world's total (Huang and Yan, 2009). China's renewable investments mainly focused on hydropower because of its enormous potential (Huang, 2009). China has ranked first in installed capacity for hydropower for many years, accounting for nearly 25% of the global total (IRENA, 2019a).

Renewable energy policies were initiated for the purpose of developing rural energy structures (Lanfang and Wei, 2012). The renewable energy policies between 1990 and 2005 were generally designed to combat air pollution (Liu, 2019). As such, the government announced the Air Pollution Action Plan in 2013, which sought to reduce air pollution by constraining future coal consumption (Lin et al, 2013).

In 2007, the National Development and Reform Commission (NDRC) of China announced its medium and long-term development plan for renewable energy. The target was to increase the share of renewables in total energy consumption to 15% by 2020 with the help of substantial investment and invest on R&D in order to manufacture domestically (IEA, 2017; Jiang, 2017). Table 1.11 shows the renewable energy targets of China.

Table 1.11 Renewable Energy Targets of China

	2005	2010	2020
RE share in energy consumption	7.20%	10%	16%
Annual RE consumption	112 Mtoe	189 Mtoe	371 Mtoe
RE share in power generation (hydro excluded)	-	1%	3%
Hydropower installed capacity	117 GW	180 GW	300 GW
Wind power installed capacity	1.26 GW	5 GW	30 GW
Biomass power installed capacity	2 GW	5.5 GW	30 GW
Solar PV installed capacity	70 MW	300 MW	1.8 GW

Source: IEA, 2017b; Jiang, 2017

Financial investments played an important role in China’s renewable energy integration. According to the REN21 (2018), China alone accounted for 45% of renewable investments globally followed by Europe (15%) and the US (14%) in 2017. Solar and wind markets benefitted from these investments.

China is also the leader in renewable energy technology. According to Forbes (2019), over 150,000 renewable energy patents, 29% of the global total, belonged to China as of 2016. There is a tremendous increase in the number of patents in since 2000s. According to IRENA (2018), number of total RE patents increased from 883 to 168,028 within 16 years.

Chinese government has promoted the domestic production and gave special attention to create competitive manufacturing. Supportive mechanisms such as tax incentives and loans with low interest rate were included into five year plans. In 2008, the government has started to grants special funds for RE manufacturers for domestic production (Kennedy, 2013). With the help of these supportive policies China became the global manufacturer leader since 2011, especially in solar panels and wind power equipment, with competitive prices (Jiang, 2017).

These patents contributed significantly to the fall in renewable energy costs. IRENA (2017) indicates that PV module prices have fallen by 80% and wind turbines by 30%-40% since 2009. Also, the cost of electricity from solar PV decreased more than 60% from 2010 to 2016. The average of levelized cost of energy in solar PV has dropped to $0.08/kwh, nearly the same prices levels as fossil fuel-generated electricity (Yang et al, 2016). Electricity generation from coal fell by 28.4 TWh, while generation from solar PV increased by 15.1 TWh, wind by 29.7 TWh and hydro 141.5 TWh in 2014 (Line et al., 2015; BP, 2018). Chinese investments focused on small-scale asset financing (Jiang, 2017).

China dominates the global electric vehicle (EV) market. Howell et al. (2014) identified four main goals of China's EV policy: reduce CO_2 emission, secure its energy market, become a sector leader, and decrease air pollution. Electric cars offered a solution to rising air pollution, particularly in cities, and the government started to invest in EVs in the 2010s. In order to accelerate the switch from conventional cars to EVs, China strongly promoted them through strong policies. Many cities adopted the one-car ownership policy. According to this policy people have 3 choices; 1) people wait 24 months to get a conventional car, 2) they pay extra premium to get one, 3) They immediately buy an electric car with a small amount of subsidy from government (Yang et al, 2017). After these legislations, the electric cars stock boosted from 480 to 1.227.770 with a share of 40% globally (IEA, 2018). Also, within a decade China become the biggest manufacturing power and largest EV market with the help of policy boost (Du et al,. 2019; IEA, 2018).

Despite all these developments in renewable energy, fossil fuels still dominate in China (BP, 2018). Table 1.12 shows recent shifts in China's primary energy sources; coal and oil remain the main sources of energy. However, coal consumption has decreased since 2013, after decades of rising.

Table 1.12 Primary Energy Sources of China by Fuel Type (Mtoe)

	Oil	Natural Gas	Coal	Nuclear energy	Hydro electric	Renewables	Total
2016	587.2	180.1	1,889.1	48.3	261	81.7	3,047.2
Share	19.3%	5.9%	62.0%	1.6%	8.6%	2.7%	100%
2017	608.4	206.7	1,892.6	56.2	261.5	106.7	3,132.2
Share	19.4%	6.6%	60.4%	1.8%	8.3%	3.4%	100%

Source: BP, 2018

Supportive policies and financial investments nurtured the development of RE projects (Liu, 2019). The coal share still fluctuates; though renewables started to take share from the coal but coal will remain a dominant energy source until 2030 (Zhang et al., 2017). Nevertheless, China is continuing to invest in RES, and the growth of its renewable energy sector could contribute to the world (Birol and Oreljarnik, 2012; IEA, 2016; He et al., 2017)

2. THE RENEWABLE ENERGY TRANSITION IN TURKEY

This section will provide detailed information about the renewable energy transition in Turkey and will examine in detail Turkey's renewable resource potentials, installed capacities and electricity market structure.

2.1 Overview of Turkey's Energy Status

Turkey has the 18th largest economy in the world. It is a developing country with a population of about 80 million. The economy has been growing at an average rate of 6.8% since 2008 (TÜİK, 2018). In order to maintain economic growth, energy consumption is imperative. Turkey relies on fossil fuels for 87% of its energy. At the same time, its net import dependency for fossil fuels is 77% (EIGM, 2018). On the other hand, renewable sources are abundant in Turkey; due to its geographical characteristics, there is adequate potential for solar, wind, hydro and geothermal energy (Ediger and Kentel, 1999; Balat, 2005; Özgür, 2008; Kırtay, 2010; Melikoğlu, 2017; Kılıçkaplan et al, 2017). Biomass potential is also ample to generate economical electricity (Toklu, 2017). Evrendilek and Ertekin (2003) estimated that Turkey has a total 495.4 TWh/year of potential energy with the 196.7 TWh/year of biomass, 124 TWh/year of hydropower, 102.3 TWh/year of solar, 50 TWh/year of wind, and 22.4 TWh/year of geothermal.

The government is incentivizing RE generation through FITs and tax exemptions. The FIT mechanism is vital, and the government is giving a 10-year purchase guarantee to the certificated RE producers. Table 2.1 shows the base price by energy types, while Table 2.2 shows the additional incentives that are added to the base price.

Table 2.1 Feed-in Tariff in Turkey

Energy type	USD cent/ kWh
Solar Energy	13.3
Biomass	13.3
Geothermal	10.5
Wind	7.3
Hydroelectric	7.3

Source: Official Gazette, 2011

Table 2.2 Technology-Based FIT and Domestic Content Extra by Source in Turkey

	Domestic Production	Domestic content extra $ cent/kWh
Hydroenergy	Turbine	1.3
	Generator and Power Electronic	1
Wind Energy	Wing	0.8
	Generator and Power Electronic	0.1
	Turbine Tower	0.6
	Rotor Mechanic Parts	1.3
Solar PV	Pv Panel Integration	0.8
	Pv Modules	1.3
	PV Cells	3.5
	Inverter	0.6
	PV focusing materials	0.5
Biomass	Fluid-bed steam generator	0.8
	Liquid or gas steam generator	0.4
	Gasification and Gas Cleaning Group	0.6
	Steam and Gas Turbine	2
	Internal Combustion Engine or Stirling Motor	0.9
	Generator and Power Electronic	0.5
	Cogeneration system	0.4
Geothermal	Steam and Gas Turbine	1.3
	Generator and Power Electronic	0.7
	Steam injector or vacuum compressor	0.7

Source: Official Gazette, 2011

2.2 Electricity Market Structure

The first electricity in Turkey was generated from a 2-KW water mill hydro plant in Mersin in the late Ottoman era. Electricity became very popular and spread quickly all over the country (Yılmaz, 2012). Supplying, transmitting, and distributing electricity was the responsibility of local municipalities from the foundation of the Turkish Republic until 1970, when the government founded the Turkish Electricity Institution (TEK), which thereafter assumed municipalities' responsibilities. This system continued until 1984, when the government created more horizontal integration. The electricity market was essentially a monopoly because Turkey was not economically stable enough to attract substantial private investment. The government also wanted to control the market because of energy-supply security concerns. Thereafter, the government slowly started to privatize the market, following global trends. In 1993, the TEK was divided into the Turkish Generation and Transmission Corporation (TEAŞ) and the Turkish Electricity Distribution Company (TEDAŞ). Figure 2.1 shows the further division of government entities over time.

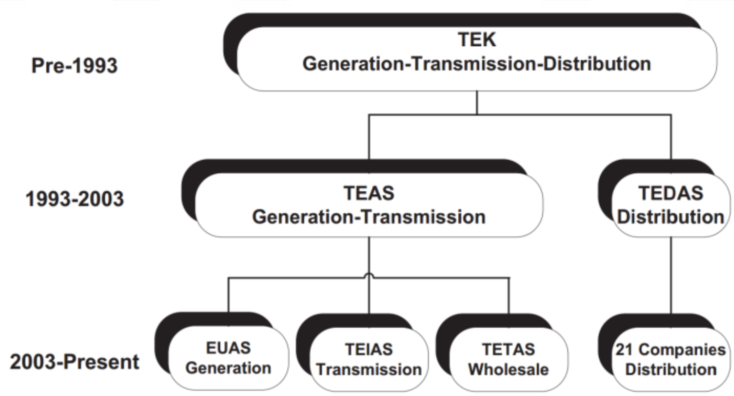


Figure 2.1: Divisions of Turkish Government Entities Regulating the Electricity Market

Source: Taşdöven et al., 2012

In 2003, the TEAŞ was divided into the Electricity Generation Company (EÜAŞ), the Turkish Electricity Trade and Contracting Corporation (TETAŞ), and the Turkish Electricity Transmission Company (TEİAŞ). Today, the EÜAŞ has authority over the Turkey's electricity generation, the TEİAŞ oversees the electricity transmission across the country and the TETAŞ deals with the wholesale electricity trade. The TEDAŞ was also divided again into 21 different distribution companies. Companies such as the Boğaziçi Electricity Distribution Company (BEDAŞ) or the Başkent EDAŞ (Electricity Distribution Inc.) are responsible for the local distribution of electricity in different regions.

To foster the trading of electricity, the government founded the Energy Exchange Istanbul (EXIST). Also, in 2001, the Energy Market Regulatory Authority (EMRA/EPDK) was founded to regulate the energy market, which signaled a more liberal market that anybody could enter. The Ministry of Energy and Natural Resources oversees the whole structure.

Energy trading is a key factor for the Turkish economy. Energy generation companies and users of electricity should meet on a transparent, reliable platform in order to conduct their daily business, which prompted the founding of EXIST. EXIST also builds contacts with foreign markets for derivatives and other financial systems (EXIST, 2019). Trading can be made through various instruments. Generally, consumers and electricity generators sign bilateral, longer-term contracts. The EMRA gave a 49-year license to EXIST. Price fluctuations and other unfavorable status have diminished since EXIST's founding, and international energy trade became possible. There are many foreign investors in EXIST, which gives the Turkish economy additional benefits through the export of energy from the exchange market. EXIST operates markets for natural gas, oil and renewable resources and includes many participants, including investors, generators, and customers. EMRA approves the market regulations, rules, and tariffs governing EXIST. The Petroleum Pipeline Company (BOTAŞ) has the 30% type-A share of EXIST. After BOTAŞ, the Istanbul Stock Exchange (BIST) has 30% type-B shares. The remaining 40% are type-C shares that are open to public trading; any company can obtain them unless they have a license, given by the EMRA, for supply, generation, wholesale or import/export license.

EXIST's main duties include:

- Act as an operator for electricity transactions in day-ahead market and intraday market.
- Arranging and conducting the financial transactions of the market
- Cooperating with the Turkish Electricity Transmission Company for stabilizing the market efficiency
- Organizing the new potential energy market both wholesale or retail
- Be an affiliated member of international energy market

- Act as a representative when it is needed in the international field

Capital Markets Board of Turkey (SPK) and Energy Market Regulatory Authority have the power that control over the financial activities that happened in the energy market. They act as a supervisor to the EXIST. Also some derivatives are controlled by the EXIST. Futures and options market can serve the investor for financial purposes.

2.3 Solar Energy

Considering the renewable energy sources, solar power is the most abundant one. Solar energy can be defined as the solar radiation that comes from the sun (WOC, 2009). That energy can be used for many purposes such as lightning, heating or electricity generation. Turkey has adequate solar potential (Figure 2.2, Table 2.3, Table 2.4). In southern Turkey, it is very common that using solar power for heating and electricity generation individually. According to the REN21 (2018), Turkey ranked second in solar water heating capacity.

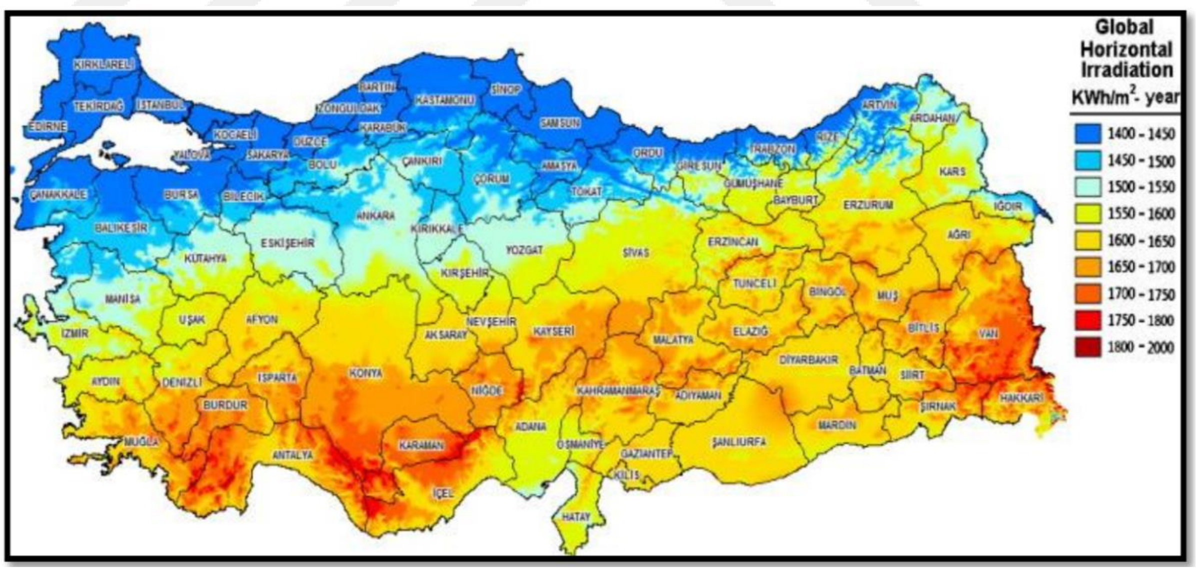


Figure 2.2: Solar Radiation Rate in Turkey
Source: YEGM, 2017

Turkey has 7.2 hours per day and 2,640 hours per year of average sunshine duration, which is higher than most European countries. However, the usage of solar is quite low. The solar energy has a share of 0.7% in total energy supply and 5.8% in total installed capacity

(MENR, 2018; TEİAŞ, 2019). A big proportion of Turkey's energy consumption can be supplied if Turkey gives necessary importance to the implementation of solar energy systems (Evrendilek and Ertekin, 2003; Kırtay, 2010; Kılıçkaplan et al, 2017). Among other types of solar energy, importance of photovoltaics (PVs) started to increase. Photovoltaics can generate electricity with a range of 15% to 27% efficiency level and the efficiency of PVs is expected to fold in the near future (MIT, 2015; IEA, 2016).

Table 2.3 Distribution of Solar Energy Potential by Months in Turkey

	Total Solar Energy		**Sunshine Duration**
	(Kcal/cm²-month)	**(KWh/m²-month)**	**(Hour/Month)**
Jan	4.45	51.75	103
Feb	5.44	63.27	115
Mar	8.31	96.65	165
Apr	10.51	122.23	197
May	13.23	153.86	273
Jun	14.51	168.75	325
July	15.08	175.38	365
Aug	13.62	158.4	343
Sept	10.6	123.28	280
Oct	7.73	89.9	214
Nov	5.23	60.82	157
Dec	4.03	46.87	103
Total	**112.74**	**1311.16**	**2640**
Average	**30 Kcal cm²-day**	**3.6 KWh/m²-day**	**7.2 hour/day**

Source: YEGM, 2017

All RES generation units with an installed capacity and cogeneration units below 1 MW do not require licensing (EMRA, 2013). The Turkish government allows these units to be connected to the distribution grid and sell excess generation. Since the costs were decreasing and regulations became in favor of producers, investors started to establish small-scale solar plants.

Table 2.4 Solar Energy Potential Distribution by Regions in Turkey

Region	Total Average Solar Energy	Max Solar Energy	Min. Solar Energy	Avg. Sunshine Duration	Max. Sunshine Duration (June)	Min. Sunshine Duration (Dec)
	(KWh/m²)	(KWh/m²)	(KWh/m²)	hour/year	hour	hour
South Eastern Anatolia	1460	1980	729	2993	407	126
Mediterranean	1390	1868	476	2956	360	101
Eastern Anatolia	1365	1863	431	2664	371	96
Central Anatolia	1314	1855	412	2628	381	98
Aegean	1304	1723	420	2738	373	165
Marmara	1168	1529	345	2409	351	87
Black Sea	1120	1315	409	1971	273	82

Source: YEGM, 2018

The Turkish solar market was open to foreign manufacturers for a long time. In 2017, the Turkish government has decided to encourage domestic producers by imposing a new tax. Main reasons were to award contracts and reward the development of production capacities in their own country for tax revenue. Therefore, the Turkish Ministry of Economic Affairs has strictly limited the import of PV modules from abroad since June 2016. However, an additional anti-dumping regulation was proposed for module imports from China. A corresponding law has been accepted 1 April 2017. This law increases the cost of modules imported from China by $20-25 (Official Gazette, 2017). In addition, from 1st January 2018 the system usage fees for unlicensed solar power plants (SPPs) tripled. It is expected a 20% decrease for plants' revenues. As a result, the government supported licensed solar power generation, mainly Renewable Energy Resource Areas (YEKA), and domestic module manufacturers.

According to renewable energy sources legislation in Turkey, $0.13 incentive is given for per kilowatt electricity that was produced from the solar energy (Table 2.1). This incentive rate is valid in ideal conditions. Currently almost 700 different power plants with a 17,400 MW installed capacity are benefitting from YEKDEM (Renewable Energy Resources Supporting Mechanism) (EXIST, 2018). YEKDEM power plants sell electricity to the market via the day-ahead market or bilateral contracts. The price difference (guaranteed price - market price) is compensated by TETAŞ.

After 2017, the government started to support licensed solar power instead of unlicensed ones; licensed solar power is more convenient and includes fewer procedures for both the public and private sectors. Also, these tenders provide large-scale electricity generation. The consortium of the Kalyon Energy Group and Hanwha Cells won Turkey's 1-GW solar PV tender with the $6.99 cent/kwh in March 2017 (MENR, 2017). The plant will have a 15-year purchase guarantee without any currency risk. Also, Turkey plans to benefit from the highest entry of foreign capital in this $1.3 billion investment. The plant planned to begin operating within 36 months and to have a domestic 500-MW factory operational within 21 months. However, it did not meet this deadline due to financial problems. Hanwa decided to leave the consortium and transfer its shares to Kalyon.

Together with the Council of Ministers Decision, published in December 2015 in the Official Gazette, the "National Tariff" application was extended until 31 December 2020 as Turkey's eastern regions continue to observe high loss (technical and non-technical) ratio. Additionally, the imbalance between revenue requirements and forecasted distributed energy volumes in 21 regions will continue to require the tariff; otherwise, electricity tariffs will be lower in the western part of Turkey than in the eastern part (Taşdöven et al., 2012). This is undesirable, as eastern Turkey needs cheaper energy to boost its economic development. The EMRA determines the regulated tariffs, which cannot be exceeded by bilateral contracts as long as customers (resident, commercial, or industrial) are eligible and properly registered. As a result, people are paying the costs of losses. Using decentralized solar, however, will eliminate these costs.

The Turkish government also affected by decentralizing trends and designed a better energy system as a result. Instead of vertical integration, the government has tried to establish a more horizontally decentralized integration through planning and appropriate legislation. It has succeeded in distributing responsibility from large entity to several relatively small ones, which in turn has nurtured privatization, resulting in a more efficient market structure. There is a new trend called *prosumer*, a combination of producer and consumer, that allow generation and utilization at the same time in a small-scale. *Prosumers* can generate their own electricity, use it for their homes and can sell the excess amount to the grid. This system is very appropriate for the solar PV usage and have popularized in the recent years. Policies are being adapted in order to ease the processes. Germany, the UK and some parts of the United States are utilizing this system which offers credits for PV electricity injected into the grid (Tükenmez and Demireli, 2012). Therefore, self-consumption is becoming a major driver of solar PV installations, often completed with a feed-in tariff for the excess electricity generated. Table 2.5 shows that solar PV plants alone accounted for 93.57% of total excess generation sales. The Turkish government can support and make necessary legislation in order to encourage the implementation of this concept as soon as possible.

Table 2.5 The Amount of Excess Energy Sold to the Grid in Turkey

Resource Type	2016		2017	
	The amount of energy given to the system as surplus (MWh)	**Share (%)**	**The amount of energy given to the system as surplus (MWh)**	**Share (%)**
Solar PV	1.031.358,00	90,64	2.836.553,09	93,57
Biomass	92.129,90	8,1	138.657,08	4,57
Wind	8.268,44	0,73	36.801,92	1,21
Hydropower	6.115,42	0,54	19.434,29	0,64
Total	**1.137.871,76**	**100**	**3.031.446,38**	**100**

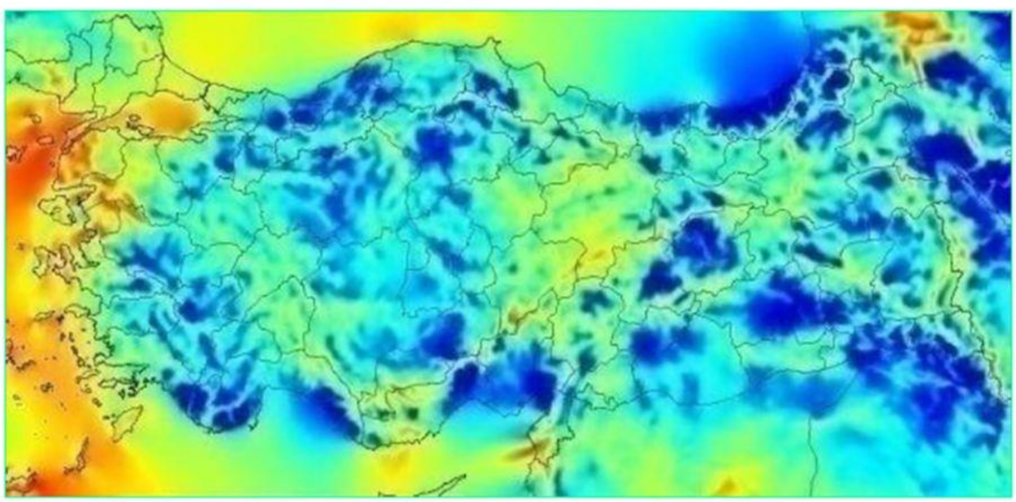
Source: EMRA, 2018

Turkey already provides specific FITs for each renewable energy sector, as well as additional incentives for domestically produced equipment. The base FIT and the domestic equipment component can be combined in order to increase the feasibility of renewable projects. Turkey has already declared its intent to increase the percentage of renewable energy in the primary energy supply from 10% to 30% by 2023 (SETA, 2017).

Turkey electricity market has been suffering from energy losses for many years. Technical and non-technical losses are lowering the efficiency level. Roughly 15% of energy was lost in the transmission process. There is a significant distance between electricity generation and electricity usage. For instance, biggest hydropower dams, such as Keban and Atatürk, are located in the eastern parts of Turkey. However, energy demand is very high in the west part of the country (EMRA, 218). Since the establishment of small scale solar PV systems relatively easier and cheaper than the other RES plants. There are thousands of buildings in big cities, yet most of its solar potential stand idle. There are so many potentials in rural areas that solar can be implemented at lower costs. If this potential could use efficiently, there will be a considerable amount of electricity generation. In order to reduce related energy losses and create more decentralized, efficient system turkey should promote the small-scale solar PV usage.

2.4. Wind Energy

Turkey’s first wind power plant was built in Çeşme AltınYunus in 1986. It was a 55-KW Westa brand turbine that generates roughly 100,000 kWh every year depending on the region’s conditions (Özdamar, 2000). The first wind farm was constructed in Germiyan, Çeşme in 1998. Turkey has an average potential of wind, according to REPA (The Atlas of Wind Energy Potential) (Figure 2.3). Western Turkey has more potential for wind, so wind powered plants (WPPs) are concentrated in those areas.



ON-SHORE (MW)	OFF-SHORE (MW)
37,836	10,013

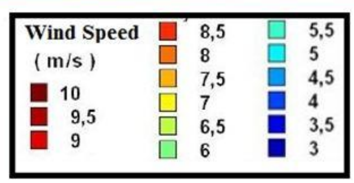


Figure 2.3: Wind Potential of Turkey
Source: Çalışkan, 2010; YEGM, 2016

According to the Turkish Wind Energy Statistics Report (2018), WPPs in operation by region are the following: Aegean 39.06%, Marmara 33.74%, Mediterranean 13.38%, Central Anatolia 8.56%, Black sea 3.91%, and Southeastern Anatolia 1.35%.

Onshore wind potential is significantly higher than the offshore. Different parts of the country have different levels of potential than others, but we can say that Turkey's average annual wind speed is between 7.0 meters per second (m/s) and 8.0 m/s (Çalışkan, 2010). The installed capacity of renewable energy is increasing significantly in Turkey in line with the strategic targets of the country, and there is still high potential to develop new projects.

Çalışkan (2010) estimated that Turkey has a total of 47,849 MW of wind energy potential (29,259 MW of good potential, 12,994 MW of excellent potential, 5,400 MW of outstanding potential, and 196 MW of superb potential). There is a good potential of wind energy, yet we have not reached substantial level of these potential. Currently there are 164 wind power plants in operation and 26 plants in construction phase (TÜREB, 2018).

Total installed capacity of Turkey is 6872.15 MW as of 2017 (Table 2.6). It can be stated that Turkey carried out a fruitful policy towards wind energy. The wind capacity increased from 146.3 MW to 6872,15 MW, 47-fold increase, within 10 years (TÜREB, 2018).

Table 2.6 Turkey's Total Installed Capacity of Wind

Year	Total Installed Capacity (MW)	Capacity Addition (MW)	Increase rate
2007	146.30	217.40	148.0%
2008	363.70	427.90	148.6%
2009	791.60	537.55	117.7%
2010	1329.15	476.70	67.9%
2011	1805.85	506.30	35.9%
2012	2312.15	646.30	28.0%
2013	2958.45	803.65	28.0%
2014	3762.10	956.20	27.2%
2015	4718.30	1387.75	25.4%
2016	6106.05	766.05	29.4%
2017	6872.10	558.78	12.5%

Source: TÜREB, 2018; IRENA, 2019a

Construction of wind power plants has been increasing since 2000s. However, due to some bureaucratic walls and licensing problems the movement has been slowed down since 2015. Figure 2.4 shows the power plant construction over the years. From January 2012 to July 2015 there is an increase in wind power plants contraction (green arrows). However, after 2015 the construction acceleration has slowed down due to governmental decisions (red arrows). The licensing procedures become a problem for the producers. These kinds of problems prevent new investors to become a part of renewable energy transition. State should ease the bureaucratic procedures for potential producers.

Figure 2.4 Turkey's Wind Power Plants Under Construction
Source: TÜREB, 2018

The government has changed the licensing policy for new constructions. Instead of giving a separate license, they started choosing to give license on a big scale (YEKA). The Ministry of Energy and Natural Resources announced its first tender for wind energy in 2017. The consortium of Siemens, Türkerler and Kalyon won the 1,000-MW tender with a price of \$3.48 cents/kWh (DW, 2017). The consortium also accepted to execute R&D actions on different areas of wind energy, including turbine production, plant software, and technical analysis for a 10-year period. The total investments in wind power plants would be over \$1 billion, and plants would service 1.1 million households. Also a reduction of carbon emissions around 1.5 million ton per year was expected (DW, 2017).

In 2019, the second tender for 1,000 MW of wind was announced, four different areas – Balıkesir, Çanakkale, Aydın and Muğla – having a capacity of 250 MW each. The initial investment was estimated at $1 billion, and the project was expected to generate electricity for 1.2 million households (BloombergHT, 2018).

2.5. Hydropower

The history of hydropower dates back to old times. It was mainly used for agricultural activities or irrigation. First hydropower station was established in 1902 and after that time it became an important domestic source for Turkey. The Ministry of Public Works began hydro projects in 1930s. In order to determine the Turkey's energy demand, develop hydropower and other source potential the Electrical Power Resources Planning and Survey Administration (EIE) was founded in 1935 (Erdoğdu, 2011). State Hydraulics Works (DSI) was founded in 1954. The main purpose of DSI was enhancing water utilization by constructing and operating hydropower plants (HPP) and dams. DSI and public sector have built 537 dams and 133 HPPs until 2004 (Öztürk, 2009). Today there are 645 (524 river type, 118 hydro dam) hydropower stations (TEIAS, 2019).

The estimated potential of Turkey's hydropower is roughly 45,000 MW and 140 TWh/year, 1% of world total and 14% European total (Erdoğdu, 2011). Hydropower is one of the major primary energy sources in addition to coal and natural gas for Turkey. Coal and hydropower were widely used for electricity generation until 1980s (Greenpeace, 2015). When the natural gas became accessible around 1990s, the share of both sources has started to decrease accordingly in the upcoming years (Erdoğdu, 2011).

A hydropower plant with a reservoir area of less than 15 km^2 was defined as Small Hydropower (SHP) in 2005. This definition allows private sector to establish a plant and could benefit the feed-in tariff mechanism. In 2010, government started to privatize small scale hydropower plants (Greenpeace, 2015). After the promulgation of RES regulations and other developments hydropower initiatives gained momentum significantly. HPP owners were benefitting from the feed-in tariff mechanism, $7.3 cent/KW plus additional premiums if they are using domestic products (Table 2.3). The installed capacity nearly doubled within 10 years (IRENA, 2019a). As of January 2019, there are 642 hydropower plants which have 28351.2 MW total installed capacity with a share of 31.90% in total (TEİAŞ, 2019). Hydropower has the biggest share in terms of electricity generation among all RES (Table 2.7).

Table 2.7 Yearly Generation of YEKDEM participants by years (MWh)

Type	2012	2013	2014	2015	2016	2017
Solar	-	-	-	-	-	24.268
Unlicensed	-	-	-	222.724	1.134.024	3.031.558
Hydropower	2.296.047	528.646	1.072.832	5.683.331	25.520.255	24.417.133
Wind	2.081.745	234.000	2.378.819	8.275.992	14.163.403	16.765.418
Geothermal	487.364	857.527	1.436.579	2.710.856	3.706.764	4.503.345
Biomass	374.002	750.715	925.516	1.050.796	1.306.057	1.789.053
Total	**5.239.158**	**2.370.888**	**5.813.746**	**17.943.699**	**45.830.503**	**50.530.776**

Source: EMRA, 2018

The hydropower energy consumption fluctuated in the recent years (Table 2.8). Other renewable energy sources such as wind and solar substituted hydropower at some point. In spite of fluctuations, hydropower generation follows an increase trend in the long run. Also the government targeted to have 32,000 MW total installed capacity by 2023. DSI is targeting to reach 127.8 TWh by 2030 (Öztürk, 2009), and Greenpeace (2015) estimated that electricity generation from hydropower will increase by 30% by 2050.

Table 2.8 Hydropower Consumption in Turkey

	mtoe	Change (%)
2009	8.1	8%
2010	11.7	44%
2011	11.8	1%
2012	13.1	11%
2013	13.4	3%
2014	9.2	-32%
2015	15.2	65%
2016	15.2	0%
2017	13.2	-13%

Source: BP, 2018

2.6. Geothermal and Biomass Energy

Geothermal and biomass energy have been widely used mainly for heating. Melikoğlu et al. (2017) estimated that Turkey has a geothermal potential between 31,500 MW and 38,000 MW. Toklu (2017) estimated Turkey's biomass potential at roughly 33 Mtoe. Geothermal exploration began in the 1960s in İzmir (Serpen et al, 2018). Geothermal was mainly used for heating for the next fifty years. After the 2000s, this shifted from heating to electricity. Geothermal power plants sell electricity at a starting price of $10.5 cents/kwh. Electricity generation has increased accordingly (Fig. 2.5).

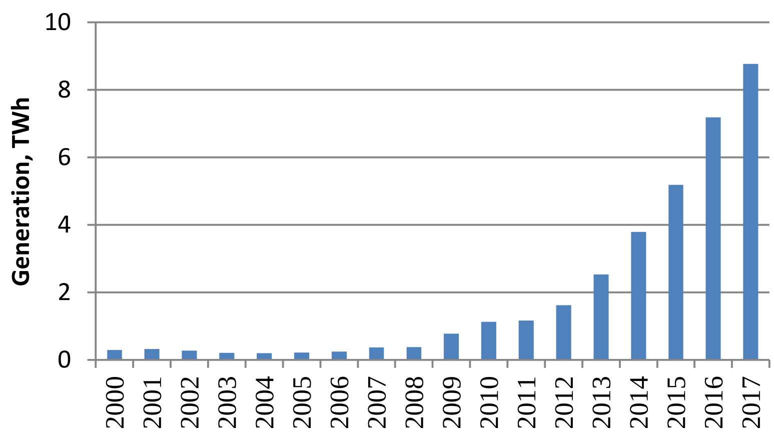


Figure 2.5 Geothermal and Biomass Generation in Turkey, 2000-2017
Source: BP, 2018

In 2010, the 2023 energy targets aimed to have 600 MW of installed capacity of geothermal (MEU, 2010). In 2014, it was targeted to reach 1300 MW installed capacity (MENR, 2015). Today, the installed capacity of geothermal is 1,302.5 MW (TEİAŞ, 2019). Governmental policies have accelerated the process, and Turkey ranks fourth after the US, the Philippines and Indonesia in terms of total geothermal power capacity, and second after Indonesia in terms of geothermal power capacity addition since 2016 (REN21, 2018).
Geothermal resources were protected by declaring them state-owned under the Geothermal Law in 2007 (Şimşek and Şimşek, 2013).

The validation of license for geothermal activities was limited to 3 years. 30-year license is needed for operational activities and in geothermal sector, this license can be extended by 10 years, and these licenses are delegable.

Turkey's biomass potential is very suitable for the electricity generation because of prevalent agricultural and forest areas (Balat, 2008). Özgür (2008) estimated that Turkey has 40 mtoe technical potential with a 25 mtoe/year available potential. Additionally, Toklu (2017) indicates that Turkey's annual total biomass potential is 168.7 TWh. However, the potential has not been utilized properly. The share of biomass in total energy supply was only 1,72% in 2017 (MENR, 2018). In order to stimulate the biomass sector proper regulations and efficient biomass technologies and governmental support are needed (Erdil and Erbıyık, 2015; Toklu, 2017).

3. TURKEY'S TRANSITIONAL DISCUSSION

The following section examines Turkey's renewable energy transition. It identifies several points of emphasis and compares Turkey with Germany and China.

3.1 Turkey's Transitional Discussion

State-owned institutions administrated Turkey's energy sector for a long time. Liberalization and decentralization of energy market started around 1980s. Allowing private sector to enter the energy market in 1984 was a milestone in the privatization period (Şimşek and Şimşek, 2013). Another major step was the establishment of EMRA as an independent institution in 2001 (Şekercioğlu and Yılmaz, 2012). When the renewable energy generation became globally popular and affordable after 2000s, renewable energy legislations were established accordingly. In 2001 and 2002, Electricity Market Law (No. 4628) and Electricity Market Licensing Regulation came into force. Electricity Market Law promoted the renewable energy generation for the first time. And in 2003, the enactment of the Modification of the License Regulation defined the renewable energy resources (Şimsek and Şimsek, 2013).

Electricity market regulations generally designated by Electricity Market Law and Electricity Market Licensing Regulation. To become an electricity producer in the market, an EMRA license is required. There are two types of license: pre-license and full license. All the related obligations such as approvals, local permits before the power plant investment are the subject of pre-license. When the pre-license acquired, producer can apply to EMRA for a full generation license. According to the EMRA (2018), the unlicensed total installed capacity reached to 3173,32 MW increasing by 202,73% compared to previous year (Table 3.1). The main increase happened in solar PV market (93,87%) from 2016 to 2017. The most important step was the promulgation of Utilization of Renewable Energy Law (No. 5346) in 2005. Solar, wind, geothermal, wave and tidal energy, biomass, biogas, river type-canal type-hydropower or hydropower generation plant with a reservoir area of less than 15 km^2 are qualified as renewable energy resource. The aim of this law was to promote the renewable energy generation by practicing feed-in tariff mechanism.

Table 3.1 Unlicensed Installed Capacity in Turkey by Sources 2016-2017

Resource Type	**2016**		**2017**	
	Installed Capacity (MW)	**Share (%)**	**Installed Capacity (MW)**	**Share (%)**
Solar (Photovoltaic)	939,19	89,6	2.978,84	93,87
Natural Gas	51,85	4,95	85,88	2,71
Biomass	36,42	3,47	66,72	2,10
Wind	13,75	1,31	32,2	1,01
Hydraulic	5,78	0,55	8,69	0,27
Solar (Concentrated)	1,22	0,12	1,00	0,03
Total	**1.048,21**	**100**	**3.173,32**	**100**

Source: EMRA, 2018

In 2007, Energy Efficiency Law (No. 5627), Law on Utilization of Renewables in Electricity Generation (No. 5346) and Geothermal Law (No. 5686) entered into force. The goal of these laws was to increase the efficiency of energy generation and reduce related costs. The feed-in tariff of renewable energy electricity was set between €5-5.5 cents/kWh (Official Gazette, 2007). In 2008, the Electricity Market Law (5784) of 2001 was amended and the renewable energy facilities under 500 KW were exempted from licensing. Later this exemption was increased to 1 MW in Energy Market Law Amendments in 2013.

In 2011, Electrical Power Resources Planning and Survey Administration (EIE) was closed down. At the same year General Directorate of Renewable Energy (YEGM) was founded by MENR. Some of the EIE's duties such as energy conservation and efficiency were transferred to the YEGM. This establishment was an important milestone for renewable energy transition. Together with the Presidential Decree No.1, published in 10 July 2018, the responsibilities of YEGM were assigned to the General Directorate of Energy Affairs (EIGM) (Official Gazette, 2018). In the same decree, some additional tasks such as energy efficiency stimulation, RES utilization studies, building efficiency and evaluation of RES.

In 2014, National Renewable Action Plan was announced. According to the plan, Turkey will have a 30% RE share in overall energy mix and 10% of transportation needs will be met by renewable sources. Another target was to reduce the amount of energy per GDP by 10% until 2023 (EIGM, 2014). In 2015, MENR has announced the 2015-2019 Strategic Plans. The plan includes different targets for different source (MENR, 2015). The goals are listed as below:

- Domestic coal (hard coal, lignite and asphaltite) usage shall be increased to 60 TWh annually by the end of 2019.
- Renewable energy share in primary total shall be increased and total installed capacity of all RE sources shall be increased to 46,400 MW.
- Nuclear energy shall be included in the energy mixture
- Natural gas share in electricity generation shall be reduced to 38% by 2019, and 30% by 2023
- Energy markets should be more reliable, transparent and easy to monitor with the help of EPIAS
- Thermal power privatization process should be completed as of 2019, and public-owned plants' share shall be decreased to 20%
- Creating better business models by examining the effect of previous subsidies

In 2017, National Energy Efficiency Action Plan (NEEAP) for 2017-2023 was announced (Table 3.2). There were many topics in the action plan. Main goals are to implement 55 actions in order to increase efficiency in buildings, agriculture, transportation, industry, energy and to decrease energy consumption by 14% by 2023 (MENR, 2017). The planned investment for accomplishing determined target was $10.9 billion. As it is stated previous chapters (Table 1.6), Germany allocated a $6 billion fund for promoting RE for five years. If Turkey actualizes these investments, the outcomes will have a very beneficial effect for renewable energy transition.

Table 3.2. National Energy Efficiency Action Plan of Turkey

Total Investment Required													
2017		**2018**		**2019**		**2020**		**2021**		**2022**		**2023**	
958		1279		1593		1681		1748		1824		1846	
Energy Saving													
2017		**2018**		**2019**		**2020**		**2021**		**2022**		**2023**	
ktoe	m$	ktoe	m$	ktoe	m$	ktoe	m$	ktoe	m$	ktoe	m$	ktoe	m$
577	202	1630	571	2493	872	3378	1182	4298	15504	5264	1842	6261	2191

Source: MENR, 2018

In order to accelerate the renewable energy transition different supportive tools were initiated by several laws and regulations. Feed-in Tariff mechanism, tax incentives, quotas, public and private incentives were widely used. Feed-in tariff mechanism played a critical role because it took attention to a renewable energy industry (Şimşek and Şimşek, 2013). Many investors established solar, geothermal and wind power plants mainly because fixed price guarantee for 10 years. There is also a quota for energy demanders that obliged them to buy a determined proportion of electricity from certified RE plants. The land use discounts for first ten years, reduction in taxes, exemptions for license application fees and annual fees are other minor incentives. When the renewable energy power plants have acquired the priority of selling its electricity to the grid, the market risk is eliminated. At some point, with the help of all above incentives renewable energy generation became more profitable than fossil fuel plants.

Table 3.3 Renewable Energy Regulations in Turkey Over the Years

2001	Electricity Market Law (No. 4628)
2002	Electricity Market Licensing Regulation
2005	Law on Utilization of Renewables in electricity Generation (No. 5346)
2007	Energy Efficiency Law (No. 5627)
	Law on Utilization of Renewables in Electricity Generation Amendments (No. 5346)
	Geothermal Law (No. 5686)
2008	Electricity Market Law Amendments (No. 5784)
2011	Law on Utilization of Renewables in Electricity Generation amendments (No. 6094)
2013	Electricity Market Law Amendments (No. 6446)
2015	Strategic Plan 2015-2019
2017	National Energy Efficiency Action Plan 2017-2023

Legislation initiatives have started 2000s and the development is still continuing. Table 3.3 shows the important regulations that shape the market. Each regulation filled a gap and served a purpose. Turkey is putting these regulations in order to achieve future goals. Table 3.4 shows the Turkey's installed capacity target for upcoming years. In order to achieve these RES targets as soon as possible, legislation planning should be done carefully. As we have seen in the Germany's situation, a well-designed policy can contribute a lot to the renewable energy implementation. And instead of centralized systems, decentralized integration could be more useful.

Table 3.4. Turkey's Installed Capacity Targets 2015-2023

Renewable Energy Source (MW)	Base year 2013	2015	2017	2019	2023
Hydro	22.289	25.000	27.700	32.000	34.000
Wind	2.759	5.600	9.500	10.000	20.000
Solar	-	300	1.800	3.000	5.000
Geothermal	311	360	420	700	1.000
Biomass	237	380	540	700	1.000

Source: MENR, 2014; MENR, 2015

Switching from conventional vehicles to electric vehicles is also important. Transport sector's role in CO_2 emissions is critical. Greenpeace (2015) estimated that transportation will account for 28% of total CO_2 emissions by 2050. According to TÜİK (2019), there are 22,972,552 motor land vehicles (54,2% automobile, 16,4% small lorry, 14,1% motorcycle, 8,2% tractor, 3,7% truck, 2,1% minibus, 1% bus, 0,3% special purposed vehicle) on the road as of March 2019. However, there are only 657 registered electric cars. The share of electric cars and hybrid cars in total registered vehicles (22.9 million) is not greater than 0.1%. However, there is a global shift from conventional cars to electric cars. As of 2017, total electric car stock of world was 3,109,05 (IEA, 2018). Compared to China (1.1 million) and Germany (110.000), Turkey is falling behind this trend. The major problems of EV transition in Turkey are high taxes, exchange differences and lack of infrastructure. The tax rates for automobiles are very high. For instance, when you buy a car you are obliged to pay a specific tax called special consumption tax (ÖTV). The rate of ÖTV is between 60%-160% which roughly doubles the car prices (Official Gazette, 2018). Since most of the electric cars are imported, exchange rate becomes an important factor on the prices.

Additionally, the EV infrastructure (charging station/service point) is very limited. People do not prefer the electric cars over conventional ones mainly because previous reasons. And without any governmental support and this will not change in the near future.

Turkey accepted the UNFCCC and Kyoto Protocol. Additionally, Turkey was one of the signatory countries of Paris Agreement. In the Paris Agreement, Turkey promised to reduce its greenhouse gas (GHG) emissions up to 21% from the business-as-usual level (Kat et al, 2018). However, the agreement has not ratified the yet (Arı and Yıkmaz, 2019). In 2010, the Ministry of Environment and Urbanization (MEU) announced the Turkey's Climate Change Strategy 2010-2023. The Strategy categorized the goals as three parts; short-term plan (within 1 year), mid-term plan (within 1 to 3 years), long-term plan (up to 10 years). Short-term targets included maximum utilization of domestic RE such as wind and hydro, certificating the building by their energy level, installations of solar PV at public places such as hospitals and parks. Mid-term targets were evaluation of energy efficiency for buildings, seeking alternative energy sources and rehabilitation of old thermal plants. The long term plan was to reduce emissions to 7% by 2020 and increasing RE electricity share to 30% together with the capacity by 2023 (MEU, 2010). However, between the years of 2010 and 2017 CO_2 emissions increased from 278.6 mt to 410.9 mt (BP, 2018). It can be stated that the goals were set but the execution was quite low. Greenpeace (2015) estimated that Turkey do not take preventive actions, CO_2 emissions will increase by 76% by 2050. With the help of effective practices these emissions could be minimized.

In the renewable energy transition period, support mechanism such as FITs and quotas are still necessary in order to utilize different types of sources (Arı and Yıkmaz, 2019). This is also valid for Turkey. Many unlicensed RES plants are benefitting from the FIT mechanism since the promulgation of RES Law. The amount paid to the RES generators benefiting from feed-in tariff mechanism met generally by the suppliers who are withdrawing energy from the market. Then the suppliers are being charged by their energy usage from the market. EXIST calculate the payment amounts and reflect them to the related parties at the end of each month. The FIT mechanism can work on both ways. If the current market price is lower than the FIT price, suppliers will pay the price difference to EXIST at the end of the month. In 2017, RES support mechanism participants generated 50.5 TWh with an increase rate of 10,26% (Table 3.5).

Table 3.5 Overview of Turkish Electricity Market

Parameters	2016 Figures	2017 Figures	Change (%)
Licensed Installed Capacity (Mwe)	77.563,44	81.563,32	5,16
Licensed Generation (MWh)	272.563.626,49	292.574.578,09	7,34
Highest Peak Demand (MW)	44.734	47.660	6,54
Lowest Peak Demand (MW)	17.448	18.336	5,09
Unlicensed Generation (MWh)	1.137.871,75	3.031.558,05	166,42
Unlicensed Installed Capacity (Mwe)	1.048,21	3.173,32	202,74
RES Support Mechanism Generation (MWh)	45.830.502,47	50.530.722,34	10,26
RES Support Mechanism Amount of Payment (TL)	10.796.370.753,89	13.869.601.064,94	28,47
Average RES Support Mechanism Price (TL/MWh)	235,57	274,66	16,59
RES Support Mechanism Additional Cost (TL/MWh)	18,82	23,84	26,67
Actual Consumption (MWh)	277.522.012,26	292.003.542,76	5,22
Invoice-based Consumption (MWh)	212.328.766,43	225.713.528,13	6,3
Import (MWh)	6.400.129,12	2.729.060,87	-57,36
Export (MWh)	1.442.081,65	3.300.096,20	128,84

Source: MENR, 2018

REN21 (2018) states that feed-in tariff policies are needed to create a new energy system until the system have matured. Early phase policies may be change according to the circumstances. Tenders become prevalent over FIT mechanism because policymakers abandon the supportive mechanism if the conditions allow.

Table 3.6 shows the total installed capacities of RES of China, Germany and Turkey. It can be said that these three countries made a good start in terms of RES. However, there is a lot to do in order to achieve 100% RE consumption. BP (2018) data shows that primary energy consumption by source of these countries have not changed significantly over the years. Renewables have increased its shares rapidly but it is still not on the desired level. The transition process can be accelerated with precise investments and political support.

Table 3.6. Comparison of Total Installed Capacities of RES

	China		Germany		Turkey	
	Total	**Change**	**Total**	**Change**	**Total**	**Change**
2014	414.653	15%	90.320	8%	27.940	9%
2015	479.106	16%	98.013	9%	31.516	13%
2016	540.999	13%	104.746	7%	34.446	9%
2017	620.857	15%	112.719	8%	38.746	12%
2018	695.865	12%	120.014	6%	42.215	9%

Source: IRENA, 2019a

Germany can be an example of policymaker and a practitioner. Fukushima disaster became a turning point for Germany. Future energy plans were cancelled and reshaped without nuclear. And China showed the world that desire is the key. Within ten years, China became world leader in terms of Renewable energy generation and installed capacity.

Turkey can increase its generation by using its domestically renewable energy sources (Mete and Heffron, 2017). Since Turkey is an energy dependent country, enhancing the usage of RES will also make some serious contribution to the energy independency. The time is changing and the regulations should keep up with the change. Energy efficiency, electric vehicles are some of the major topics of energy arguments. Instead of fossil fuels, Turkey should focus on these kinds of matters. Turkey is still going through an early phase of renewable energy transition. Germany has started the transition process around 1980s, now it is one of the pioneer countries. Turkey can follow the same roadmap. Instead of building nuclear or establishing more coal power plants, investments and policies should focus on renewable energy resources, new technologies and energy efficiency. Renewable energy usage is a must in order to create a better, sustainable future. Also it would be much more environmental friendly.

Table 3.7 shows the Turkey's installed capacity as of January 2019. The share of coal and natural gas were still greater than the RE. Many experts think that Turkey is a rich country in terms of RES (Özgür, 2008; Kırtay, 2010; Erdoğdu, 2011; Mete and Heffron, 2015; Kılıçkaplan et al., 2017). It is not impossible to reach high level of RES utilization with the help of well-designed systems and proper policies.

Table 3.7 Total Installed Capacity of Turkey as of January 2019

	As of 31 January 2019		
Fuel types	**Installed Capacity MW**	**Share %**	**Number of Plants**
Fuel oil+ Naphta + Diesel	294.0	0.3	11
Coal - Domestic (Hard coal + Lignite + Asphaltite)	10,403.5	11.70	32
Import Coal	8,793.9	9.90	11
Natural Gas + LNG	22,437.8	25.20	251
Ren +Waste + Pyrolytic oil	738.8	0.80	127
Multifuel solid+liquid	697.1	0.80	22
Multifuel Liquid+ Gas	3,358.3	3.80	47
Geothermal	1,302.5	1.50	48
Hydraulic dam type	20,567.5	23.10	118
Hydraulic river type	7,783.7	8.80	524
Wind	6,946.8	7.80	175
Solar	81.7	0.10	9
Thermal (Unlicenced)	319.3	0.40	109
Wind (Unlicenced)	63.1	0.10	74
Hydraulic (Unlicenced)	7.6	0.00	11
Solar (Unlicenced)	5,098.5	5.70	6,000
Total	**88,894.0**	**100.00**	**7,569**

Source: TEIAS, 2019

In order to better quantify the energy transition potentials of Germany, China and Turkey I come up with a new energy transition index that take technology, innovation, investment and emissions into account (Table 3.8). I have obtained data for 8 different indicators that are: RE share in electricity (BP, 2017), number of RE patents (IRENA, 2017), jobs in RE sector (IRENA, 2019b), total installed RE capacity (IRENA, 2019a), CO_2 emissions per capita (World Bank, 2017), Global Innovation Index (GII, 2018), Environmental Performance Index score (EPI, 2018),), energy demand growth rate (BP, 2017), energy intensity (Enerdata, 2017). The best performing country is scored as 100 for each indicator and the other two countries are normalized according to this county. This resulted scores ranging 0-100 for each indicator. I have then given higher weight (weight of 2) to some of the indicators as they affect the transition index more directly than others (Table 3.8).

Table 3.8 New RE Transition Index for Germany, China and Turkey

		Germany	China	Turkey
1	RE Share in Electricity	25,1%	33,3%	29,7%
	Normalized Score (weight=2)	75	100	89
2	Number of RE Patents	30969	168128	516
	RE patent per 100.000 people	37,57	11,84	0,62
	Normalized Score (weight=2)	100	32	2
3	Jobs in RE sector (thousand)	291	4078	62
	Normalized Score (weight=2)	100	81	21
	RE Job/Population (1000 people)	3,53	2,87	0,75
4	Total Installed RE Capacity MW	120014	695865	42215
	(KW per capita)	1,46	0,49	0,51
	Normalized Score (weight=2)	100	34	35
5	CO_2 Emissions (mt per capita)	8,9	7,5	4,5
	Normalized Score (weight=1)	60	51	100
6	Global Innovation Index	58,03	53,06	37,42
	Normalized Score (weight=1)	100	91	64
7	EPI Score	78,37	50,74	52,96
	Normalized Score (weight=1)	100	68	68
8	Energy intensity (koe/$2015p)	0,077	0,138	0,074
	Normalized Score (weight=1)	96	54	100
		Germany	China	Turkey
	Total Normalized Score	**92,17**	**63,17**	**51,92**

Finally, I have calculated the weighted average of all 8 indicators to obtain a final score, or, an energy transition index, for each of the 3 countries. The index ranks countries as follows: Germany (92.17), China (63.17) and Turkey (51.92). Germany outperforms other countries mainly in RE patents per capita, total installed RE capacity per capita and EPI index. China outperforms other countries mainly in RE share in electricity, and Turkey outperforms mainly in CO_2 emissions per capita. This shows that both China and Turkey have some potential to accelerate energy transition but lacks some research and development in RE to support this potential.

As mentioned before, Germany has long adopted a RE transition strategy that was mainly built upon strong research and technology development and training and education of human capital as well as public awareness. This strategy has provided some advantage to Germany in energy transition compared to China and Turkey.

CONCLUSION

Turkey is an energy-dependent country; almost 77% of its energy resources are imported. Since Turkey is not energy independent, there should be a sharp shift from imported fossil fuels to renewables. Turkey's renewable energy potential, moreover, is good enough to change the direction of its energy policies (e.g., Balat, 2005; Erdil and Erbıyık, 2015; Toklu, 2017). Renewable energy resources offer an optimum solution for Turkey's energy challenges. RE costs are decreasing sharply, while efficiency is improving due to technological improvements (MIT, 2015; REN21, 2018; IEA, 2018). Turkey's 2023 energy goals also aim to use domestic energy resources efficiently and effectively.

Germany, China and Turkey are very different countries in terms of economy, population, history and geography. However, they have one similar problem: energy dependency. RES can help them in order to overcome their energy problems. As seen in the previous chapters, state involvement is an integral part of RE transition. Without the governmental support it would be impossible to achieve RE targets. Germany and China have succeeded with the help of proper policies that were initiated by the government.

Germany and China differentiates at some points. German RE transition model can be defined as a bottom-up model. The Green Party and the green movement have affected the energy policies. The public awareness has forced the policies to change. Also Germany is a developed country which has a strong background in manufacturing goods. Therefore, they used their know-how to manufacture RE equipment and technology to catch the RE transition. Where the China's RE transition is a top-down model. It was a state-initiated transition and statism is still a powerful there. In Turkey, both of the models can be used. Turkish people are aware of the climate change and energy import dependency problems (Ediger et al., 2018). And government wants to increase the RE usage in order to decrease energy import. Public preferences can create a movement, such as a political party, and this movement can affect the policies positively.

It is known that Turkey has a great potential in Renewable Energy. However, the installed capacity and RE usage is quite low. There are some problems such as lack of legislation, long bureaucratic procedures, imported goods and financing of projects. These problems can be solved with the cooperation between government and public. Turkey is planning to diversify its energy sources by build a new nuclear power plant (Stein, 2016). However, 49.6% of Turkish people does not want a nuclear power plant in their neighborhood (Ediger et al., 2018) As discussed in the previous chapters, Germany has decided to exit from nuclear after the Fukushima accident and reshaped its future energy policies. Turkey should take Germany as an example.

Another important obstacle for the RE transition is the absence of political force. The role of Green Party in the renewable energy development in Germany is undeniable (Jacobs, 2012; Hager, 2015). Turkey does not have a political formation that directly defends the environmental change in the Turkish Parliament. There are political parties that have some minor RE projects. There is not a specific and strong political movement toward RE transition. On the contrary, state policies turned back to the coal generation in order to minimize import dependency. One of the Turkey's 2023 goals is increasing the domestic coal share in total energy mix.

The technological side of the RE transition is also important. A new energy transition index formulated in this study showed that R&D and domestic production are important pillars of RE transition. Funding and start-up projects are also critical to advance the transition. Germany, the highest ranking country in RE transition index, outperforms China and Turkey in RE patents per capita, total installed RE capacity per capita and EPI index. The lack of domestic production in Turkey is another important obstacle in the RE transition. The government have been promoting the domestic production. However, domestic production is quite low. China used its manufacturing power effectively in the transitional period. Germany used its human capital and know-how for domestic production. In order to compete with other countries in the RE technology area, Turkey should make serious investment in the R&D facilities and domestic production.

Since we are trying to save the future, we should also educate the next generation about RE concepts starting in primary school. Giving basic information about renewables for the public can also create awareness. If people are more aware of the advantages of RE, developments will accelerate as we seen in the Germany example.

Turkey should also create an environment that brings different areas together. Government, universities and other independent entities can forge stronger cooperation in implementing a system that can enable Turkey to become more energy independent. Turkey has the potential to be an example of a successful country like Germany or China, but additional efforts are absolutely required. Also, as we have seen in the German transition renewable energy transition, public awareness plays a critical role. A well-detailed FIT mechanism and regulations should be implemented. The decentralization and liberalization of the energy market is another key step. Turkey is in the early phase of its renewable energy transition. In order to compete with other countries, Turkey should focus on both public and private investments in a short period. As seen in many examples from Germany and China; the RE transition began with governmental initiative then turned to financial incentives including tenders.

As an initial step, the Turkish government should revise the strategic targets for growing a sustainable energy structure. RE systems should be immediately placed in Turkey's energy production policy to meet increased energy demand. For example, the total RE capacity of Germany is 120.014 MW while Turkey's is only 42.215 MW (IRENA, 2018). The government gives different kinds of incentives but the present situation is not prospering. It is necessary to plan the use of RE by cost-effective methods, and local production of solar energy technology can significantly reduce investment costs. The government, universities and companies should be encouraged by financial support to research and develop the uses of RE throughout the country. The importance of the role of the government in formulating and implementing favorable policies for RE development cannot be overstated. But the private sector, which has the capacity to mobilize funds, also needs to take a leadership role in the renewable energy transition.

If these important steps are taken, RES can become the primary source of Turkey's energy demand and would have positive effects on both the economy and sustainability.

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