KADİR HAS ÜNİVERSİTESİ
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SWITCHING TO DECENTRALIZED RENEWABLE ENERGY SYSTEMS FOR A SUSTAINABLE DEVELOPMENT IN TURKEY

MEHMET BURAK ŞUŞOĞLU

MASTER'S THESIS

ISTANBUL, JANUARY, 2020

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MASTER'S THESIS

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DECLARATION OF RESEARCH ETHICS /

METHODS OF DISSEMINATION

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This work entitled **SWITCHING TO DECENTRALIZED RENEWABLE ENERGY SYSTEMS FOR A SUSTAINABLE DEVELOPMENT IN TURKEY** prepared by **MEHMET BURAK ŞUŞOĞLU** has been judged to be successful at the defense exam held on **08/01/2020** and accepted by our jury as **MASTER'S THESIS.**

APPROVED BY:

Prof. Dr. Volkan Ş. EDİGER (Advisor)	Kadir Has University	Volkan Ş. Ediger
Assoc. Prof. Dr. Gökhan KİRKİL (Co-Advisor)	Kadir Has University	
Prof. Dr. Meltem Şengün UCAL	Kadir Has University	
Asst. Prof. Dr. İstemi BERK	Dokuz Eylül University	

I certify that the above signatures belong to the faculty members named above.

Dean of School of Graduate Studies

Prof. Dr. Sinem AKGÜL AÇIKMEŞE

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8/1/2020

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LIST OF ABBREVIATIONS AND ACRONYMS

AC	Alternative Current
BP	British Petroleum (Oil Company)
CCGT	Combined Cycle Gas Turbine
CG	Centralized Generation
CHP	Combined Heat and Power
DG	Decentralized Generation
DRES	Decentralized Renewable Energy Systems
EPDK	Energy Market Regulatory Authority
FF	Fossil Fuels
FIT	Feed-in Tariff
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GW	Gigawatt
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
KM	Kilometer
kW	Kilowatt
kWh	Kilowatt-hour
KV	Kilovolt
LCOE	Levelized Cost of Electricity
MW	Megawatt
NIMBY	Not in My Backyard
P2P	Peer-to-peer
PV	Photovoltaic
RERA	Renewable Energy Resource Area
RES	Renewable Energy Sources

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SWITCHING TO DECENTRALIZED RENEWABLE ENERGY SYSTEMS FOR A SUSTAINABLE DEVELOPMENT IN TURKEY

ABSTRACT

We are living today what is called the “energy transition”, a term brought by the unsustainability of the world’s energy system. Most of the electrical energy that we use today are coming from fossil fuels and centralized power plants which are urging the world for this energy transition. In order to achieve a sustainable energy system, decentralized renewable energy systems have been seen as a solution. These systems provide cleaner, self-sufficient and consumer oriented electricity generation, transmission and distribution. Within these systems, people become a part of the electricity generation process and become prosumers. Hence, the electricity generation switches from big corporations that generate electricity to individuals. Blockchain, in this context, enable peer-to-peer transactions between prosumers and consumers without the involvement of any third parties. These developments encouraged people to become prosumers and engage in electricity generation processes. All of these concepts fasten the energy transition in the world. Such a transition in energy is more important for Turkey as it is suffering from vast fossil-fuel imports and inefficiency in electricity generation. In order to overcome these problems, Turkey could establish decentralized renewable energy systems. However, there are many barriers in the world and in Turkey to the applications of decentralized renewable energy systems. The purpose of this master thesis is to look at the current applications of decentralized renewable energy systems, review the barriers in the world and in Turkey and proposing solutions from global examples.

Keywords: Decentralized Energy, Renewable Energy, Blockchain, Energy Transition

TÜRKİYE'DE SÜRDÜRÜLEBİLİR BİR KALKINMA İÇİN DAĞITIK YENİLENEBİLİR ENERJİ SİSTEMLERİNE DÖNÜŞÜM

ÖZET

Bugün adına "enerji dönüşümü" dediğimiz, dünyanın sürdürülemez bir enerji sistemi üzerine kurulu olmasından ötürü ortaya çıkan bir evreyi yaşamaktayız. Kullandığımız elektriğin büyük bir kısmı fosil kaynaklardan ve merkezi güç kaynaklarından sağlanmakta ve bu da dönüşümün en büyük etkenlerinden birini oluşturmaktadır. Daha sürdürülebilir enerji sistemi için ise dağıtık yenilenebilir enerji sistemleri bir çözüm olarak görülmektedir. Bu sistemler daha temiz, kendine yeten ve tüketici merkezli elektrik üretimi, iletimi ve dağıtımı sağlamaktadır. İnsanlar bu sistem içinde türetici olarak elektrik üretiminin bir parçası haline gelmekte ve böylece elektrik üretimi büyük şirketlerin elinden bireylerin eline geçmektedir. Blockchain ise bu sistem içerisinde türeticiler ile tüketiciler arasında, herhangi bir üçüncü kuruma ihtiyaç olmadan, uçtan uca elektrik alışverişini mümkün kılmaktadır. Bu gelişmeler insanları elektrik üretimine katılmak için teşvik etmektedir. Tüm bu konseptler enerji dönüşümü sürecini hızlandırmaktadır. Böyle bir dönüşüm Türkiye için çok önemlidir çünkü Türkiye kullandığı fosil kaynakları ithal etmekte ve elektrik üretiminde de birçok sorunlarla karşılaşmaktadır. Bu sorunları bertaraf etmek için Türkiye, dağıtık yenilenebilir enerji sistemleri kurabilir. Fakat Türkiye'de ve dünyada bu uygulamaların önünde çok ciddi engeller bulunmaktadır. Bu tezin amacı dünyadaki örnekleri gözlemleyip dünyadaki ve Türkiye'deki engelleri inceleyip global örneklerden Türkiye'ye çözüm yolları sunmaktır.

Anahtar Sözcükler: Dağıtık Enerji, Yenilenebilir Enerji, Blockchain, Enerji Dönüşümü

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1. INTRODUCTION

Energy is a basic need for the development of every country in the world. Since the beginning of the very first civilizations, people used energy for their basic needs for survival. However, the sources and the ways that people harnessed their energy have always been changing. Thousands of years ago, people could only use biomass and later developed wind and water mills to facilitate the use of energy (Bithas & Kalimeris, 2016). Although, these are the energy sources that people still use today, the dominating energy sources and their technologies have changed throughout time with the development of fossil fuels (FF).

FF have been an important milestone in use of energy by human beings. With the industrial revolution, the use of coal was facilitated with the introduction of steam engine. After the use of coal, the usage of oil and then natural gas came into existence during the 19th and 20th century respectively. Today, world's primary energy consumption is dominated by FF by 85% (BP, 2019) the world's electricity generation production is mainly based on coal by 38.1%, natural gas by 23.2% and oil by 3.5% (BP, 2019). However, the state of energy has been changing recently; it is favoring and moving towards the use of more renewable energy sources (RES).

There are two significant reasons for the switch to RES; global climate change and resource scarcity. One of biggest challenges that we have today is the global climate change and its consequences. There have been rapid increases in the CO_2 and other greenhouse gas (GHG) emissions in the atmosphere. Today, the CO_2 levels in the atmosphere is three times higher than the pre-industrial levels; the glaciers in the poles are being lost at rate of 8% a year; and the global temperatures are at 1°C higher compared to pre-industrial levels (Eniva, 2013; IPCC, 2018). It is expected that the global temperatures will increase to 1.5°C higher than pre-industrial levels by 2100 under certain scenarios. This change will effect ecosystems, biodiversity, human health and many others considerably. One of the biggest reason for the global climate change is the FF combustion; today the biggest contribution to CO_2 emissions is coming from the power sector, which is dominated by FF. Electricity and heat generation accounts for 42% of the global CO_2 emissions (IEA, 2018a).

The other important reason is the resource scarcity. FF are finite resources which means that it will run out eventually if mankind to consume at the current rate. Reserves to production ratio (R/P), which shows the remaining lifespan of a natural resource, is diminishing by the year. At present, the R/P ratio is 50,2 years for oil, 52,6 years for natural gas, and 134 years for coal (BP, 2019). Even though these numbers show the world's averages, it is clear that FF are exhaustible and will finish some day. Since electricity generation and transportation is too dependent on FF, by 64.8% (BP, 2019) and 96% (EIA, 2016) respectively, the countries are taking action to move away from it.

In order to overcome the problems brought by using FF, RES have been seen as one of the more sustainable solutions. RES could be an alternative to FF since they provide electricity generation locally and environmental friendly with lower CO_2 and other GHG emissions. Since RES renew themselves, they can be used for over long periods without running out. RES also helps with the diversification of energy resources and reducing the dependence on imported resources. Hence, RES are important options for a more sustainable energy system.

The transition into RES-dominated world is happening fast. The installed capacity of RES was 2.1 TWh in 2017 while it was 1 TWh in 2008; the number more than doubled in just 10 years (IRENA, 2018). The share of RES in the world's electricity generation and total consumption is constantly rising; 9.3% in electricity generation and 4% in total primary energy consumption in 2018 compared to 3.1% in electricity generation and 1.2% in total primary energy consumption in 2009 (BP, 2019). Countries today are making new strategies to invest and increase their RES installed capacity. According to International Energy Agency, the new installed capacity of RES will surpass FF installations until 2040 (IEA, 2018d).

There have been many developments that pace up this transition. Today, countries are setting new targets for the future in order increase the share of RES and decrease the usage of FF. Policies include increasing RES installed capacity, increasing energy efficiency in electricity generation, installing energy efficient appliances, increasing the energy R&D budget etc. For example, the European Union's target for the future is that the 20% of final energy consumption will be provided from RES by 2020 and 32% by 2030 (European Commission, 2019). These targets that are put into action are binding for member states. Treaties like the Paris Climate Agreement make the process faster by putting obligations to 187 ratified states (UNFCC, 2019). With many developments, cost of RES is also decreasing dramatically. Today, in many parts of the world, cost of renewable energies are lower than FF and nuclear generation (Ren21, 2018). With the improving market conditions, the transition will happen faster.

The electrification of the energy system is rising as many of the heating, cooling, manufacturing and mobility switches to the use of electricity. In the last ten years, from 2008 to 2018, electricity generation grew by 76.8% (BP, 2019). By 2040, electrification of the energy system will reach to 20-31% (World Energy Council, 2019). This electricity generation process is mainly based on centralized generation (CG) all over the world. In these systems, generated electricity is transmitted in high amounts to demand centers. The common transmission and distribution infrastructure is expensive to build and cause losses. These facilities are most commonly based on FF and hydro. Because of the infrastructure and scale of investment, CG is also expensive to build and operate. Due to this reason, CG is not environmental friendly and sustainable.

Decentralized generation (DG) is one of the most recent systems that are being established today for a more efficient and environmental friendly electricity supply. "The decentralized power is characterized by generation of power nearer to the demand centers, focusing mainly on meeting local energy needs." (Kaundinya, et al., 2009) The DG uses local renewable resources; because of this reason it is cleaner, more efficient and economic. DG also improves energy democracy by taking electricity generation process to individuals, namely "prosumers" who produce and consume his/her own energy (Mengelkamp et al., 2018). Prosumer engagement and energy democracy is essential for DG and widespread usage of RES. Since prosumers take electricity generation to an individual level, it could help extend the use of RES. In order to prevent climate change and increase efficiency in electricity generation, transmission and distribution, promotion of decentralized renewable energy systems (DRES) and prosumers could be an important alternative to existing CG.

In the search of enabling energy democracy, new technologies are also introduced into the energy sector. "Blockchain is a special technology for peer-to-peer transaction platforms that uses decentralized storage to record all transaction data" (p. 3) (PWC, 2016). The important aspect of this technology is that it reduces the need for any intermediaries. The transaction could be carried out using smart contracts and payments can be done without the involvement of any intermediaries (Swan, 2015). All the transactions are recorded on the blockchain, creating a secure and transparent community where prosumers and consumers could interact and reach self-sufficiency. Blockchain is expected to fasten the energy transition by increasing the number of prosumers, increase energy democracy.

All these factors are driving the world for a major transition. Within this framework, Turkey's situation is similar to what is observed in the world in terms of FF and CG. Turkey's electricity generation is dependent on FF by 67.6% (TEİAŞ, 2019a). Accordingly, Turkey is suffering from rising CO_2 emissions and other GHGs; Turkey's CO_2 emissions growth from 2016 to 2017 was the second highest in the world by 12.7% after Estonia (BP Energy, 2018). Another issue with FF consumption in Turkey is the import dependency. Roughly 70% of the electricity generation is dependent on imported FF (TEİAŞ, 2017b). Out of the resources used in the electricity generation, Turkey produces only 38.1% of coal, 5.9% of oil and 0.7% of natural gas (EPDK, 2017). This creates huge burden for the economy; $43 billion in 2018 (Bloomberg HT, 2019). On the other hand, most of the installed capacities however are based on CG. Turkey has built many CG power plants in the recent years and current policies suggest that the new ones are on the way. With the current system, Turkey is facing many inefficiencies in electricity generation, transmission and distribution. In 2018, 1.7% of electricity generated was lost in transmission and 10.2% was lost in distribution (TEİAŞ, 2019a). FF Imports and inefficiencies together have a huge impact on the Turkish economy.

Despite these facts, share of RES in electricity generation or total primary energy consumption is quite low. In 2018, RES (excluding hydro) contribution to electricity generation was 15,78% (TEİAŞ, 2019a) and to total primary energy supply was 5.6% (BP, 2019). Projections for the future still show a significant FF contribution to Turkey's electricity and energy supply. However, despite the problems associated with the use of FF, DG in Turkey is quite low. Hence, DRES is an important option for Turkey to become self-sufficient and to have a more efficient and environmental friendly generation. Today, in Turkey, there are many incentives for DRES like feed-in tariffs, tax exemption etc.

However, there are many legal, bureaucratic, and technical barriers for the DRES installations and prosumer engagement in the market.

There has been many researches and many publications on “decentralization generation”, especially in the recent years as the concern for energy efficiency and environment is rising. The transition to RES also has a high influence on these publications. However, the first of the DG studies could be traced back to 1970’s as the energy-related crises create a huge concern in the international community. In his 1984 article “Cogeneration and Small Power Production: Florida’s Approach to Decentralized Generation”, Jeffrey Fuller wrote “the changing economics of electricity generation in the 1970’s, coupled with the 1973-74 oil crisis, prompted both a legislative and societal examination of the United States’ approach to decentralized electricity production.” This statement perfectly demonstrates how the transition to DG began.

One of the most important works and a milestone for energy policy is “Soft Energy Paths”; a book written by Amory Lovins back in 1977 (Lovins, 1977). In his book, Lovins described two paths: the “Hard Path” and the “Soft Path”. The hard path is where the system is basically dependent on oil, coal and gas which is dependent on foreign energy; rely on large and centralized power plants; in turn has environmental effects; has very high costs; and directly and indirectly increases unemployment. Whereas, the “Soft Energy Path” is “flexible, resilient, sustainable and benign”. Lovins suggests the use of RES for this path which he describes it as small contributions for maximum effectiveness and it is specifically targeted for the needs of end-use.

The works about DG were mainly approached from an economical, DG potential review and energy planning perspective. For example, Asbury et al. (1979) focused on the disadvantages of DG, by looking at the economies of scale of the existing systems and criticized DG supporters by saying that there are not enough evidence to support DG. Lovins (1977) too approached DG from a more economical and energy security point of view. “Planning for Energy Self-Reliance: A Case Study of the District of Columbia” written in 1978 by Institute for Local Self-Reliance reviewed the local potential in Columbia, measured the consumer behaviors and proposed a decentralized system at a community level in Columbia in which consumers are a part of the system (Beyer and Plunkett, 1979). Again by Institute for Local Self-Reliance, “Be Your Own Power

Company" was written in 1983. This book focused on power technologies, incentives to prosumers and interconnection of RES (Morris, 1983). Yaqoot et al. (2016) used to term "Decentralized Renewable Energy Systems" and reviewed the barriers to its applications.

Even though the world is producing many works on the DG and DRES applications, Turkey has not produced as much as the other countries. However, there are some works devoted to DG, mostly for reviewing the potential of DG in Turkey. Wietze Lise, in his article "Towards a higher share of distributed generation in Turkey", showed the potential and DG applications by source in Turkey (Lise, 2009); similarly, Çolak et al. assessed the opportunities of smart grid and RES (Colak et al., 2014). In Turkey, most of the scholars, focused on "smart-grid". They reviewed the opportunities and touched upon the importance "decentralized/distributed" generation (e.g., Atasoy et al.,2014; Köktürk and Tokuç, 2017; Kabalci, 2016).

As it is clear, the studies in Turkey focusing on DG are only a few. The main purpose of this thesis is the show the current status of DRES in Turkey and review the opportunities and barriers to its applications. Within this scope, the answers to the following questions will be provided in this thesis: what is the current state of DG in the world?; what are barriers to DRES applications in the world?; what are the barriers to DRES in the world?; what is the current policies of Turkey towards RES and DG?; what is the current situation of CG in Turkey?; what is the current situation of DRES in Turkey?; what are the opportunities of DRES in Turkey?; what are the incentives and barriers to DRES applications in Turkey? With the answers to these questions, this thesis will shed light on the following question: "What can Turkey do to overcome the barriers associated with the DRES applications in order to widen its applications?"

In order to review the current DG policies in Turkey, mainly the reports of state institutions, especially from Energy Market Regulatory Authority and Mineral Resources, and regulations published in the Official Gazette were used. Electricity generation and electricity consumption data from Energy Ministry's monthly sectoral reports were used in order to see the CG situation of Turkey (EPDK, 2018a). Accordingly, the cities' in which consumption exceeds their production and cities in which production exceeds the its electricity consumption is shown.

When examining the current DRES situation in Turkey, definitions of different authors have been used which will be described in the chapter 4. Opportunities of DRES in Turkey are shown parallel to the potential of RES. The incentives to RES and DRES are gathered from the regulations published in the Official Gazette. The barriers of DRES in Turkey is reviewed by looking at the barriers in the rest of the world; it is observed if the same problems exist in Turkey or not. The barriers in Turkey are mostly found in the articles written on RES and their barriers.

Finally, thesis question's answer is based on the barriers faced in other countries. By examining the similar barriers faced in other countries and solutions made by these countries to offset these barriers, different recommendations were made as a solution for the barriers of DRES in Turkey.

Upon answering these questions, the reports of international companies and institutions like BP, IRENA, EIA has been used throughout. To see the current DG state in the world and DRES applications in the world, various reports of international institutions like BP, IRENA, IEA etc. are used. To layout the current barriers and policies in the different countries, reports by international organizations and articles published in those countries are used.

In the first part of this thesis, the concept of "decentralization" is reviewed. In this chapter, the current status DG transition is show and barriers of DRES applications have been reviewed. In the second chapter, the energy structure of Turkey is reviewed. Also in this chapter, the necessities of switching to decentralized system are shown. In the third chapter, centralization and decentralization in Turkey is reviewed. In the fourth chapter, the barriers of DRES applications in the in Turkey are shown. In the last chapter, recommendations have been given to increase DRES applications in Turkey by looking at the successful applications in the world.

2. DECENTRALIZATION VS. CENTRALIZATION

Decentralization of energy is an important aspect for the development of countries worldwide. However, DG in the world need further investigation by both scholars and policy makers. In this chapter, the definitions for “Decentralized Generation” and “Decentralized Renewable Energy Systems” will be given. The historical background for DG will be explained starting from the very first electricity power plants. The differences between decentralization and centralization will demonstrated. Blockchain in the energy sector will also be presented in this chapter. The future of DG will be shown based on expected future applications and based on expert surveys. Lastly, the global barriers to decentralized renewable energy systems will be examined thoroughly. DRES barriers in Turkey will be examined in chapter 4.

2.1 Definitions

There have been many definitions given to describe what DG is. The main emphasis is given on the proximity of the generation to the demand centers and the use of RES. Although DG could be achieved without the use of RES, the recent studies point out their importance for environmental reasons. However, there is not a single definition that is accepted by every scholar. Kaudinya et al. (2009) describes decentralized power as “generation of power nearer to demand centers, focusing mainly on meeting local energy needs” (p. 2451).” Lise (2009) describes DG as “generations units connected to a low medium voltage network (<36 kv), located in the vicinity of major consumer centers” (p. 4320). On the other hand, DRES is decentralized applications based on renewable energy sources. DRES is not commonly used; it is used in some works (e.g. Yaqoot et al., 2016), Vezzoli et al., 2018).

2.2 Historical Background

One of the major changes in the energy transition period occurs in electricity generation, transmission and distribution. Along with the resources, the world is also transitioning to DG from CG. Before the emergence of CG, energy resources were mainly based on biomass and these resources were used locally by private persons and farmers. After the industrial revolution, larger power plants for manufacturing and electricity generation were built. Economies of scale had reached a peak in the 20th centruy with nuclear power plants and hyrdopower dams. With the liberalization of the electricity markets, small combined heat and power (CHP) plants became wider. Small-scale power plants accelerated with the development of solar PV, solar thermal and wind turbines (Burger and Weinmann, 2013).

The larger power plants mentioned above were publicly owned facilities. However, there have been vast liberalizations across the globe. Hence, the energy tragectory have moved from being publicly owned to privately owned power plants which are increasingly based on RES. Also, the energy tragectory started to move from centralized to decentralized after the introduction of RES (Burger and Weinmann, 2013) (Figure 2.1). Hence it can be said that the transtion is happening towards DRES.

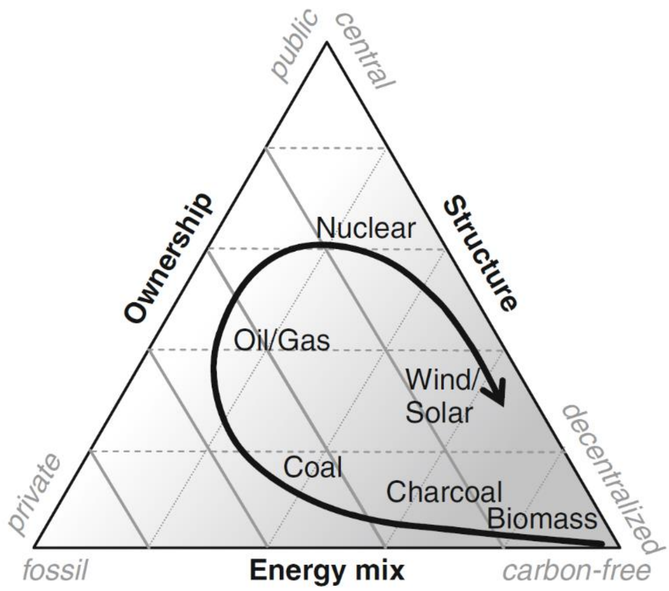

Figure 2.1 Energy System Trajectory

Source: Burger and Weinmann (2013)

When the electricity first started being utilized, there were low voltage generators. This meant that the electricity could only be consumed locally because there would have been too many losses with low voltage transmission if the electricity had carried to long distances. With the developments of alternative current (AC) and the improvements of high voltage lines, the electricity started being carried to long distances (Turgut & Selçuk, 2016).

The first power plant was introduced in 1882 in New York. Beginning with this power plant, the age of DG started because the power had to be consumed locally. By 1900, 100% of the world's electricity came from distributed power plants. The trend towards centralized power plants started with the developments in the late 19th century. (Owens, 2014). In 1886, electricity was transmitted to 1600 meters away in Great Barring, Massachusetts. Later that year, electricity was carried 27 km away in Italy and then carried to 170 km away in Germany in 1891 (Turgut & Selçuk, 2016). In 1920's, centralized power plants started dominating the world's power and by 1950, DG accounted for only 10% of the global generation (Owens, 2014). With this increase, CG still dominates the world's electricity to this day. These power plants transmit the generated electricity to different demand centers via transmission lines and the distance between the demand center and the centralized power-plant is often too long.

2.3 Differences Between Decentralization and Centralization

The main differences between CG and DG are proximity, efficiency, used resources, demand response, bidirectional electricity flow, prosumer engagement and electricity storage. In a DG system, electricity generation is close to the demand center. This increases efficiency because the amount of electricity is lost as far as it travels (Schonek, 2013). However, in a CG system, electricity is transmitted through long distances. The total amount of losses in electricity transmission and distribution was 8.26% in 2014 in the world (Indexmundi, 2014). This is also an important energy security issue since thousands of people rely on just one big power plant for their electricity. For example, in 2003, a shortage of electricity caused by overgrown trees and heat damaging a high-voltage transmission line in Ohio left about 50 million people without electricity in the United States and Canada. This event caused 11 deaths and cost $6 billion (Minkel, 2008).

The level of the proximity changes; it could be in a neighborhood level, in a district level or even in a street level (Hiremath et al., 2007). Modelers of DG propose tailor made solutions depending on the need of a specific location. There are two types of decentralized systems; grid connected and off-grid (Kaundinya et al., 2009). Grid connected applications are more frequent than off-grid applications. In a grid connected application, the system is connected to a local distribution company. The system could meet the local demand or just can feed the grid. If there is an insufficiency within the system, the local distribution company can provide the shortage that is needed for the system. However, there are remote places that are hard to reach and expensive to extend the grid to these places. These places are may be more suitable for an off-grid system (Sen & Bhattacharyya, 2014). Off-grid or stand-alone systems are dependent on local resources and it is concentrated on local needs. The operation may be seasonal due to production of local resources at hand. Stand-alone systems are not connected to a distribution network hence the excess electricity is needed to be stored for later use. Due to this reason, excess use of storage technology is needed to be provided in order for a continues use of electricity (Kaundinya et al., 2009). Since off-grid systems are completely free from a centralized power plant, a renewable based off-grid system could be much more beneficial for the economy and for the environment. However, with the existing renewable energy technologies and storage technologies at hand, the off-grid may be insufficient to meet the electricity demand.

Another difference is the sources that are used in a DG and in a CG. In a DG system, RES and CHP are used more frequently. There are even some definitions of DG that show RES as the mandatory resource for DG (e.g. Wolfram Jörß et al., 2003). The most common sources that are used in DG is solar PV, wind, hydro and biomass (Jörß et al., 2003). Hence, DG provides electricity generation with lower CO_2 emissions and GHG's. Centralized power plants, on the other hand, are commonly based on FF. Because FF emit CO_2, fossil based power plants stand out as large polluters of the environment. The pollution caused by centralized power plants is often too high that it effects human health, causes premature deaths, lost of working days and years of life lost. It is estimated that there will be 153 million premature deaths by the end of 21st century if mankind consume FF at the current rate (Collins, 2018).

Demand response is another important difference between DG and CG. In a DG system, demand of the consumers are taken into consideration. With the digitalization of electricity grid, consumption and production are monitored. Hence, the system can show the times when there is no electricity consumption, the electricity can be stored using storage systems. Also, when using RES sources in a DG, by using accurate forecasting, people can be encouraged to use electricity during high RES output. This can help integration of RES deployment by matching energy demand with the times when the sun is shining or the wind is blowing. People are made aware when there is peak of energy so that they could use their home appliances accordingly. New systems even show when the electricity from RES are at peak to encourage the use of RES. Thus, this way of using electricity increases efficiency. In the EU, the curtailment of solar PV and wind could be lowered by demand response and storage technology to 1,6% from 7% by 2040. This could help avoiding 30 million tons of CO2 emissions (IEA, 2017). There have been different kinds of DRES applications introduced into the power sector that increases efficiency. Digitalization of the system-smart grids- is an essential part that could increase efficiency in a DG. Smart grid is defined as “an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supply” (Ourahou et al., 2018). It differs from the conventional grid in many ways. Smart metering, information gathering and bidirectional electricity can increase efficiency in generation, transmission and distribution and prevent certain issues like downtime caused by overload (Bayindir et al., 2016). Smart meters, in terms of digitalization, is an important tool to achieve energy efficiency and RES integration. Smart meters can inform consumers of unusually high consumption, can make consumers aware of the consumption and production levels. These are important methods as consumers’ behavior may be shifted to more RES use (IRENA, 2019b). Energy efficiency and RES exist at a multiple level. Hence, it is important that these two concepts used together as they result in higher share of RES and reduction of energy intensity. Due to this reason, consumer behavior to reduce overall electricity is just as important.

In a DG system, electricity flow is bidirectional (Ourahou et al., 2018). This means that electricity can flow both ways. This enables prosumers to engage in electricity generation and to feed the greed. Prosumer engagement have been seen as a crucial aspect for a successful DRES application. However, in a centralized system, the electricity flow is unidirectional which do not allow prosumer engagement. Overall, the main differences between DG and CG are the resources used, bidirectional electricity flow, prosumers, demand response and being digital (Table 2.1).

Table 2.1 Differences Between CG and DG Systems

Centralized Generation	Decentralized Generation
Analog	Digital
Unidirectional	Bidirectional
Private Companies	Prosumers
Mainly Fossil Fuels and Hydro	RES and CHP
Supply Driven	Demand Response

2.4 Blockchain in the Energy Sector

Recently, the introduction of the blockchain into the electricity sector is seem as a game changer for the energy sector. A blockchain is a digital data structure, a shared and distributed database that contains a continuously expanding log of transactions and their chronological order (p. 145) (Andoni et al., 2019a). The importance of blockchain is that it fills the trust gap between transacting parties. Today, as it always been in the history of mankind, there is no trust between consumers and providers. To provide the trust between these two parties, there are middleman or intermediaries; third parties to provide trust between two parties in their transactions. Banks, credit agencies act as an intermediary and provide trust (Swan, 2015). In the blockchain system, the trust is maintained by other participants within the system. With the consensus of these participants, the transactions are verified and thus a new block that contains transaction data is created and chained to the blocks that have been created previously. Every participant in the system can access the data thus increasing the transparency of the system.

Today, blockchain applications spread out to become more than to serve cryptocurrencies. It is now used in many sectors such as health, banking, insurance and energy. In the conventional way, electricity generation, transmission and distribution involves large scale power plants, transmission system operator and distribution system operators work arduously. Blockchain simplifies this system by enabling peer-to-peer (p2p) electricity transactions. Thus, prosumers who generate their electricity from solar, small scale wind turbines or CHP could sell the excess electricity to their neighbors without any involvement from an intermediary like a bank or an energy company (PWC, 2016).

The transaction could be carried out using smart contracts like ethereum and the payments could be done through cryptocurrencies like bitcoin. All the transactions could be recorded on the blockchain, creating a secure and transparent community where prosumers and consumers could transact with each other and reach self-sufficiency (PWC, 2016).

The applications of blockchain in different sectors are very new. Hence, there are only a handful of applications in the world. The Brooklyn Microgrid is a good example for a blockchain application in the energy sector. There are many prosumers within the system who generate electricity from solar PV or CHP. The difference of this system from many other DRES comes from the enabled peer-to-peer transactions. The system is grid-connected; it is in the Con Edison Distribution Company's region. Thus, if there is an insufficiency within the system, the grid operator intervenes and feeds the grid. In this system, the consumers can choose from whom they buy the electricity. This transaction occurs without any third party's involvement like a distribution company or a bank. Two parties, the prosumer and the consumer, bid the buying and the selling price online. When the two price meet, the transaction occurs automatically. The payment could either be done via cryptocurrencies or cash payments; either way the transaction automatically gets recorded on the blockchain system. This system is encouraging people to participate in electricity generation process (Mengelkamp et al., 2018).

There are many views for the future of blockchain in the energy sector. According to reports of Deloitte and PWC, the energy sector will be radically changed by blockchain. According to a survey conducted by German Energy Agency among energy decision-makers, 20% of the respondents replied that blockchain will be a game-changer for energy suppliers (Andoni et al., 2019b). In a another survey conducted among experts, 49% of the respondents replied that blockchain is very important or important for the future of electricity (Schleich et al., 2018).

2.5 Future of Decentralized Energy

With all these developments, DRES is rising and is expected to continue to rise in the future. It is expected that in the future, DG will have an important place in the electricity generation process. According to a survey conducted among experts, roughly 50% of the interviewees from Europe, China and Africa agreed that the trend will go towards DG (Ren21, 2017). Also, experts from Australia, Oceania, Europe and from other international organizations agreed that consumers will become prosumers to a large extent in the future. However, experts from regions where the new installed electricity is mostly centralized, like experts from India, stated that the system will continue centralized.

DG will also be a solution to energy poverty that we see in the world. Today, there are 860 million people without no access to electricity (IEA, 2019b). Most of these people are located in India, Pakistan and Central African countries. Japanese experts agreed that DG is essential for providing one billion people who lack electricity (Ren21, 2017). Off-grid decentralization could be a solution for people who lack electricity and for people who live in rural areas (IRENA, 2019).

The transition to DG is already happening. With vast amount of policies, regulations, financing, investments and changes in the consumer behavior is accelerating this transition. In 2016, $717 billion was invested in the global power sector; 80% out of which is invested in RES, transmission and distribution. Energy efficiency improvements in the recent years is pacing up this transition towards DG. Again in 2016, $231 billion was invested in energy efficiency; 57% of it was invested in building efficiency technologies and systems (Owens, 2017).

In the future, with the falling cost of RES and meter solutions, the number of big projects will decrease and this will encourage the use of DG (World Energy Council, 2019). In 2000, the share of DG market was relatively small compared to today’s situation. The total DG consisted of 47 GW of installed capacity and accounted to 21% of the capacity additions (Owens, 2014). The total DG market size was $30 billion in 2000. In 2012, the installed capacity of DG increased to 142 GW, the share of capacity addition increased to 39% and the market share of the DG increased by 400% to $150 billion (Owens, 2014).

The distributed generation market is expected to have an annual growth by %15.5 between 2018-2024 (Energias, 2018). In 2020, it is expected that DG will account to almost 50% of the world's capacity additions.

2.6 Application Barriers

In order to establish a DRES, there is a certain process that the project needs go through. Usually this process requires several and often complex stages. The basic stages of DRES projects are authorization and permitting; interconnection; contracting; financing; and operation (Jörß et al., 2003). A DRES project is too dependent on external factors that a project developer has little or sometimes no control over. This makes a DRES system very difficult to implement. Because starting from the very first stages of DRES implementation, the system faces significant barriers. Due to this fact, today, a DRES application is very challenging. Because there are only a handful of applications in the world, the challenges and problems have not yet been addressed thoroughly and they differ from country to country.

Yaqoot et al. (2016) examines the barriers to DRES applications in five categories. These categories are technical barriers in which the resource availability, technology and skill requirement barriers are examined; economic barriers in which costs and market barriers are examined; institutional barriers in which policy, regulatory, infrastructure and administrative barriers are examined; socio-cultural barriers in which societal norms, awareness, lifestyle issues are examined; and environmental barriers in which environmental impacts associated with DRES use are examined (Table 2.2). According to Yaqoot et al. (2016) technical, economic, institutional and socio-cultural barriers are critical barriers. The barriers in this thesis are examined under the same categories which are mentioned as critical barriers by Yaqoot et al. (2016).

Table 2.2 Application Barriers of Decentralized Renewable Energy Systems

Source: Vezzoli et al. (2018)

Barrier	**Sub-barriers**
Technical	Resource availability; technology (design, installation and performance); skill requirement for design and development, manufacturing, installation, operation and maintenance
Economic	Cost; market structure; energy pricing; incentives; purchasing power and spending priorities; financial issues; awareness and risk perception
Institutional	Policy and regulatory; infrastructure (institutions for research, design and aftersales services); administrative
Socio-cultural	Societal structure; norms and value system; awareness and risk perception; behavioral or lifestyle issues
Environmental	Resources (land and water); pollution; aesthetics

2.6.1 Technical barriers

One of the most important barriers are the technical barriers that a DG face upon its application. Resource availability is one of the technical barriers. The electricity production of RES changes throughout the year. A system which is based on DRES may experience insufficiencies in its electricity generation due to intermittency issues of RES. If a country lack RES or have inconsistencies with the RES availability, this may hamstring the development of DRES. In this context, the inconsistency means that the electricity generation times from RES may be different from the time when the electricity demand is high. For example, in Ontario, there is a large capacity of wind peaks in the winter, however, the load demand peaks in the summer (Ren et al., 2017). Due to this reason, DRES may not be a preferred option to increase energy security.

The design of the DRES infrastructure is another technical barrier to DRES applications. As it is mentioned previously, a DG is based on bidirectional nature of the electricity system. The existing system may not be designed to enable the applications of DRES. The interconnection of generated electricity from DG to a central distributed system could cause malfunctions within the operations (Altmann et al., 2010). The effects of a DG depend on the scale and the design of the DG; the type of RES that used; interactions with other DG's or loads; and location and the characteristic of distribution (Uzun, 2015). Thus, the infrastructure may need to be changed in order pave the way for a DRES. The interconnection of RES to the existing transmission and distribution network is a difficult challenge.

For the deployment of DRES, the storage technology that is available is very crucial. Today, most of the battery technologies are in their infant phases and they need further improvement. There are many R&D projects working to improve this technology. Also, the existing technologies may differ from region to region and from country to country. For example, in Sri Lanka, the battery and solar PV performances are lower compared to its neighbors India and Bangladesh (Karakaya & Sriwannawit, 2015).

In addition to these reasons, the DRES technology is still in an infant phase in many countries. Lack of knowledge and lack of skilled workers to work in this area are standing in the way of DRES (Yaqoot et al., 2016).

In order to offset the technical difficulties faced when establishing a DG, there should be many measures taken. For resource availability and intermittency issue, accurate resource assessment is need to made (Yaqoot et al., 2016). To be able to choose the optimal mix for generation; digitalization and future forecasting is very important. An energy company in the US, in conjunction with National Center for Atmospheric Research, developed a wind energy forecast system that predicts the weather 35% better than the previous models (Deloitte, 2018). Developments like this is important for the reliability of DRES applications.

Basically, it all comes down to R&D investments and expenditures that enhance the grid capability. This include increasing product efficiencies, training capable workers and streamlining the resource interconnection into the system. In order to achieve these, many countries are establishing pilot projects to increase the DG share in their electricity system. An energy company in the USA started a pilot project where grid stability was increased through visualizing DG and load in the grid (Deloitte, 2018).

In terms of blockchain applications, the newness of the technology is a barrier. Because blockchain is a fairly new concept, its applications in the energy sector face technical and legal challenges. There are only few applications in the world, hence there is not enough expertise. For new blockchain startups, one of the biggest challenges is the lack of skilled workers (Lee, 2018). The technology also has been viewed as to complex to implement. Due to this reason, it is unclear the determine the return on investment of blockchain applications (Sadhya and Sadhya, 2018). Cost and performance issues are also hindering the growth of blockchain applications (Browne, 2018).

Scalability of blockchains is another issue that needs to be solved. In a blockchain system, every block could contain a specific amount of data. This means that there could only be a limited number of transaction recorded on each block. Considering all the data from electricity meters and transactions in a blockchain based decentralized energy system, there will be high amounts of data that needs to be stored. Consensus mechanism in blockchain systems handling big data can cause delays for transactions to be met (Hertz-Shargel and Livingston, 2019).

2.6.2 Economic barriers

Economic barriers are mainly the costs incurred by DRES. The initial investment and maintenance cost for RES are high in many countries and payback periods are too long. Also, for some countries, RES equipment needs to be imported from other countries which adds on the initial costs for these resources. For example, in Vietnam, the main barrier to wind power installments is the high investment costs which was as high as $2.3 million/MW (Nguyen et al., 2019). In Nigeria, most of the solar PV is decentralized, however the applications are hampered by the high initial costs (Ohunakin et al., 2014). As it is mentioned, energy efficiency applications and products are essential for the application of DRES; however, energy efficiency products also have high costs in many countries.

In many countries, RES and DRES projects are not well financed. As it is mentioned in the previous paragraph, DRES projects often comes with high initial costs. Despite this fact, there are not sufficient credits or loans channeled to these projects. Local financial institutions, like local banks, do not provide affordable financing (Vidal, 2018). The lack of data and sector knowledge often prevents these institutions to finance decentralized energy. High capital costs offered by local banks also hampers the growth of DG. The financing from international institutions for RES is also not well channeled (Vidal, 2018).

The financing of clean energy project in poor and developing countries are often slow or not delivered at all due to developed countries backing of from their pledges.

R&D investments are also important for economic barriers. There should be funds directed to R&D investments and these investments should focus on cost reduction of DG applications (Yaqoot et al., 2016). Currently, there are many projects aiming at increasing the efficiency and reducing cost of the applications. For example, an energy company in the UK developed a smart inventory system which helped the company to save £5 million. This system acquires data from the previous inventory usage and provides an optimal inventory (Deloitte, 2018).

2.6.3 Institutional barriers

One of the most important challenge for DRES applications is the energy market structure. Today, many countries give incentives for RES applications; however, these incentive sometimes cannot compete with the incentives that are given to FF (Yaqoot et al., 2016). In many countries incentives make FF combustions to have a significant share in electricity mix today. This is expected to continue in the future. For example, in Australia, federal government are giving too many incentives to coal production (Da Silva, 2018). In Indonesia, the government is taking too many actions to support the growth of coal within the country and plant to add new coal power plants until 2027 (Roker, 2018). Although these governments are also giving incentives for RES, the coal incentives and production are staggering the growth of RES deployment.

Institutional barriers are arising from lack of legal framework such as difficult procedures of installing RES, lack DG strategy, uncertainty of the renewable energy market etc. The current legal status in many countries are not suitable for DRES applications or it slows the process of these applications. For example, in Russia, the regulatory framework is poorly designed to enable distributed generation (Brilliantova and Thurner, 2019). Another institutional barrier is, as it is mentioned in the previous paragraphs, in many parts of the world, there is a lack of information in the RES sector (Yaqoot et al., 2016). The information available for renewable energy sector is much less than information available to other resources.

To be able to offset the market barriers, the RES should be compatible with FF. Hence, the government should provide long-term incentives to RES like subsidies, tax breaks and reduced import duties. Prosumers who generate electricity from RES should also receive higher incentives from the governments. There should be effective financial schemes to increase the usage of RES like soft loans and grants. Micro-credit facilities should be established to help the people install RES. In addition to incentives to RES, the government should also establish disincentive policies to limit the usage of FF (Yaqoot et al., 2016).

In order to overcome the institutional barriers, the essential step is to set up policymaking agencies for DRES applications. The communication of these agencies with business stakeholders and other institutions is crucial. These stakeholders should also be a part of the decision making process. The DRES policies should be determined all together and these policies should be integrated into the development program of the countries (Yaqoot et al., 2016).

For blockchain applications, the biggest challenge to blockchain in the energy sector comes from the legal part. Within a blockchain system, p2p electricity transaction is enabled; the electricity generated by prosumers is sold directly to consumers and the transactions are carried out using smart contracts. Smart contracts differ from conventional contracts in many ways. In order to be legal in many legal systems, a contract should contain the followings; offer and acceptance, consideration, intentional to create legal relations and certainty of terms. The usage of blockchain and thus smart contracts may interfere with these concepts. First of all, for a contract to be legally binding, there has to be a proof of a signature. This means that there has to be a wet-ink signature for a contract to be accepted. This also needs to be documented for that it could be legally valid. There has to be a signed paper version of a contract, however, contrary to this aspect of a conventional contract, a smart contract consists of pages of codes which makes blockchain and smart contracts to be harder to implement. Although paper documentation is not always the case since some agreements could also be done orally. Finally, it comes down to what court determines what a contract is (Norton Rose Fulbright, 2017).

2.6.4 Socio-cultural barriers

Socio-cultural barriers generally arise from public perception of RES and DRES. Socio-technical reasons could also be categorized under the “socio-cultural” title. Since the use of FF are widespread, the acceptance of RES is still questionable; people may still prefer FF over RES. This is a crucial barrier since public -namely prosumers- are important aspects for the successful implementation of DRES. In general terms, main problems of the public perception of RES are lack of information about the economic and ecological benefits; lack of information about RES technology; and concerns about the feasibility of RES projects (Seetharaman et al., 2019).

On the other hand, socio-technical barriers could arise from the lack of knowledge on how to use the RES technology (Karakaya and Sriwannawit, 2015). Improper usage or maintenance of RES could affect the production from these resources. For example, in China, the incorrect usage of solar panels is breaking the trust of the public towards solar PV. This also prevents new customers from adopting RES.

Also, there are concerns about the productivity of RES. This concern arises from the intermittent nature of these resources. In Ethiopia, non-functional system during rainy times cause fear among the people that prevents them from purchasing solar PV. The discouragement to RES also comes from the mistrust to certain renewable products; people might prefer some brands or some country products to others. For example, again in Ethiopia, there is a mistrust to RES products from Asia, specifically for the goods from China.

Some people also stand against the installations near where they live. Not in my backyard (NIMBY) syndrome makes people oppose the certain energy installations within their community. Although NIMBY often opposes FF generation plants, in some cases it opposes RES installments. Since distributed generation often takes generation into a street level, NIMBY sometimes causes setback in RES developments.

To overcome the socio-cultural barriers, people should be made aware of the benefits of DRES and the harmful effects of FF usage to people’s health and to the environment. Again, local stakeholders should be consulted for raising awareness. The needs of the end-user are essential to raise awareness. Also, the public should also be made aware of energy efficiency measures to implement them in their daily lives. Altogether, demonstration programs should be organized to make people more aware of the importance of DRES and energy efficiency measures (Yaqoot et al., 2016).

Lack of knowledge also appears as a negative public view for blockchain. Although blockchain started off as a distributed ledger for “bitcoin”, blockchain and bitcoin do not mean the same thing. However, people perception of the blockchain technology is usually the same as bitcoin. Due to this reason, the criminal activities that have occurred in the recent years with bitcoin are attributed to the blockchain (Sadhya and Sadhya, 2018). Hence, even though blockchain provides secure network, people may not agree with the security of the technology.

3. OVERVIEW OF TURKEY'S ENERGY STRUCTURE

Turkey is a fast developing country; the GDP growth of the country was 7.4 percent in 2017 (World Bank, 2019b), making Turkey one of the biggest growing countries in the world. In line with its growing economy, Turkey has a high energy demand growth. In fact, the growth rate is the highest among OECD countries in the last 15 years (MFA, 2019); the energy demand growth rate was 9.5% in 2017 (BP, 2018). However, one of the most critical energy problems, and also an economical problem, that Turkey has today is the energy dependency problem. The country lacks any sufficient energy resources thus it has to import from outside in the form of mainly oil and gas. Turkey is able to meet only 26 percent of the total primary energy supply (MFA, 2019). In terms of electricity, in 2017, the installed capacity was 87.139 MW (ETKB, 2019a). The electricity generated in 2017 is from natural gas (37%), coal (33%), hydro (20%); the total contribution of fossil fuels was roughly 70 which is mostly imported (TEİAŞ, 2019b). However, only 65.2% of coal, 5.9% of oil, and 0.7% of natural gas consumption are produced domestically and the rest is imported (ETKB, 2018). Energy imports have one of the highest shares in total imports of the country by roughly 19% totaling up to $49 billion (TE, 2019)[1]. Hence energy imports create a significant burden for Turkish economy.

Turkey's economic growth and rapid urbanization has brought serious air CO_2 emissions. In line with its high FF usage in its electricity generation, the CO_2 emission are increasing. In fact, Turkey's CO_2 emissions growth is one of the highest in the world. In 2017, CO_2 emissions rose by 12,7 percent; this percentage of growth was the second highest in the world after Estonia. Turkey's share in total CO_2 emissions in the world has been constantly rising; the share was 1.2% in 2017 (BP Energy, 2018).

Fossil fuel powered thermic power plants have a significant share in Turkey's electricity generation. There are 401 fossil-based thermic power plants in Turkey with a total installed capacity of 45.862 MW which corresponds to 52% of the total installed capacity. Among these power plants, natural gas has the highest installed capacity with 316 power plants corresponding to 28.8% followed by lignite and imported coal which correspond to 10.8% and 10% respectively. Non-fossil based resources consist of dams and river

[1] Energy imports; Mineral fuels, oils, distillation products

hydropower which have 120 and 538 power plants respectively. Solar has the highest number of power plants in Turkey however corresponding to only 5.8%. Among RES sources, wind has the highest installed capacity by 7006 MW corresponding to 7.91% (Table 3.1) (TEİAŞ and TÜBİTAK, 2019).

Table 3.1 Number of Power Plants and Installed Capacity by Source in Turkey Source: TEİAŞ and TÜBİTAK 2019

Source	Number of Power Plants	Installed Capacity (MW)	Share of Total Installed Capactiy
Natural Gas	316	25,588	28,88%
Dam	120	20,536	23,18%
Lignite	48	9,597	10,83%
Imported Coal	14	8,939	10,09%
River	538	7,755	8,75%
Wind	250	7,006	7,91%
Solar	6009	5,180	5,85%
Geothermal	48	1,303	1,47%
Fuel Oil	16	709	0,80%
Biomass	144	648	0,73%
Bituminous Coal	3	616	0,70%
Asphaltite	1	405	0,46%
Waste Heat	68	322	0,36%
Naphtha	1	5	0,01%
Diesel	1	1	0,00%
LNG	1	2	0,00%
Sum	**7578**	**88611**	**100%**

These power plants are big contributors to the country's electricity generation as well as its CO_2 emissions and its air pollution. The levels of SO_2, NO_2 and PM10 are at critical levels at some municipalities creating health hazards for the public. Data retrieved from 20 air quality monitoring stations show that SO_2, NO_2 and PM10 levels are significantly high and exceed the EU limit value (Büke and Köne, 2016). In Turkey, the biggest reason for the CO_2 emissions is the power sector, followed by industrial combustion, building and transport (Muntean et al., 2018)

Despite its high and growing CO_2 emissions and rising air pollution, Turkey is acting poorly against fighting CO_2 and taking action against global climate change. Even though country signed several international treaties to combat climate change, there is no important binding treaty that limits the CO_2 emission in Turkey. The country has yet to develop a major long term low emissions development strategy and other GHG reduction targets for the future (Climate Transparency, 2017). Turkey has submitted to Intended National Determined Contribution (INDC) in which Turkey's planned GHG reduction target is below 21% in the business as usual scenario. However, Turkey's action shows otherwise and do not come near the targets to achieve a warming below 2 degree Celsius. Climate Action Tracker, a research organization, rates Turkey's effort as critically insufficient to reach climate targets which means that if all countries were to take similar actions, the warming would be at 4 degree Celsius (Climate Action Tracker, 2019a).

One of the biggest reason why Turkey is not capable of meeting its GHG targets is its coal policy. Turkey has 66 coal (or coal derivatives) fire power plants with a total installed capacity of roughly 19,000 MW. These coal power plants are huge contributors to air pollution and GHG emissions. CO_2 emissions from coal was 156.8 million tones which is 156.2% higher than 1990. The CO_2 from coal consumption also exceeds the emission from natural gas and oil consumption (IEA, 2019a). However, in addition to the existing coal power plants, Turkey is now aiming at building new ones.

One of the biggest ambition in the field of energy is obviously securing the supply of energy. Electricity Energy Market and Supply Security Strategy Paper, which was published in 2009 stated the drive for the utilization of national resources. The strategic plan for between 2015-2019 put too many emphases on the national energy in order to secure energy supply. Within this regard, in order to increase the share of national resources, RES have been seen as an important option. However, there are also too many emphases given on the use of fossil fuels such that the utilization of coal is seen as an important source to become more self-sufficient in electricity generation (ETKB, 2009). In line with this policy, there have been many incentives given to coal production. Today, while many countries in the world are phasing out coal power plants, Turkey is building new coal power plants every year. Turkey has installed 9.935 MW of coal power since 2006, ranking Turkey at 11th in the world in new coal installations (Figure 3.1) (EndCoal, 2019c). This number will increase in the future since Turkey is planning on adding new coal fired power plants. As of January, 2019, the number of announced, pre-permitted and permitted coal power plants is 34 with a total capacity of 36.666 MW. With this amount of capacity installations, Turkey ranks 3rd in the world after China and India (EndCoal, 2019a, 2019b).

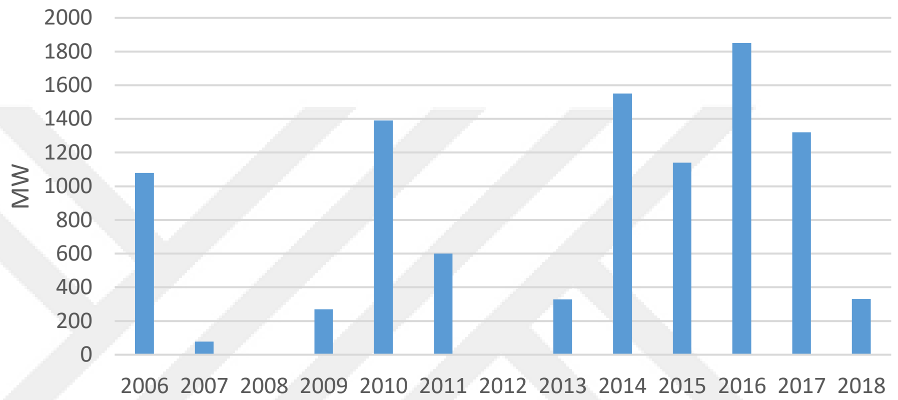

Figure 3.1 Coal Power Plant Installations by Year – Turkey
Source: EndCoal (2018)

The country also invests in natural gas for its energy security. However, because Turkey lacks major natural gas reserves and produces only 0.7% of its demand domestically. However, natural gas in electricity generation is planned to be increased and the sources of supply is planned to be diversified. Also, Turkey plans to build natural gas storage facilities because it is situated between Europe and Asia, the country want to take full advantage of being the natural gas route in the region (ETKB, 2017a).

In addition to these power plants, Turkey is also aiming at installing nuclear power plants. To contend with the energy demand, Turkish government has long been considering nuclear power plants. Negotiations began between Russia and Turkey for a nuclear power plant to be built in Mersin, a city south of Turkey. The construction of the power plant has begun and the intended installed capacity is 4800 MW which will be the biggest electricity power plant in Turkey (Akkuyu Nükleer, n.d.).

Even though there is high dependence on fossil fuels and foreign energy, Turkey has achieved important renewable energy deployment in the last decade. With new policies that incentivize the installations of RES and with support mechanisms, their installments are made easier. In fact, Turkey had one of the fastest growing markets for renewable energies. In the last decade, installed capacity of renewable energies increased dramatically. Turkey added 3.995 MW of installed capacity in 2018; reaching a total installed capacity of 88.526 MW. Over 90% of the new installed capacity came from RES. The installed capacity of RES has risen dramatically compared to 2017 and compared to 10 years ago. In 2018, installed capacity of biomass increased by 31% percent, geothermal by 18%, hydro by 4%, solar by 85% and wind by 7% (TEİAŞ and TÜBİTAK, 2019).

The electricity generation from RES are far below the country's RES potential. Although the total economic potential for RES is 138,000 MW; total installed capacity of RES is at 42.428 MW (Ozcan, 2018). When RES are examined separately, the potential is 50.000 MW for solar, 48.000 MW for wind, 36.000 MW for hydro, 2000 MW for geothermal and 2000 MW for biomass. The government has set ambitious target for 2023, increasing the installed capacity for RES. Although the installed capacities of RES remain short of the 2023 target, solar target has already been reached (Table 3.2).

Table 3.2 Renewable Energy Potential and Installed Capacity

Source: Ozcan (2018)

Source	**Potential (MW)**	**Installed Capacity(MW)**	**2023 Target**
Hydropower	36,000	28,291	34,000
Wind	48,000	7,006	20,000
Solar	50,000	5,180	5,000
Geothermal	2,000	1,303	1,000
Biomass	2,000	648	1,000
Total	**138,000**	**42,428**	**61,000**

4. DECENTRALIZATION AND CENTRALIZATION IN TURKEY

There have not been many studies to conclude the decentralization and centralization in Turkey. In order to show the DG and CG in Turkey, different methods are used in this thesis. CG in Turkey is shown in the first part of this chapter (Chapter 3.1). To show the CG in Turkey, the electricity generation and consumption of each city is taken. By looking at the differences of electricity generation and consumption, it is argued that cities in which electricity consumption exceed electricity generation, there is not local production. Likewise, it is argued that cities in which electricity generation exceed electricity consumption have centralization. In order to prove the centralization of RES, the 2010 report “Decentralized Energy Systems” by European Parliament was also taken into consideration (Altmann et al., 2010). In this report, there are certain capacity limits for energy sources to be DG. Hence, it is argued in this chapter that power plants which exceeds the limits explained in European Parliament report are centralized power plants.

In the second part of this chapter (Chapter 3.2), the policies toward DRES applications in Turkey are shown. These policies are commonly parallel to RES policies. The related policies are gathered from related regulations and strategy papers. The most important point in this chapter is the goal set out in unlicensed generation regulation. The goal of this regulation is to increase “on site” generation from RES. Because this regulation emphasizes local generation, unlicensed generation in Turkey will be shown when showing the decentralization situation in Turkey.

4.1 Centralized Generation in Turkey

The first power plants in Turkey dates back to the Ottoman Empire era. In 1902, 2 KW power was generated through a generator connected to a wind mill and electricity supply started in Tarsus, Mersin (Turgut and Selçuk, 2016). Widespread usage of electricity started in 1913 with Silahtarağa power plant in Istanbul. The electricity from this power plant was transmitted to another district in Istanbul via 15 kv transmission line. Switch to interconnection systems started in 1945 as the electricity transmitted via 66 kv transmission lines between Ereğli and Çatalağzı in Zonguldak. With further developments, the centralization of the electricity increased gradually.

Today, Turkey's electricity generation mainly comes from centralized power plants which are unevenly located throughout the country. The biggest electricity consuming cities are located of the west of country while electricity generation is spread across the country. Looking at the electricity generation data and invoiced consumed electricity, many cities get their electricity from other cities. Out of 81 cities in Turkey, 37 cities' consumption exceeds their generation by large amounts. In top five electricity consuming cities, these ratio reaches 480,5% in Istanbul, 88,7% in İzmir, 137,8% in Ankara, 141,2% in Bursa and 169,6% Kocaeli. Among these cities, İzmir is the only one with the electricity consumption lower than electricity generation (Table 4.1).

Table 4.1 Invoiced Consumption to Generation Ratio[2]

Cities	Invoiced electricity consumption (TWh)	Total electricity generation (TWh)	Invoiced consumption to generation ratio
İstanbul	40,45	8,42	480,5
İzmir	16,46	18,56	88,7
Ankara	14,31	10,38	137,8
Bursa	11,82	11,82	141,2
Kocaeli	10,26	10,26	169,6

The electricity consumption exceeds the electricity generation in 37 cities and the electricity generation exceeds consumption in 44 cities. The difference between electricity generation and consumption varies. The difference is highest in Çanakkale, Zonguldak, Adana, Sakarya and Hatay are the largest producers in Turkey (Figure 4.1). Power plants in these cities are mostly based on imported coal and they range up to 2,790 MW (Imported coal power plant in Zonguldak). Other most used resources are Lignite and Hydro[3].

[2] The data is collected from monthly sectoral reports of EPDK. The electricity generation and consumption data from sectoral reports of every month in 2018 were used. Retrieved from: https://www.epdk.org.tr/Detay/Icerik/3-0-23/aylik-sektor-raporu

[3] Data is retrieved from: https://www.enerjiatlasi.com/

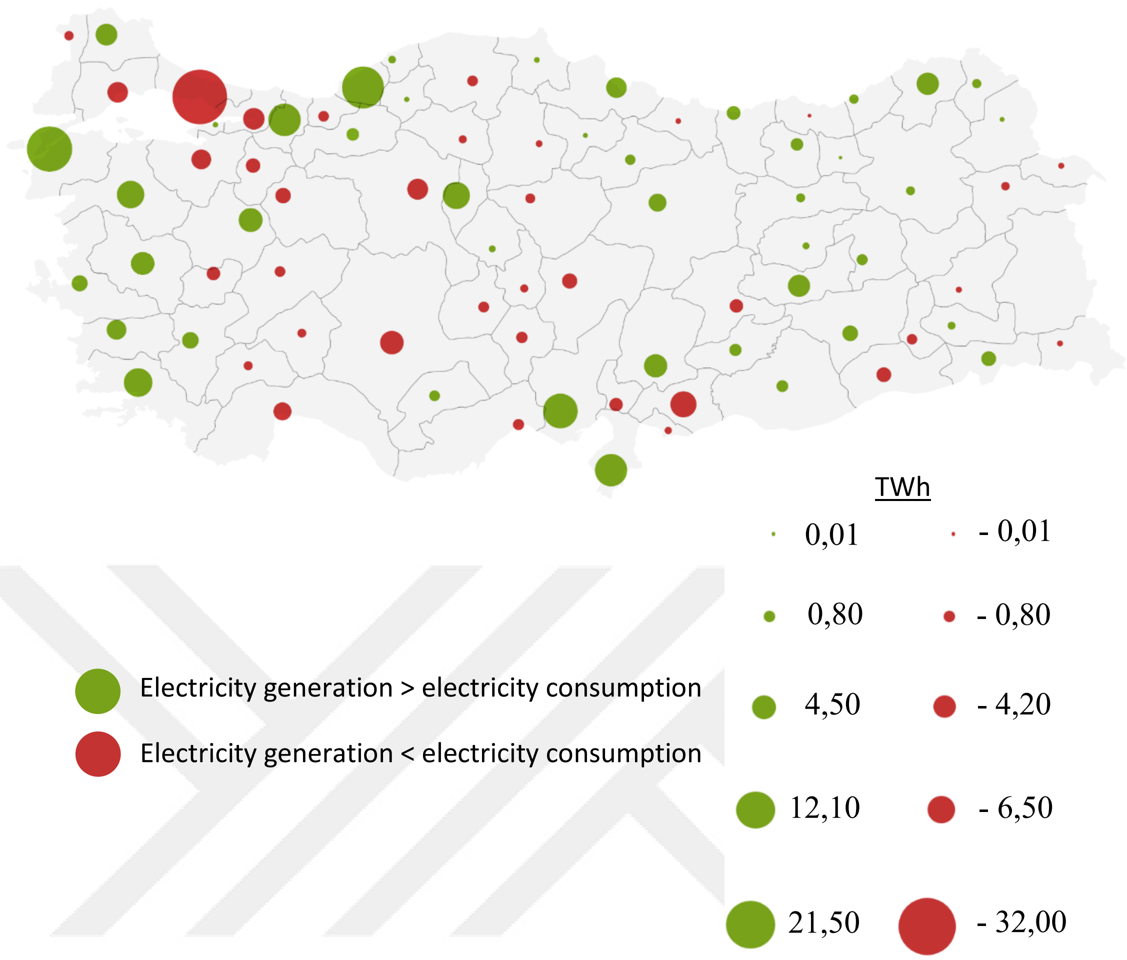

Figure: 4.1 Difference Between Electricity Generation and Consumption[4]

This situation requires a long-distance transmission of electricity. In Turkey, the total electricity transmission could reach up to hundreds of kilometers; even so that, Turkey's total transmission lines reaches 66.285 km (TEİAŞ, 2017a). Out of these transmission lines, 23248 km are 380 kv which are high voltage line which are used to transmit electricity from longer distances and to transmit higher amounts (Figure 4.2). Considering the layout of the high voltage lines in Turkey, it is clear that high voltage lines are situated to carry electricity from cities with lower electricity consumption to the cities with higher electricity consumption. This of course creates a huge burden for the Turkish economy

[4] The green circles indicate that the difference between electricity generation and consumption is positive. The red circles indicate that the difference between electricity generation and consumption is negative. The bigger the circles are, the bigger the absolute value of the difference. The data is collected from monthly sectoral reports of EPDK. The electricity generation and consumption data of every month in 2018 were used. Retrieved from: https://www.epdk.org.tr/Detay/Icerik/3-0-23/aylik-sektor-raporu

since it is expensive to build the infrastructure and because of the losses of electricity during transmission due to long distances. In Turkey, of the total electricity generated, 1.7% was lost in transmission and 10.2% was lost in distribution (TEİAŞ, 2019a). Although the distance cause significant loses in transmission and distribution, one of the biggest reasons for the loses is electricity theft. Within some regions in Turkey, electricity theft reaches as high as 70% causing billions of dollars.

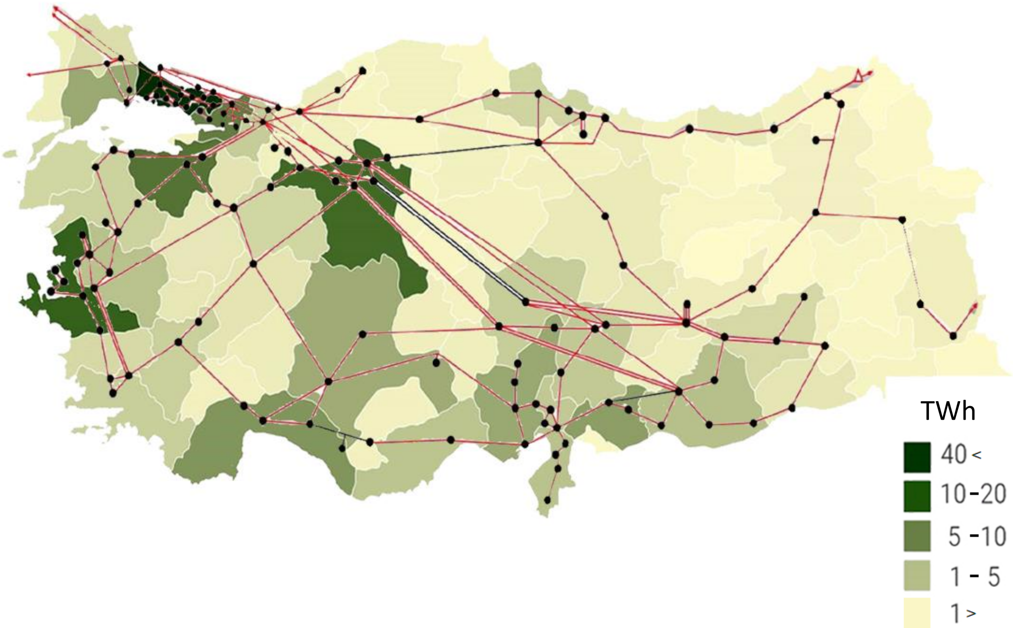

Figure: 4.2 Consumption by City and the Layout of High Voltage Transmission Lines (380 Kv)[5]

According to the report of European Parliament (Altmann et al., 2010), DG described as microgeneration with capacities lower than 3 MW for solar PV, 1 MW for small hydro, 6 MW for wind, 3 MW for geothermal and 10 MW for biogas plants. In Turkey, the percentages of power plants within these limits are 86% for solar, 7% for hydro, 15% for wind, 4% for geothermal, and 87% for biogas (Table 4.2). Solar is one of the most important energy sources that people could easily engage in. Even though the solar PV within limits are at 86%, the total solar installed capacity is quite low.

[5] The data for the map is collected from monthly sectoral reports of EPDK. The transmission lines map is interpreted from: http://www.emo.org.tr/ekler/91c64a4f58f3c88_ek.pdf?tipi=2&turu=X&sube=14

Table 4.2 Percentages of RES Power Plants Above EU's DG Limits[6]

Energy Source	DG Limits	Percentage of Power Plants Above Limits
Solar PV	< 3 MW	14%
Hydro	< 1 MW	93%
Wind	< 6 MW	85%
Geothermal	< 3 MW	96%
Biogas	< 3 MW	13%

4.2 Decentralized Energy Policies in Turkey

Until 1970, the electricity generation, transmission and distribution process was led by the state. However, after 1970, the liberalization of electricity market began. Liberalizations kept happening until 2001; it was decided to assign every step of the electricity generation process, from the producer to consumer, to private entities. Today, after certain processes, applicants can acquire license to engage in generation and distribution activities. Certain processes include the necessity of forming a company (Çınar, 2018).

There have been many policies towards increasing the share of DRES in Turkish electricity mix. Liberalization of the electricity market was an essential step towards increasing DRES. Regarding RES, DRES and energy efficiency, it is important to look at regulations and action plans published on this field. The most relevant regulations and action plans is shown in table 4.3 and furthers described in detail in this chapter.

[6] Definition containing DG limits retrieved from: http://www.europarl.europa.eu/document/activities/cont/201106/20110629ATT22897/20110629ATT22897EN.pdf
Scale of RES powerplant retrieved from: https://www.enerjiatlasi.com/

Table 4.3 Policies Towards RES, DRES and Energy Efficiency

Date	Publishing	Type	Details
5.10.2005	Renewable Energy Law	Regulation	- Feed-in Tariff for renewable energy generation
18.04.2007	Energy Efficiency Law	Regulation	- Energy efficiency certificate for buildings - Energy efficiency and renewable energy awareness - Support for energy efficiency
2.10.2013	Unlicensed Electricity Generation Regulation on Electricity Market	Regulation	- Removing the obligation of forming a company - Electricity generation up to 1 MW for unlicensed applications
12.05.2019	Unlicensed Electricity Generation Regulation on Electricity Market: Amendment	Regulation	- Electricity generation up to 5 MW for unlicensed applications - Direct connection of small scale solar PV (3-10 kW) - Net Metering scheme for unlicensed power plants
2.07.2013	10th Development Program	Action Plan	- Energy efficiency of buildings - Importance of decentralized generation ("on site generation") and cogeneration - Increasing the share of RES in electricity mix
1.12.2014	Renewable Energy Action Plan	Action Plan	- Importance of legal change - Importance of decentralized renewable energy generation
4.12.2014	Strategic Plan for Energy Ministry	Action Plan	- Easing of approval and permit processes for DG - Infrastructure building for RES interconnection - Increasing DRES applications
1.11.2017	National Energy Efficiency Action Plan for 2017-2023	Action Plan	- Energy efficiency of new buildings - Removing barriers for RES applications - Obligations of cogeneration

In order to do increase RES output and to improve clean and self-sufficient generation, renewable energy support mechanism (YEKDEM) was introduced in 5.10.2005 with the law no. 5346 “Renewable Energy Law”[7] which enabled the foundations of the RES supports in Turkey. This is basically feed-in tariff that is provided to encourage RES installations. YEKDEM provides purchase guarantee for 10 years for completed installations until 31 December 2020 (EPDK, 2018d). Wind, solar, geothermal, biomass, gases from biomass including landfill gas, hydroelectric power plants including wave,

[7] Official Gazette No: 25819 dated: 18.05.2005

stream, tide or dams with reservoir areas smaller than 5 km^2 can benefit from YEKDEM. The purchase guarantees are 7,3 cents/kWh for hydroelectricity and wind; 10,5 cents/kWh for geothermal and 13,3 cents/kWh for solar and biomass. Both licensed and un-licensed power plants can benefit from these purchase guarantees.

As a part of the RES incentives, Turkey now prioritize the domestic production of RES equipment. There are extra incentives for the people who use domestic RES parts in their installment will have extra incentives. The rates are 2,3 cents/kWh for hydro; 7,3 cents/kWh for wind; 6,7 cents/kWh for geothermal; 9,2 cents/kWh for biomass; and 5,6 cents/kWh for solar (Table 4.4) (Shura, 2018).

Table 4.4 RES FIT Mechanism

Source: Shura (2018)

Renewable Energy Source	Feed-in tariff rate (USD Cent)	Domestic part support (USD Cent)	Total support (USD Cent)
Hydroelectricity	7,3	2,3	9,6
Geothermal	10,5	6,7	20
Solar	13,3	5,6	18,9
Wind	7,3	3,7	11
Biomass	13,3	9,2	22,5

With the “Renewable Energy Law” of 2005, there was a limit for licensed solar applications at 600 MW. The small amount of solar applications was reached this limit. Another support for RES that entered into force with the “Renewable Energy Law” is Renewable Energy Resource Areas (RERA). According to the RERA policy, the state determines areas for private companies to install RES. The companies make bids to make an investment in the subject areas. The companies that make their bid need to guarantee that they use domestically produced equipment or produce their own equipment domestically. This is an important step for making the production domestic (Boden Law, 2019).

One of the most important steps towards DG is the " Unlicensed Electricity Generation Regulation on Electricity Market" which was put on force on 02.10.2013[8]. It is mentioned in the first article of the regulation that the goal of the regulation is “to provide electricity to consumers from nearby producing plants, to expand small scale power plants in the country, to minimize the losses in the electricity grid and to remove the obligation to form a company to generate electricity” (EPDK, 2019a). Nonetheless, the main goal of this regulation is to increase the use of RES. With this regulation, people were able to generate electricity only up to 1 MW, which was increased to 5 MW with changes on Unlicensed Electricity Generation Regulation on Electricity Market" on 12 May, 2019 (EPDK, 2019a)[9]. Although the definition laid out by European Parliament suggests different limits for DG and CG, it is important to look at unlicensed installations lower than 5 MW, since the description put out by Turkish authorities show similarities with the EU’s DG definition. Unlicensed applications will be shown in chapter 3.3.

“Energy Efficiency Law”[10] (law no. 5627) introduced in 2007 and aimed at increasing energy efficiency and decreasing overall energy consumption in industrial and residential buildings, raising awareness among people and utilizing RES. The most important part of this law is that the requirement of building residential building with energy efficiency measures. The buildings without the “energy performance certificate” cannot get a permit. This is an important step for DRES since overall energy consumption of residential and industrial building are lowered.

In the 10th development program of the government for 2014-2018[11], the importance of energy efficiency in buildings and industry is emphasized. It is aimed that the energy efficiency of the buildings increased and the required support mechanisms are established in order to do so. Important aspect alongside energy efficiency was DG – in the report it is referred as “on site generation”- and cogeneration. The plan was to increase RES share in total electricity mix, make use of heat waste in coal power plants as cogeneration and increase efficiency in buildings and industry. The policies related to DRES and RES in this development program are; increasing the governance in the energy markets;

[8] Official Gazette No: 28783 dated: 02.10.2013
[9] Official Gazette No: 30772 dated: 12.05.2019
[10] Official Gazette No: 26510 dated: 18.04.2007
[11] Official Gazette No: 28699 dated: 06.07.2013

privatization of a big portion of electricity generation power plants and of all distribution grids; increasing the diversification in electricity generation and increasing domestic and renewable sources in electricity mix; making the necessary investments for the successful integration of RES sources without risking the energy security; increasing the energy efficiency in all sectors; rehabilitation of hydroelectric power plants and decreasing the losses in electricity transmission and distribution. The other policies included in this development program are utilizing domestic coal reserves for electricity generation; the completion of regulative and corporate processes for nuclear energy generation; increasing the inspection in the energy sector for pricing of electricity. One of the most important policy is the building of necessary infrastructure for making Turkey an energy hub.

In the National Renewable Energy Action Plan For Turkey published in 2014 by the Energy Ministry (EPDK, 2014), decentralized generation based on RES has been mentioned several times and in the 4th section of the plan, it was stated that there is a need for legal change for increasing DRES. It is suggested that the aim of the legal change should be easing the procedures and processes to investors and individuals who want to engage in electricity generation. In order to achieve this, the need for evaluating the grid interconnection, stabilization in these systems and digitalization of the grid was also mentioned. The action plan provides vast policies to facilitate RES growth in Turkey. There is a detailed policy roadmap until 2030. The policies on DRES include the continuation of feed-in tariffs; easing the procedures in order to facilitate RES installments and also decrease the costs of procedures; developing the directive of 2010/31/EU dated 19 May, 2010 in order to increase energy performance of buildings and to encourage DRES applications in residential buildings, developing renewable energy cooperatives, tax exemptions for biofuels. (ETKB, 2014b).

In the strategic plan of the Energy Ministry for 2015-2019 (MENR, 2014), the importance of DG also has been emphasized and a goal was set for the future in this reports. In the 4th goal's 7th objective, it was stated that; the approval and permit processes will be eased; the needed infrastructure will be provided for the system integration of intermittent RES; monitoring and screening systems will be established for the new RES projects; to enhance DRES, cogeneration and microgeneration facilities and ease the processes to have more “on site” generation. Through these policies, it is aimed that the losses in electricity transmission and distribution will be minimized. The goal was to have "on site" generation up to 1.000 MW (ETKB, 2014a).

The most recent action plan that included DG was published in November, 2017 which is called "National Energy Efficiency Action Plan for 2017-2023"[12] (ETKB, 2017b). As it is mentioned, in the buildings have the highest share in electricity consumption in Turkey. In addition to the existing buildings, there are 100.000 more buildings added. It is stated in the action plan that the new buildings should be built with energy efficiency standards. It is mentioned that buildings in Turkey has high RES and DG potential. The goals related to DG are: removing the barriers of RES in order facilitate their use in buildings; facilitating the interconnection of buildings with solar PV with the gird; regulations for the purchase of decentralized electricity and heat; efficient use of cogeneration facilities; raising awareness for the benefits of RES and cogeneration; for industrial buildings with a need for heat over 20 MW will be obliged to make feasibility studies for cogeneration in order to have DG and reduce transmission and distribution losses.

In the end of 2018, tax exemptions were also brought to RES applications under certain criteria with a new law. RES applications for organized industrial zones and small industrial areas were made free of value added tax (Yeşil Ekonomi, 2019). This was an important step to autonomize the industrial areas in term of their electricity generation.

Net metering regulation was published in 12.05.2019. This allows unlicensed solar PV's ranging from 3-10 KW and other RES up to 5 MW to be sold to the grid. This regulation is an important step for small scale RES applications (EPDK, 2019b). According to the regulation, the production and consumption should be within the same region. The stated aim of this regulation is to ease the processes for rooftop solar PV located at consumption location. According to this regulation, the applications will be taken monthly and will be finalized by the 20th of the following month. However, the applications will be accepted depending on the capacities. Installed capacities up to 3 KW will be connected directly (EPDK, 2018c; TEDAŞ, 2018).

[12] Official Gazette No: 30289 dated: 02.01.2018

As energy efficiency measures play an important role in the transition for DG, in fact it is mentioned as an essential part of it. Despite Turkey's high dependency on foreign energy, the country is also not doing well with energy efficiency measures. Compared to other countries, especially compared to the European Union countries, Turkey ranks low in energy efficiency measures and policies (ACEE, 2018).

However, Turkey is allocating higher R&D to energy to improve energy efficiency and RES. In the recent years, the total amount allocated to R&D expenditures are increasing (Figure 4.3). The expenditure for R&D increased specially in the recent years after a long steady level. Total R&D budget for energy was $14 million in 2008 which increased to $186 million in 2018 (IEA, 2019b). Renewables had the highest share in the total budget by 41%; energy efficiency had the second highest share in the total budget with 31% followed by storage technologies with 16% (Figure 4.4). These specific spending for energy efficiency, RES and storage technologies are crucial for future DRES applications.

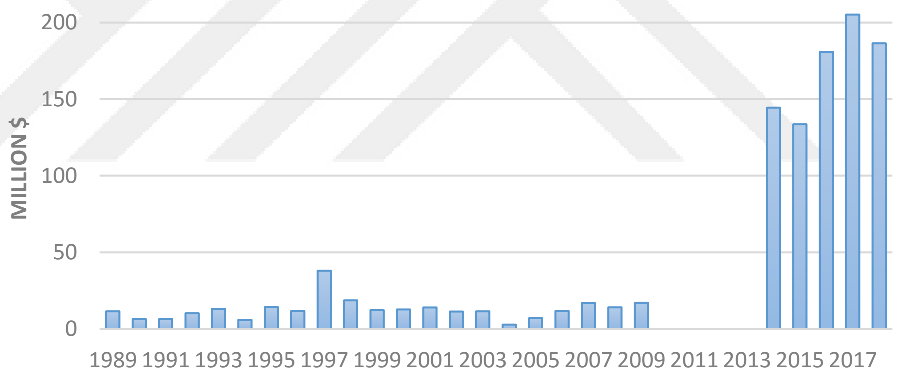

Figure 4.3 R&D Spending in Turkey (Million $)

Source: IEA, (2019b)

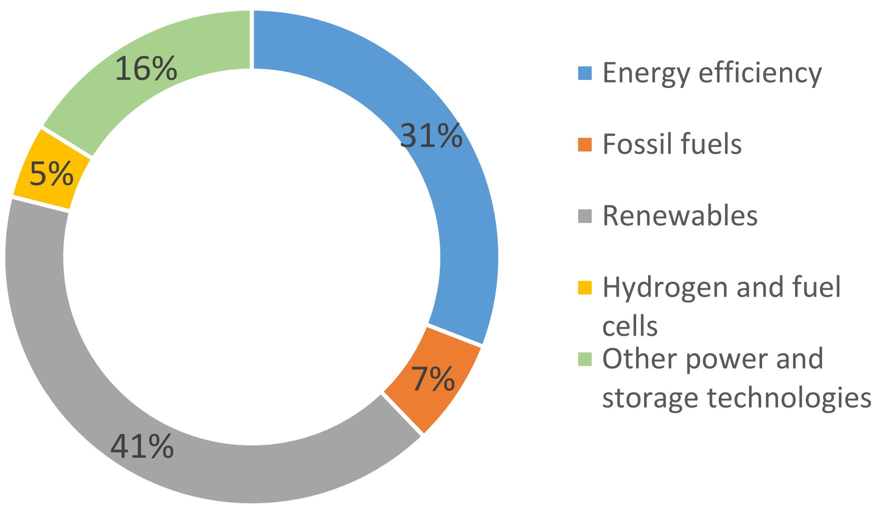

Figure 4.4 R&D Spending in Turkey by Field

Source: IEA, (2019b)

4.3 Decentralized Energy Applications in Turkey

In order for Turkey to increase energy security, reduce import dependency and protect the environment, the switch to DRES is very important along with decarbonization, digitalization and diversification. The works that have been published about the energy in Turkey focused on the importance of DG in Turkish electricity market. For example; for Turkey to reach 100% self-sufficiency in electricity generation by 2050, distributed generation and prosumers are essential (Kilickaplan et al., 2017).

The potential of DG has not been fully examined by scholars in Turkey that there have been only a handful of works on DG. Thus, there is not enough data or work to conclude the past figures on decentralization in Turkey. However, Lise (2009) gave the amount of DG, according to the amount of power plants connected to low medium voltage. According to this definition, 8.5% of the power plants connected to the Turkish electricity grid was decentralized (Lise, 2009). The biggest contribution to DG came from natural gas by 58%; the second was oil and diesel by 14%. Majority of the applications were CHP power plants. The same study was unable to be conducted because of the lack of current data on TEİAŞ website.

Because of the DG definition's similarity to unlicensed generation definition mentioned in unlicensed generation regulation, it is important to mention the current situation of unlicensed power plant applications. As of December, 2018, there are 5.253,42 unlicensed installed capacity in Turkey (EPDK, 2018a). Solar PV accounts to 94,73% of the total installed capacities by 4.976,43 MW. Natural gas has the second highest share which accounts to 2,60% of the total unlicensed installed with 136,59 MW; biomass has 79,18 MW and wind has 51,85 MW and hydroelectricity has 8,91 MW (Table 4.5).

In Turkey, Parallel with the solar potential, the unlicensed installed capacity of RES is mostly concentrated in the Mid-Anatolia and Southern Anatolia (EPDK, 2018a). Konya has the highest unlicensed installed capacity (503,23 MW- 10% of total), followed by Kayseri (310,15 MW-6% of total) an Ankara (307,09 MW-6%). Out of the 81, there are not any unlicensed installed capacity in 10 cities.

Table 4.5 Unlicensed Installed Capacity by Source[13]

Resource type	Unlicensed installed capacity (MW)	Share(%)
Solar PV	4,976.43	94.73
Natural Gas	136.59	2.60
Biogass	79.18	1.51
Wind	51.85	0.99
Hydroelectricity	8.91	0.17
Solar (Concentrated)	0.50	0.01
Total	5,253.47	100.00

The unlicensed generation is guaranteed to be bought by the distribution companies if it is fed to the grid. All of the unlicensed installed capacity is a part of the YEKDEM support mechanism. The excess electricity that was fed into the grid from unlicensed RES was 3.031 GWh in 2017. Solar PV account to 93,57% of the total excess electricity by 2.836 GWh; biomass has the second highest share of excess electricity by 4,57%; wind follows by 1,21% and hydroelectricity by 0,64%. Parallel to the unlicensed installed capacity,

[13] Data is collected from monthly sector reports of EPDK

Konya had to highest excess feed which accounts for 17,87% of the total excess supply. The total amount paid for the unlicensed generation was 1,4 billion TL; the total amount paid for solar PV was 1,39 billion TL. The second highest amount was paid the biomass power plants followed by wind and hydro power plants (Table 4.6) (EPDK, 2018b).

Table 4.6 Annual Amount Paid to RES Owners Source[14]

Resource type	Excess supply(MWh)	Amount paid (TL)
Solar PV	2.836.553,09	1.394.110.605,71
Biomass	138.657,08	71.776.216,62
Wind	36.801,92	10.038.095,17
Hydro	19.434,29	5.227.757,72
Total	3.031.446,38	1.481.152.675,22

Unlicensed installed capacities were commonly located south of Turkey where the number of sunny days are higher. Biggest contribution to unlicensed-installed capacity came from Konya followed by Kayseri and Ankara (Figure 4.5).

[14] Data is collected from December Electricity Sector Report of EPDK. Retrieved from: https://www.epdk.org.tr/Detay/Icerik/3-0-23/aylik-sektor-raporu

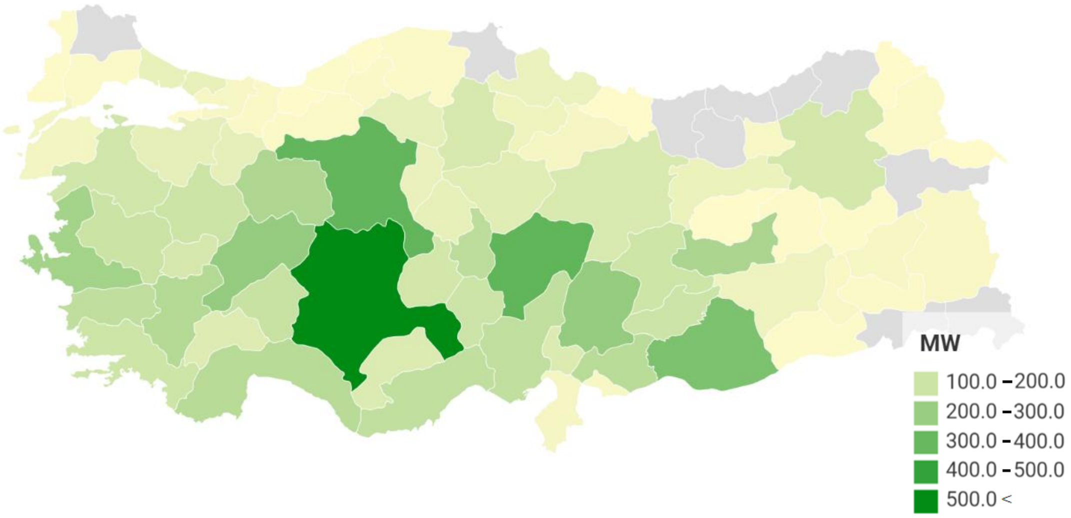

Figure 4.5 Turkey Unlicensed Installed Capacity Map[15]

Even though, current DRES applications in Turkey is not yet in a satisfactory level, with all the policies towards DG, DRES in Turkey is expected to increase. Along with the developments of DG, the usage of batteries and demand response will increase dramatically. However, the majority of the electricity will be dependent on CG. It is expected that by 2050, total installed capacity in Turkey will be 260 GW; approximately 200 GW (77%) will be CG and the rest (23%) will be DG (Figure 4.6) (Poseidon, 2019).

[15] The data is collected from monthly sectoral reports of EPDK. The electricity generation and consumption data of every month in 2018 were used. Retrieved from: https://www.epdk.org.tr/Detay/Icerik/3-0-23/aylik-sektor-raporu

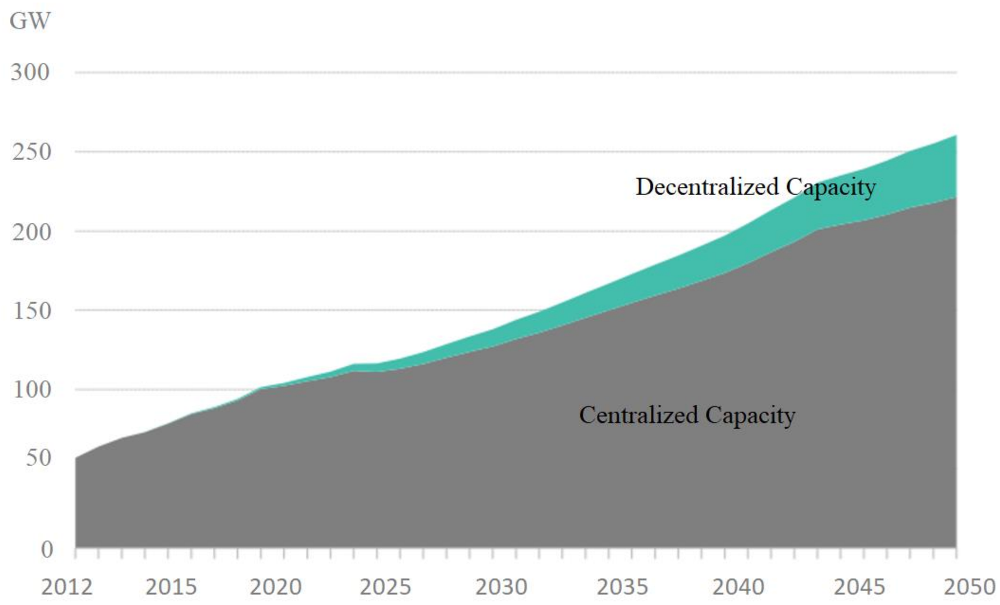

Figure 4.6 Future Decentralized Capacity in Turkey

Source: Poseidon (2019)

Also, by 2050, the number of demand response installments and battery installments will increase. In terms of flexible installed capacities, peaker gas will have the highest share follow demand response applications and utility scale batteries (Figure 4.7).

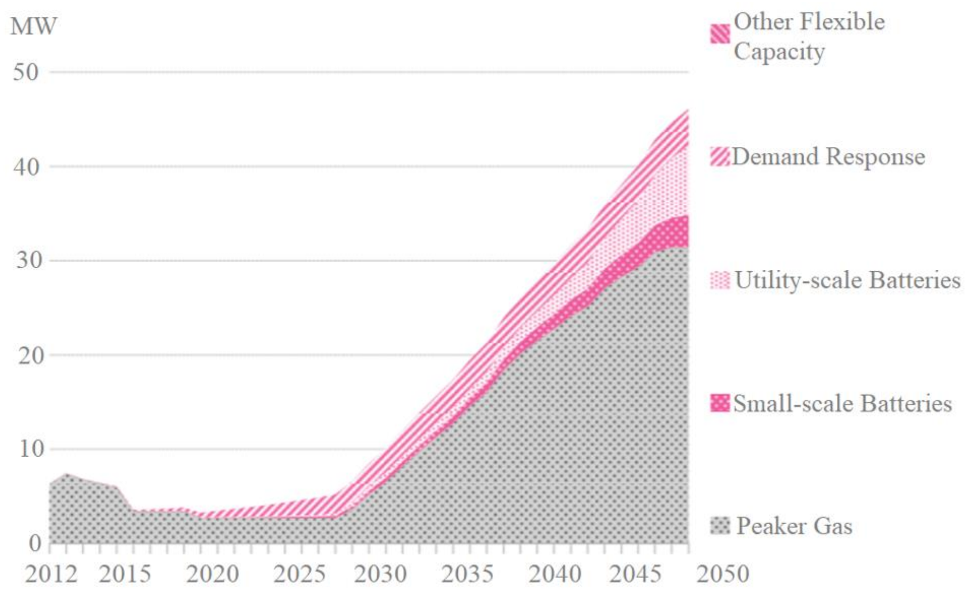

Figure 4.7 Cumulative Installed Flexible Capacity

Source: Poseidon (2019)

5. BARRIERS OF DECENTRALIZED RENEWABLE ENERGY SYSTEMS IN TURKEY

There is a tendency and an effort to increase DRES in Turkey. To facilitate the DRES applications, the government has published many regulations and development plans as explained in chapter 3.2. However, as there are many barriers to DRES applications in the world, there are also many barriers exist in Turkey.

In this chapter, the DRES application barriers in Turkey will be examined. The taxonomy of the barriers in this chapter are the same as in chapter 1; technical barriers, economical and financial barriers, institutional and market barriers and socio-cultural barriers. In order for Turkey to successfully transition to DRES, these barriers are need to be dealt with.

5.1 Technical Barriers

There are many barriers to DRES deployment in Turkey. Technical issues are very high, hampering the growth of DRES applications. Taking into account the resource availability, unlike many other countries, resource availability for RES in Turkey is very high. Despite this fact, it is reported that the intermittency of RES stood in the way of their deployment. For example, the applications of solar water-heaters was hampered by the uncertainty of solar availability in Turkey (Yaqoot et al., 2016). Since the electricity generation from RES are seasonal, the intermittency of the sources could hamper the growth of these resources.

Looking at the capacity factor of all resources, studies show that, in Turkey, capacity factors for RES are lower compared to fossil fuel power plants. Some companies are not capable of running RES power plants at high capacities. This is the main reason why people still prefer fossil fuels despite the falling costs of RES. Although the capacity factor is very high for geothermal and biomass power plants, it is low for wind and solar (Table 5.1).

Table 5.1 Capacity Factor by Source Source: İbis 2019

Resource	Working Hour	Capacity Factor
Wind	3500	40 %
Solar	2000	22.8 %
Biomass	7000	80 %
Geothermal	8000	92 %

Interconnection is an important challenge that needs complex modellings to be to establish. The existing transmission system requirements do not always allow the new installment of RES. Interconnection of one small scale DG plant may not be very effective for the distribution system, however, the interconnection of many DG plants to the existing load may contribute to short-circuit affect (Uzun, 2015). This is a crucial aspect that effects the security and reliability of the existing distribution system. Depending on the scale, source and type, the new applications may not be applicable. People who apply for a new RES application often get rejected because of the exceeding of system requirements. In 2017 alone, 14.718 MW worth of RES applications were rejected. 14.186,95 MW of it was Solar PV applications which accounted for 96% of total rejected applications and the rejected solar PV amount was equal to 497% of the solar installed capacity in 2017 (EPDK, 2018b).

In most of the countries and also in Turkey, the distribution system is designed for unidirectional electricity flow. However, the DG requires a bidirectional electricity flow. The integration of a DG within this distribution network leads to complexity where the system is operating beyond its design. In order to contend with this problem, the existing distribution system should be designed in a way that supports DG integration (Uzun, 2015).

Other technical reason is that Turkey lack technical workers or systems to work in DRES. During the applications and operation of DRES systems, there is a lot of need for skilled workers. However, Turkey is behind in terms of technical capability. For example, in Turkey, due to the lack of skilled workers in the solar power sector, workers have to be brought from abroad (Yeşil Düşünce Derneği, 2017). Generally, there are many workers coming from abroad to work in Turkish RES sector (Baykan, 2017). The country also lacks institutions and schools to educate people on these new systems. The same goes for Blockchain applications as not many skilled workers are educated in this field as there are not many schools devoted to this area.

For blockchain applications, technicality is a serious issue. The global technical barriers also exist in Turkey. There is not enough technical expertise to implement these technologies. Currently, there is only one blockchain based electricity company in Turkey. Hence, it can be argued that there is a major lack of technical know-how for blockchain applications in the energy sector as well as in other sectors.

5.2 Economic Barriers

Costs play a significant role in the deployment of DRES. However, in the recent years, the exchange rate affect was made prominent since the Turkish Lira has depreciated against American Dollars. The value of USD increased 125% against the TL from the beginning of 2015 to the end of 2018. The prices given to retail suppliers and to customers increased because of the increased pass-through cost (Köksal and Ardıyok, 2018). For example, although, Turkey increased the production of locally produced solar panels, there are lot of foreign inputs used in the production of these solar panels (Enerji Enstitüsü, 2018). Hence, the prices and thus the start-up cost of RES are increasing rapidly.

As it is mentioned before in this study, solar PV is an important source for prosumer engagement. Looking at the installation costs for 10 KW Solar PV and their comparison to average annual income, Turkey ranks one of the highest among G20 countries by 116%. This is a very high percentage comparing to countries like Germany (24%), the United States (25%) and Australia (29%) (Table 5.2). The high cost of RES hardens the participation of prosumers into the electricity generation process. Not only the costs of RES installments are too high but it is also hard the finance the RES investments.

High cost are also the reason why Turkey is behind in technological advancements and new start-ups in the energy field, especially in term of RES. In a survey done by the Ministry of Energy and Natural Resources, Start-ups View Report, people reported that the biggest risk for their energy start-ups are financial deficiencies (ETKB, 2019c).

Table 5.2 10 kW Solar Cost to Average Annual Income[16]

Country	Average Income ($)	Solar Cost per 10 kw ($)	10 Kw Solar Cost to Average Annual Income
India	2,020	7,930	393%
Indonesia	3,840	11,920	310%
South Africa	5,750	16,710	291%
Russia	10,230	23,020	225%
Brazil	9,140	15,190	166%
Mexico	9,180	14,810	161%
Turkey	10,380	12,060	116%
Argentina	12,370	14,330	116%
China	9,470	8,790	93%
Saudi Arabia	21,540	12,670	59%
Canada	44,860	24,270	54%
Japan	41,340	21,010	51%
Korea	30,600	13,260	43%
United Kingdom	41,340	13,620	33%
Australia	53,190	15,540	29%
France	41,080	10,740	26%
Italy	33,540	8,700	26%
Unites States	62,850	15,490	25%
Germany	47,180	11,130	24%

Because of the project risks and uncertainties of the RES projects, financial institutions are generally reluctant to loan any credits to RES investors. In terms of access to sufficient financing, this is a major barrier since the investment cost of RES is high. In Turkey, it is generally the case that RES investor choose to finance their investment 20-30% from their capital and 70-80% from financial loans. Return on investment periods vary from 5 to 7 years for RES (Table 5.3) (İbis, 2019). However, the uncertainty of the support mechanisms in Turkey, coupled with high initial cost, may discourage RES investors. The project risks, high cost of RES and high costs of financing is another factor hindering the development of DRES applications in Turkey.

[16] Average income data is retrieved from: https://www.worlddata.info/average-income.php
10 kW solar power plant costs are retrieved from "Renewable Power Generation Costs in 2018", IRENA

Table 5.3 Loan Aspects by Energy Sources in Turkey

Source: Ibis (2019)

Resource	Cost USD/MW	Project Finance	Annual Interest	Payback Period	Unit Production Cost (USD Cent/kWh)	Return on Investment	Amortization
Domestic Coal	750,000	%25-30 Capital %70-75 Loan	8-10%	12 Years	8.15	5.5 Years	30 Years
Natural Gas	650,000	%30 Capital %70 Loan	8-10%	12 Years	9.37	14.5 Years	30 Years
Wind	1,000,000	%20-30 Capital %70-80 Loan	8-10%	12-14 Years	5.20	6.7 Years	20 Years
Geothermal	2,500,500	%20 Capital %80 Loan	8-10%	12 Years	5.56	5.5 Years	30 Years
Solar	2,000,000	%25-35 Capital %65-75 Loan	8-10%	12-14 Years	10.52	9.5 Years	25 Years
Hydro	1,650,000	%25-30 Capital %70-75 Loan	8-10%	12-14 Years	5.37	6.0 Years	30 Years

It is predicted that cost per MWH of solar and wind will be lower than of gas and coal in the near future (Figure 5.1). However, cost per MWH for combined cycle gas turbine (CCGT), which is commonly used in DRES, will remain higher than other resources. Despite decreasing cost of RES, marginal cost of solar PV, wind and CCGT will remain much higher than gas and coal (Figure 5.2) (Poseidon, 2019).

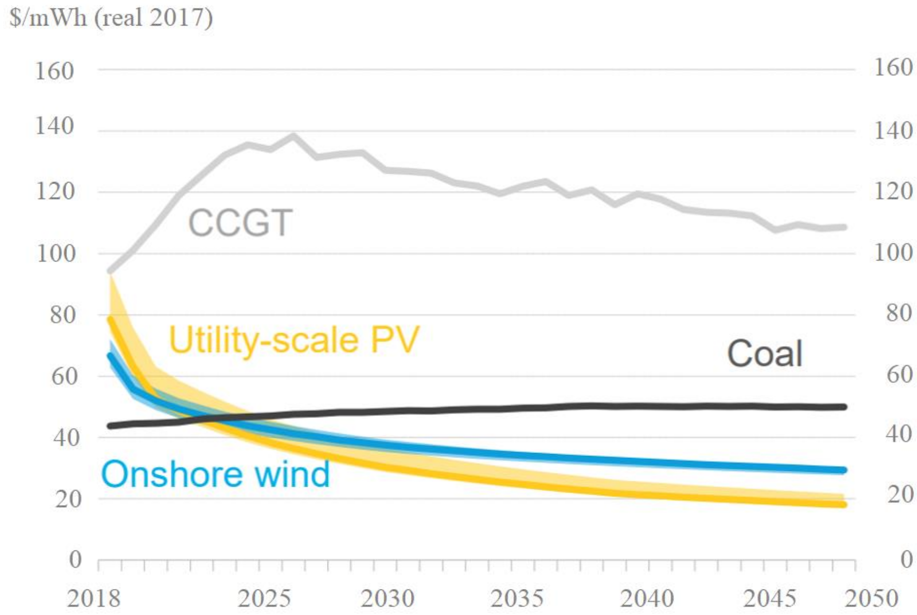

Figure 5.1 Cost per MWh Generation by Source

Source: Poseidon (2019)

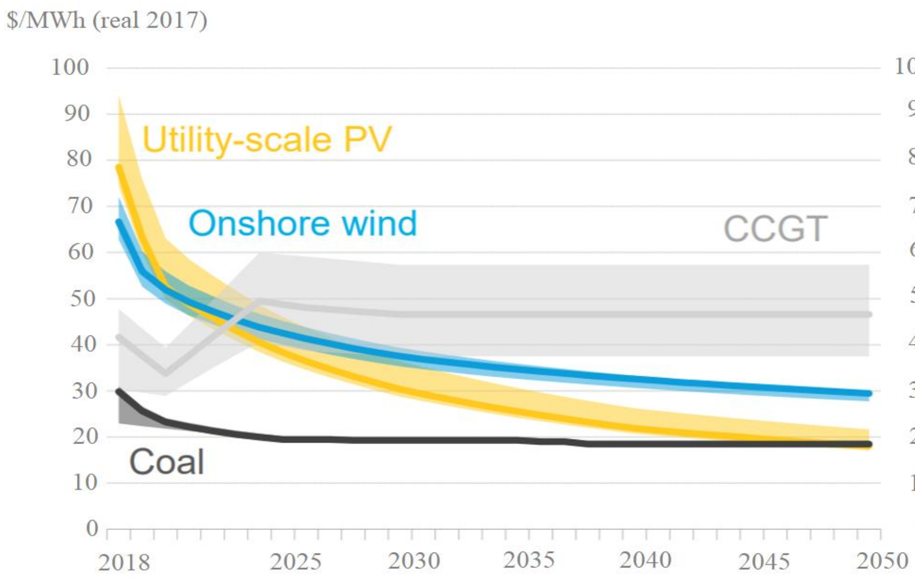

Figure 5.2 Marginal Cost for per MWh Generation by Source

Source: Poseidon (2019)

5.3 Institutional Barriers

In Turkey, institutional barriers for DRES come in many forms. First of all, there are many uncertainties with the RES incentives, the biggest of all being the feed-in tariff provided to prosumers. It is stated that the feed-in tariffs will be available for applications began operating before the end of 31 December 2020. Hence, people who want to invest in RES do not know what will happen in the near future. This is another reason for discouragement to invest in RES. Also, the effectiveness and applicability of published laws are sometimes misleading or uncertain. These sort of laws lead to rather small pace of RES market development. For example, as it was mentioned before, RERA were established in 2005 with "Renewable Energy Law" in order to promote the use of RES in Turkey. However, the published law had too little to say about the details concerning the implementation of RERA (Boden Law, 2019). The result of this was that no entity benefited from RERA until a new and more detailed version of the law on RERA's were published in 2016. This type of problems have slowed down the development of RES in Turkey. In the Start-ups View Report, it is also reported by the people that one of the biggest risk for their start-ups is the regulatory measures (ETKB, 2019b).

Another legal barrier for DRES applications is the lack of support to CHP. As Turkish consumers have higher and higher access to natural gas, DRES systems are made easier to integrate with CHP plants. Another legal barrier in this context is the absence for support mechanism for CHP technologies. Currently, there is no feed-in tariffs provided for CHP applications.

One of the most important institutional barrier is the current energy policies and strategies. For many years, policies are usually in favor of promoting the use of fossil fuels (Yaqoot et al., 2016). In order to increase domestic energy production, the government is giving too many loans to utilization of domestic coal reserves. The importance of domestic coal reserves was stressed out in the national energy and mining policy of Turkey (T.C. Cumhurbaşkanlığı, 2019). Thus, in order to ensure production and energy security, there are many incentives provided. The incentives and support for coal are both given to producers and consumers. There are many reasons for coal incentives. First of all, the industry is too big and it employs thousands of workers who working in the hard coal and lignite sector (Acar et al., 2015). Monetary aid is given for R&D expenditures, improvement support, mine exploration and the building of coal based power plants. There are also investment, price and purchase guarantees. The incentives for coal do not just come as a monetary aid but also as exemptions from environmental regulations. Incentives to consumers come only as coal aids to families in need. In an environment where RES output needs to increase, RES are struggling to compete with coal. Although the price of RES is keep falling, these resources are dwarfed by the incentives for coal. Incentive-driven market for coal would continue to make renewables hard to penetrate to the market (Acar and Yeldan, 2016; Ozcan, 2018).

Another institutional barrier is the bureaucracy. Today, in order to start an unlicensed RES installment, the applicant needs to go through various steps. These steps often take too much time to finish. According to the director of the Unlicensed Electricity Generation Association, the installation of a single plant take 7,3 months instead of 1,5 days (Yilmaz and Hotunoğlu, 2015).

In the case of blockchain application, the biggest challenge in Turkey is the legality of this technology. Smart contracts used in Blockchain transaction differ from conventional contracts in many ways. In order to be legal in many legal systems, a contract contains the following; offer and acceptance, consideration, intentional to create legal relations and certainty of terms (Norton Rose Fulbright, 2017). The usage of blockchain and thus smart contracts interfere with these concepts.

For a contract to be legally binding, there has to be a proof of a signature. This means that there has to be a wet-ink signature for a contract to be accepted. This also needs to be documented for that it could be legally valid (Norton Rose Fulbright, 2017). There has to be a signed paper version of a contract, however, contrary to this aspect of a conventional contract, a smart contract consists of pages of codes which makes blockchain and smart contracts to be harder to implement. Despite the current documentation, with the changing technology, legal systems are adjusting to these changes. In the recent years, e-signature was introduced in Turkey. E-signature is equivalent to a wet ink signature and it is a legally binding signature that allows people to sign documents electronically[17]. However, e-signature is only accepted by certain institutions which are usually public institutions.

In terms of p2p transaction in Blockchain applications, prosumers can choose who they are selling to and consumers can choose their providers. Hence, if there is a prosumer generating electricity, the electricity could only be sold to the grid; the prosumers cannot decide whom they are selling to. On the other hand, consumers can decide from which electricity retail company that they are willing to buy electricity, if only their electricity exceeds an annual total of 2000 kWh or they pledge to consume the same amount annually (Gazelektrik, n.d.). However, this is do not include prosumers.

Another barrier is the stamp tax requirement for every agreement. Currently, written agreements are subject to stamp tax by 0.948%[18]. However, the nature of a blockchain agreement interferes with the conventional agreement. Due to this reason, stamp tax is not collectible from smart contracts. This fact, in one hand, may be an opportunity for p2p transaction via blockchain since there will be lesser costs. On the other hand, currently there is an uncertainty about the future of smart contracts. The legal framework is far behind of being satisfactory.

[17] Law no 5070 dated 15.01.2004
[18] Law no 488 dated 1.07.1964

5.4 Socio-Cultural Barriers

When looking at the socio-cultural barriers in Turkey, it is important to mention the consumption characteristics of the country. Average residential consumption in Turkey is 200 kW/m^2 while this figure is 100 kW/m^2 in Europe (Utlu, 2017). Since less consumption of energy is crucial for DG system, this trend of high consumption in residential buildings might hinder the development of DRES.

People of Turkey are becoming more in favor for the use of RES and more concerned for the environment. However, there are still socio-cultural barriers if not the biggest barriers of them all. According to a survey made on top 500 industrial companies in Turkey, 43% of the companies were not well aware of the actual cost of energy imports. However, majority of the companies were in the favor of using RES. In terms of energy efficiency, 96% of the companies have taken measures to increase energy efficiency and 53% of the companies have made social responsibility projects to increase awareness (Biresselioglu et al., 2017). On the other hand, surveys conducted on consumers have shown different signs about the awareness on RES and energy efficiency. For example, a survey conducted on households in Istanbul, Ankara, İzmir and Kayseri. 87.5% of the respondents stated that they are trying to decrease the energy consumption. However, LED lighting, which is a simple but important step to achieving energy efficiency in apartments, was among the least used lighting preferences; the percentage of LED lighting was only 9.2% in Ankara, 2.4% in Istanbul, 4.8% in Izmir and 4.8% in Kayseri. The percentage of households which say that they take energy efficiency tags of the electrical home appliances into consideration is quite low in the same cities; 71.9% in Izmir, 60.1% in Ankara, 28% in Kayseri and 20.6% in Istanbul. 93% of the respondents are not aware of the energy labeling of the apartments they live in (Harputlugil and Harputlugil, 2016). On another survey, to question "Given similar costs and ease of accessibility, which energy source would you prefer to use at home?", natural gas was the most preferred energy source by 62.5% followed by solar and wind (21.0% and 6.2% respectively) (Ediger et al., 2018). This means that there are still a lot of people prefer FF over RES. There have not been any surveys conducted specifically on the views of DG or DRES in Turkey before. However, consumer preferences on which energy source they would prefer in their neighborhood could give an idea about the DG. In the same survey, to the question “How much do you agree or disagree with installation of different types of power plant in your neighborhood?”, wind and solar energy was the highest preferred option by the respondents (Table 5.4). Hence, it could be said that the Turkish public is growing more aware of the benefits of RES however they need to be more aware of the energy efficiency measures. This is a positive sign for future DRES applications.

Table 5.4 How much do you agree or disagree with installation of different types of power plant in your neighborhood? Source: Ediger et al. (2018)

Power plant type	Total disagree (%)	Total agree (%)
Wind power plant	2.4	86.2
Solar power plant	3.0	86.0
Natural gas power plant	9.3	68.8
Geothermal power plant	11.5	58.2
Hydroelectric power plant	24.6	50.4
Bioenergy power plant	12.9	50.1
Nuclear power plant	49.6	26.6
Coal power plant	45.8	26.5

As energy efficiency performance among residents, the education of energy efficiency as well doing very poorly (Kaliber, 2017). In Turkey, there is a lack of energy efficiency and renewable energy education. Starting from first grade to eight grade, students are only educated on energy efficiency and RES in sixth and seventh grade. In high school, student get the similar education only in ninth grade (Table 4.5).

Table 5.5 Classes thought on energy efficiency and renewable energies in elementary schools Source: Kaliber, (2017)

Grade	Science class hour	Classes on energy efficiency and renewable energies	Relevant subject hour to total class hour
3	108	-	-
4	108	-	-
5	144	-	-
6	144	2	1.38%
7	144	6	4.16%
8	144	-	-

6. EVALUATION AND SUGGESTIONS

In Turkey, the main focus on meeting the demand is building large power plants. The government's plan to increase natural gas, coal and nuclear power plants prove this tendency towards large power plants. The new power plants show that they are mainly built around high demand centers, specially Istanbul. The number of power plants located in the Marmara region has increased recently, making high surplus electricity generation for cities like Çanakkale and Kırklareli.

The government's plan of increasing domestic coal is an ambitious target in cutting down coal imports. Despite the efforts to decrease the foreign coal share has not been successful. Event with the subsidies given to domestic coal to cut down imported coal, foreign coal is keep increasing. The subsidies often do not protect the domestic coal suppliers but they increase the foreign coal instead (Figure 5.1) (Karagöz, 2019).

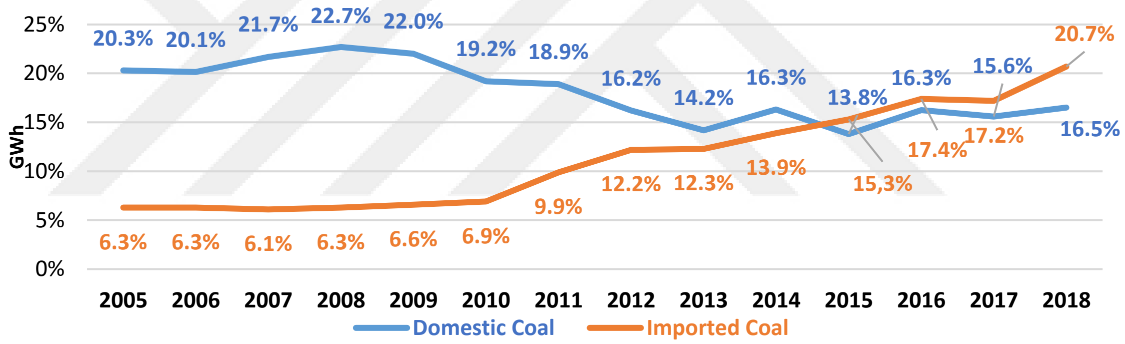

Figure 6.1 Share of Domestic Coal and Imported Coal in Total Generated Electricity Source: Karagöz, (2019)

In order for Turkey to successfully switch to DRES, the barriers mentioned in chapter 4 need to be addressed. In this chapter, potential solution for Turkey will be presented. Potential solutions are a collection of successful policies towards DRES from the rest of the world. Taking main barriers into consideration, the solutions presented in this chapter could be applied in Turkey.

6.1 Certain Legal Framework

Although there have been many failures and wrong doings in Turkey about the energy policies, support mechanism for RES have been very successful so far that it encouraged people and investors to undertake RES investments. However, the uncertainty for these support mechanisms should be addressed quickly to adapt new investors to the support mechanisms. It is widely reported in Turkey that RES investors are keenly seeking for new mechanisms. The continuation of feed-in tariffs should be made available as well as VAT exemptions to RES.

The support mechanisms should also include CHP technologies in Turkey. For example, in Germany, with the Combined Heat and Power Act[19] that passed in 2008, feed-in tariffs are also provided for CHP power plants. This also includes heating, cooling and storage systems (Scheller et al., 2018). Hence, for the continuation of new DRES applications new feed-in tariffs and other support mechanisms should be introduced.

6.2 Increasing R&D Expenditure

One of the biggest failures for Turkey have been the lack of R&D expenditures on energy. As shown before, R&D expenditures for energy is quite low compared to other countries. In order for Turkey to have more expertise in RES technology and to increase decentralization, Turkey needs more research. The research should be spread across energy companies to increase the know-how. In China, the government supported R&D and created test centers. With these centers, inventions were tested publicly and the know-how was shared with others (Gallagher, 2014).

In line with the R&D expenditures, Turkey could set up pilot projects for more utilization of RES and keeping up with the energy technology race. In China, government is aiming to increase DG and the Chinese government is making DG policies to meet the needs of the local communities (Wu et al., 2018). The government is setting experimental programs to increase DG applications. The policies are toward pilot programs like “New Energy Demonstration City”. With these pilot programs, the government is aiming at

[19] Kraft-Wärme-Kopplungsgesetz (KWKG)

developing tailor made solutions for specific regions. Hence, these programs offer specific targets and measures for different cities. However, the success of these programs were controversial and there have been many technical issues during the integration of distributed solar PV to the distribution network. However, in 2017 alone, distributed PV increased drastically in the world by more than 32 GW of installed capacity and 14 GW of it came from China (IEA, 2018c). The largest utility corporation in the country, the State Grid Corporation of China, added 15.600 DG power plants by the end of 2012. The total installed capacities of these power plants were 34 GW (Owens, 2014).

6.3 Digitalizing the Grid

In order to transition to a DRES based country, Turkey needs to modernize its electricity grid. Hence, the policies of expanding the Turkish electricity grid should be directed to establishing smart grids and installing smart meters. The upcoming policies should include these aspects.

In the world, there are many countries that issued regulations on developing smart-grids. In the United States, the Energy Policy Act of 2005 was a federal law that promoted the use of smart-meters. With this law, utility regulators need to consider time-based pricing; utilities need to provide customers with time-based schedule. This is a positive scheme towards developing demand response toward smart-grids (Brown, 2009). The United States also passed Energy Independence and Security Act[20] in 2007. The goal of this act is to modernize national electricity transmission and distribution system. This law required the establishment of Smart Grid Task Force that will work to establish smart-grid policies. Also this act aims to develop information technologies to investigate on demand response measures, distributed generation, storage and make data mining, visualization, feasibility studies for a successful transition to smart-grids. In addition, funds are directed every fiscal year within the scope of this act for local distribution system in order to modernize them. In 2009, the American Recovery and Reinvestment Act passed. This act accelerated the development of smart-grids by providing funds up to 50% of smart-grid investments made by utilities and private companies.

[20] Public Law 110-140 dated December 19, 2007

In Netherlands, many pilot projects toward DRES were tested. In addition to pilot community projects, Netherlands have also published an Experimental Decree in 2015[21]. Similar to Turkey, a prosumer in Netherlands can only feed the grid with excess supply. However, with the Experimental Decree, the prosumers can choose who they are selling the electricity. Thus, with this decree, p2p transactions were enabled (Lammers and Diestelmeier, 2017). Similar experimental decrees should also be established in Turkey.

The British government have established various institutions in order to direct funds to smart-grid applications. For example, Energy Technologies Institute promotes the usage of technologies like energy storage, building energy management and distributed generation by directing private and public funds (Brown, 2009).

Smart systems could also be a solution for Turkey's long lasting electricity theft problem which cost billions of dollars. In Turkey, electricity losses which occur in the transmission, distribution and consumption levels could be stopped via decentralization and digitalization. Today, by using smart and demand responsive measures, countries are increasing efficiency at the consumption level. By making the grid digital, the utility companies could monitor what is going on within their system and track down the illegal activity. For example, in Brazil, the sources of the electricity theft was sorted out by using smart meters and complex algorithms to monitor the distribution grid (Medium, 2017). This measure reduced the theft in the country dramatically. Similarly, a distribution company in Jamaica reduced the high electricity theft ratio by introducing machine learning (Deloitte, 2018). This type of solutions could also be implement for the Turkish electricity market.

6.4 Energy Cooperatives

Another solution for successfully implementing DRES is energy cooperatives. Energy cooperative are essential in contributing to energy democracy and energy citizenship. These concepts refer to joint decision-making and consciousness of energy issues. (Soeiro and Ferreira Dias, 2019). Cooperative members take strategic, social and economic actions locally, contributing to DRES in their community (Eichermüller et al., 2018).

[21] Besluit van 28 Februari 2015, Houdende Het bij Wege van Experiment Afwijken van de Elektriciteitswet 1998 voor Decentrale Opwekking van Duurzame Elektriciteit

Thus, renewable energy cooperatives increase the number of prosumers and lead to a bigger acceptance of RES. Cooperatives and municipalities can work hand in hand to be able to prepare a tailor made solutions to local communities e.g. local planning, financial policies and public procurement (FOE, 2018). Renewable energy cooperatives should also be widely implemented among public in order to expand the applications of DRES, especially in the industrial zones.

Number of RES cooperatives is very high in European countries. RES Coop, which is a federation of RES Cooperatives in Europe has more than 1,500 RES cooperative members with 1,000,000 citizens (Table 6.1) (Rescoop, n.d.). It is stated in the federation website that RES Coop is contributing to the transition from centralized market to a decentralized market with their prosumers (Rescoop, n.d.). The number of RES cooperatives registered to federation is quite high, reaching to 850 in Germany and 681 in Italy (Rescoop, 2019). The number of renewable energy cooperatives was only 22 in 2018 in Turkey (Damcı, 2018).

Table 6.1 Number of Renewable Energy Cooperation in the EU

Source: Rescoop 2019

Country	Number
Germany	850
Italy	681
UK	221
France	153
Wales	70
Netherlands	56
Belgium	25
Spain	17

Energy cooperatives also work to reduce the energy poverty within their communities. Cooperatives in the EU member states sometimes develop “solidarity schemes” and help people with their energy bills; they educate their members on how to reduce their energy consumption; they use revenues from RES to help people with low incomes (FOE, 2018).

These energy cooperatives commonly use similar methods to raise financing for their projects. They issued shares for the cooperative and offered to the public; they raised capital from the local community; they applied to different institutions for grants. For example, Yorkshire Dales Rivers Trust made a project called “Bain Hydro Project”. This was a small-scale hydro project of 45 kW in Yorkshire, UK. The total cost of the project was £450,000 and was financed through issued shares worth £200,000, £100,000 local grants and the rest was financed through bank credit of £150,000. The cooperative then sold the generated electricity to Good Energy, a renewable energy supplier company. Another example is again from the UK. Green Energy Naylan, an energy cooperative raised £37,900 in shares for 15 kW solar PV project worth £47,607. Solar PV was located on the roof of local elementary school which also contributed to raising awareness among children (Willis and Willis, 2012).

Turkey should also benefit from energy cooperatives to increase DRES especially in the industrial zones. There are 325 industrial zones in Turkey (Avrasya OSB, 2019). With the incentives given to RES installations in the industrial zones, Turkey could cut FF consumption significantly and increase DRES. Since industrial zones have a high electricity consumption, the effect will be enormous.

6.5 Carbon Tax

The incentives to RES should be accompanied by disincentives to fossil fuels and imported energy. This would not only increase the domestic RES output of Turkey but also lower the country’s energy dependency to other countries. A very important disincentive is “Carbon Tax”. This is a measurement used in many countries to cut down the electricity production of fossil based power plants. This measurement is taken widely because of environmental concerns. In many cases, these measurements are successful to decrease the usage of fossil fuels and increase RES output within applied countries. Today, there are 57 countries implemented or scheduled the implementation of such carbon pricing schemes (World Bank, 2019a). Sweden is one of the first countries to apply a carbon tax; it was implemented in 1991 by a rate of €24 per ton. This rate increased to €114 in 2019 which is one of the highest rates in the world. This had enormous effect on cutting down GHG emissions. As the Swedish GDP grew by 78%

since the implementation of the carbon tax, GHG decreased by 26%. The carbon tax policy was also successful in reducing energy consumption, increase in energy efficiency and switching to RES (Government of Sweden, 2019). Australia is also implemented a carbon tax policy for two years. During the years of implementation, the CO_2 was significantly reduced and there has been an important switch to RES (Geroe, 2019). Turkey could also apply a carbon tax to increase the use of DRES and to cut down CO^2 emissions. Currently, Turkey is in a consideration phase of the carbon tax (World Bank, 2019a). This policy would also be effective in cutting down energy imports as well as decreasing the pollution levels in the country.

Blockchain applications could also be important for the carbon tax policies. The transparency feature of the Blockchain can be used as an incentive to reduce carbon emissions. A blockchain based tracking system can help the tracking of successful mitigation policies. Thus, people can monitor the necessary information regarding carbon policies and verify their implementations. Blockchain could also be effective in tracking down each countries' actions towards meeting Paris Agreement Goals (Unep and DTU, 2019).

6.6 Prosumer Encouragement Through Blockchain

Prosumer engagement in the electricity generation should be increased in Turkey. In order to do so, people should be encouraged to participate in the energy trade. Peer-to-peer electricity trade should be made possible as an additional source of income. In a Mckinsey report, it stated that Blockchain could establish "energy Ebay" and this will encourage people to participate in the power market (Rogers and Henderson, 2019). This also enables consumers to adjust their electricity consumption based on electricity availability. In the UK, an energy company incentivize their consumers to consume electricity during high availability of RES. By doing this, the energy efficiency is increased. Hence, applications for Blockchain should be established. Today, there are only few start-up companies that is willing to base their operations on Blockchain with many barriers standing in their way. To enable these applications, Turkey must lay out new and clear regulations that would enable Blockchain applications in the energy and the other sectors.

Today, many countries like India, China and Australia are issuing new regulations on Blockchain (Kaaru, 2019).

6.7. Energy Efficiency Measures

Energy efficiency is also an important factor that needs to be developed. China is an important example for this. Energy efficiency was an important aspect of the DG growth in China. During the eleventh five-year plan of 2006-2010, one of biggest goals was to decrease the energy intensity of the country by 20%. Chinese government was able to save 527 million tons of coal equivalent between 2006 and 2008. The most important part of these programs was the financial support to companies that promoted energy efficiency; the government allocated financial support for energy efficiency programs from treasury bonds and from the central budget. Energy inspection was also an important factor for the success. Energy Conservation Law that passed in 2007 requires the collection and reporting energy statistics by local governments and requires companies to record energy use. Governors were held responsible for their targets and companies have undergone energy audits. Also, within this period, the Chinese government had shut down 26.2 GW of inefficient fossil fuel power plants (Gallagher, 2014).

As a way of increasing energy efficiency, people should be encouraged to buy energy efficient products. For example, Japan created a rating system for automobile industry and gave rebates to people who use the most efficient products. Also, the same system is established for non-efficient products as people have to pay fees to buy non-efficient products. Similar policies were used for computers and air conditioning. The policy was successful that people have moved to more energy efficient products (Gallagher, 2014). Although similar policies are being established today, there has to be policies to discourage people from using non-efficient products.

6.8. Social Awareness

Raising awareness on the benefits of DRES and energy efficiency is a significant step toward eliminating socio-cultural barriers in Turkey. Today, residential electricity consumption is too high. People need to be educated from early ages to decrease their energy consumption. According to a study, in the USA, people adopt sustainable habits from other people's encouragement. The children had the strongest social influence on elderly by 32% (Head, 2016). A survey done on pupils and their parents in Crete, Greece, to see the influence of effect of children on energy efficiency. After school education, the children and their parents has shown significant improvements in energy efficiency methods (Zografakis et al., 2008). Similarly, in an energy efficiency development program conducted in 850 schools in Turkey, overall 20% efficiency has been achieved (MEB, 2018). Thus, the number of classes thought on these subjects to children and youth in primary schools, high schools and universities should be increased.

Spreading information on the benefits of DRES is another serious step to overcome social barriers. In order to increase information and awareness, demonstration programs should be established. The information to spread out should include remotest locations to increase DRES and eventually off-grid systems. To increase the knowledge and encourage people, sample DRES applications should be established. For example, in Nicaragua, installation of solar systems for public view raised awareness among of potential users in the applied neighborhood (Yaqoot et al., 2016).

7. CONCLUSION

Electricity has an enormous place in our lives today, more than ever. The way that we obtain electricity is getting older and it has become unsustainable. Electricity generation, transmission and distribution processes all over the world is dominantly based on centralization, which has tremendous effects on economies, health and environment. At a point that the world is heading toward an irreversible point in global climate change, sustainable methods of electricity generation, transmission and distribution must be established. Because of this must, the world is now transitioning to RES since these resources provide clean and efficient electricity generation. Decentralized of these resources, namely DRES, could be the solution to the problems that we face in our electricity transmission and distribution.

DRES provides cleaner and much more efficient electricity generation, transmission and distribution. Because of the detrimental effects of using fossil fuels, the world is transitioning into DRES. With the technological advancements in technology and falling cost of RES, the transition is happening much faster. However, this transition often faces major barriers. Countries all over the world are setting up targets and laying out policies to pace up the transition.

Turkey is one of the many countries in the world that struggle with the lack of energy resources. Due to this reason, Turkey imports majority of its energy. As not only this creates a huge burden for the Turkish economy but it also damages the environment as the most energy imports are coal and natural gas. These resources are used mostly in centralized power plants which face huge deficiencies in operation and cause environmental damage. Turkey, on the other hand, have a huge RES potential and can make use of this resources. Despite this high potential, Turkey is still investing high amounts to the energy imports and facilitating the use of domestic coal. To offset the many problems caused with the existing power plants, DRES is an important option for Turkey.

Turkey has put out many policies towards RES, however, there has not much been done for DRES application. There are still many barriers to DRES applications in Turkey just like the rest of the world. The main barriers for DRES applications are technical, legal, institutional, financial and economic barriers. Technical barriers mainly come as a lack and interconnection issues and complexity of the grid; institutional and market barriers exist because of the lack of proved roadmap for the RES sector; the existing energy market structure and high FF usage and legal issues and bureaucratic issues; financial and economic barriers exist mostly because of the high investment costs and financing difficulties for RES.

In order for Turkey to successfully carry out the applications of DRES, there is a vital need for road map for decentralization and more consistent RES policy. First and most importantly, support mechanisms for RES applications should be continued in the future. Currently, the uncertain policies hinder the development of DRES applications. Also, in addition to incentives to RES, the government should also impose disincentive like a carbon tax in Turkey to phase out FF usage in Turkey. Turkey's R&D expenditures on energy and DRES should be increased to have know-how and to have a widespread usage of DRES. Pilot projects should also be established in order to experiment with decentralization. By doing this, Turkey can create optimal solutions for communities across the country. There are many successful policies for DRES in the world especially from countries like China, Belgium, Netherlands and Germany.

Communities in Turkey should be encouraged to establish DRES. To be able to establish these systems, energy cooperatives could be established. Energy cooperatives could serve aa crowd-funding to eliminate the financing problems of DRES. There are good examples for renewable energy cooperatives from the United Kingdom. Turkey could use similar models to increase both decentralization and democratization.

Electricity consumption behaviors should also be fixed. Currently, there is a high consumption trend in electricity by residential buildings. There should be programs aiming at raising awareness among public on energy issues like energy efficiency and renewable energies. Demonstration programs should be created for this goal. This programs should not also be raising awareness on the potential of RES in Turkey.

DRES applications are crucially important for Turkey to cut down energy imports and to have a more environmental friendly and efficient electricity supply. By following the right steps, Turkey could achieve sustainable development.

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CURRICULUM VITAE

Personal Information

Name Surname	Mehmet Burak Şuşoğlu
Date of Place and Birth	Istanbul, June 21, 1994

Education

09/2017 - 12/2019	Postgraduate with dissertation, Energy and Sustainable Development, Faculty of Engineering, Kadir Has University, Istanbul, Turkey (GPA: 3.61)
10/2018 - 11/2019	Postgraduate, Summer Exchange Programme, Foreign Languages Faculty, Hangzhou, China
09/2012 - 06/2016	Undergraduate, International Trade and Finance, Faculty Economics, Administrative and Social Sciences, Istanbul, Turkey (GPA: 3+, with honor degree)
01/2016 - 04/2016	Undergraduate, Exchange Programme, Arcadia University, London, United Kingdom
10/2013 - 02/2014	Undergraduate, Erasmus+ Programme, SRH Hochschule Berlin, Berlin, Germany

Work Experiences & Internships

09/2019 – Present	Project Assistant, İsra Group, Istanbul, Turkey
02/2018 - 06/2019	Research Assistant, Energy and Sustainable Development Center, Kadir Has University, Istanbul, Turkey
06/2015 - 07/2015	Intern, Treasury & International Institutions Departments, Turkish Finance Participation Bank, Istanbul, Turkey

Volunteer Experience & Society Membership

05/2019	Organizer and Host, Graduate Student Conference, Kadir Has University, Istanbul, Turkey
04/2018	Moderator, Energy Talks, Kadir Has University, Istanbul, Turkey
10/2015 - 06/2016	Co-founder & Member, AKUT Club, Kadir Has University, Istanbul, Turkey
12/2014 - 06/2016	Co-founder & Member, Political Science and International Relations Club, Kadir Has University, Istanbul, Turkey

Certificates

05/2019	Paper Presentation, "Switching to Decentralized Renewable Energy Generation for a Sustainable Development in Turkey", 7th Multinational energy and Value Conference, Center for Energy and Value Issues, Ankara, Turkey
04/2018	Training, "Blockchain and Cryptocurrencies", Kadir Has University, Istanbul, Turkey

05/2018	Paper Presentation, “Blockchain in Turkey: Opportunities and Challenges”, Graduate Student Conference, Kadir Has University, Istanbul, Turkey

Computer Skills
Microsoft Office, Adobe Premiere, Python

Languages
Turkish (native), English (advanced), Arabic (intermediate), German (intermediate)

Contact Information
Email buraksusoglu@gmail.com