MASTER THESIS

Impact of Wind Energy Generation on Wholesale Electricity Prices in Turkish Electricity Markets

Student: Emre Özçakmak

Number: s1763326

Supervisor: M.J. Arentsen

MASTER OF ENVIRONMENTAL AND ENERGY MANAGEMENT PROGRAM

UNIVERSITY OF TWENTE

ACADEMIC YEAR 2015/2016

Abstract :

As the result of the National Energy Plan (Energy Issues, 2015); Turkey pursues to have an installed capacity of 30% of renewable energy by 2023 and lower the emissions level to EU standards. Moreover, day by day the share of renewable generation of electricity increases and integrated into wholesale market.
Study aims to understand possible the impacts of increasing intermittent wind electricity generation on electricity prices and merit order. Secondly; existing regulations are investigated to secure electricity supply in Turkish electricity market.

In Chapter 1, Turkish electricity markets and main energy policies are described, problem statement on wind energy and electricity prices are defined, research objective and research questions are formed. In Chapter 2, current situation organization and functioning of Turkish electricity markets with actual renewable shares and reforms are explained. In Chapter 3, academic literature on impacts of wind generation penetration on market and price interaction investigated, possible implications of large amount of wind generation penetration into Turkish wholesale market structure and on merit order is explained; In Chapter 4; concept of competitive wholesale electricity markets are defined and regulatory options for securing electricity supply in a competitive wholesale electricity market are discussed. In Chapter 5; Overall results of the possible impact of wind generation penetration on market prices with merit order relationship and necessary regulatory options for securing RES generation in Turkish electricity markets are stated.

TABLE OF CONTENTS

List of Figures………………………………………………………………………….…………4

List of Tables…………………………………………………………………………….………..4

Abbreviations…………………………………………………………………………………..5

CHAPTER 1: INTRODUCTION……………………….……………………………….……..6

1.1.Background Information…..……………………………..…………………….…….6

1.2. Problem Statement…..………………………………………..………………………...7

1.3. Research Objective…..…………………………………………………………………8

1.4. Research Questions…..……………………………………….…………………………8

CHAPTER 2: ORGANIZATION AND FUNCTIONING OF TURKISH ELECTRICITY MARKETS..9

2.1. Current Situation of Electricity Markets in Turkey…..………………………………………9

2.2. Current Situation of Renewable Generation Share in Turkey……………..……………………10

2.3. Historical Background of the Reforms……………………………………………………..…13

2.4. Current Functioning of Price Mechanisms In Wholesale Electricity Markets in Turkey………..15

2.4.1. Bilateral Contracts…………………………………………………………………...16

2.4.2. Day Ahead Market……………………………………………………………….……..16

2.4.3. Funtioning in Balancing Power Market……………………………………………….……..18

2.4.4. Intra-day markets……………………………………………………………………….18

2.4.5. Derivatives Market……………………………………………………………………..19

Chapter 2 Findings ………………………………………………………………………………19

CHAPTER 3: WHOLESALE ELECTRICITY MARKETS AND RENEWABLE PENETRATION…………………………………………………………………………………..…20

3.1. Competitive Wholesale Electricity Markets……………………………………………………...20

3.2. Brief Definition of Merit Order and Merit Order Effect…………………………………...…21

3.3. Impact of Large Amount of Wind Generation on Electricity Markets and Systems…………….22

3.4. Impact of wind generation to the Turkish Electricity Martket and Preferred Merit Order…...….27

Chapter 3 Findings……………………………………………………………………………30

CHAPTER 4) SECURING ELECTRICITY SUPPLY WITH LARGE AMOUNT OF INTERMITTENT RENEWABLE GENERATION IN COMPETITIVE ELECTRICITY MARKETS……………………………………………………………………………………32

4.1. Definition and Classification of Security of Electricity Supply………………………..…...…32
4.2) Literature Review for Strategies Considering Security of Electricity Supply…………………..33

4.3) Developments with Capacity Mechanism Design and Implementation in European Union…....38

Chapter 4 Findings………………………………………………………………………………40

CHAPTER 5: CONCLUSIONS………………………………………………………..……....…41

BIBLIOGRAPHY……………………………………………………………………….…………43

List of Figures

Figure 1: Electricity Generation By Fuel Type in Turkey..………………………………………….…10

Figure 2: Installed RES Energy Capacity Source.……………………..…………………………..13

Figure 3: Supply and Demand on Electricity Markets ………………..………………………..…....15

Figure 4: Day Ahead Market Process Daily procedure……………………………………………16

Figure 5: Supply and Demand on Electricity Markets…………………………………………….…20

Figure 6: Figure 6. Merit order Curve……………………………………………………………..21

Figure 7: Merit Order Curve Before the Termination of BO/BOT Plants in Turkish Electricity System…………………………………………………………………………………………...28

Figure 8: Merit Order Curve After the Termination of BO/BOT Plants in Turkish Electricity System…………………………………………………………………………………………...28

Figure 9. Security of Electricity Supply……………………………………………………………32

List of Tables

Table 1: Electricity generation and shares by energy resources.…………………………..……......9

Table 2: Installed RES Energy Generation Capacity by end of 2016…….………………..……........11

Table 3: Installed Wind Energy Capacity………………………………..………………………….11

Table 4: Fixed Feed-in Tariff for RES Generation……..………………………………..…………27

Table 5: Types of Capacity Mechanisms in Europe……………………………………….……….34

Abbreviations :

BO	: Build and Operate
BOT	: Build , Operate and Transfer
BOO	: Build Operate and Own
EMRA	: Electricity Market Regulatory Authority (EPDK)
ENTSO -E	: European Network of Transmission System Operators
EPIAS	: Enerji Piyasaları İşletme Anonim Şirketi
EU	: European Union
EÜAŞ	: Turkish Electric Generation Company
FIT	: Feed-in Tariff
FMCP	: Final Market Clearing Price
IMF	: International Monetary Fund
MWh	: Megawatt hour
MYTM	: National Load Dispatch Center (NLDP)
PMUM	: Market Financial Settlement Center
PVPS	: Photovoltaic Power Systems Program
RES-E	: Electricity from renewable energy sources
SMP	: System Marginal Price
TEAS	: Turkish Electricity Generation Company
TEDAS	: Turkish Electricity Distribution Company
TEIAS	: Turkish Electricity Transmission Company
TEK	: Turkish Electricity Authority
TOR	: Transfer Operating Rights
TSO	: Transmission System Operators
UMCP	: Uncontrained Market Clearing Price

CHAPTER 1) INTRODUCTION

1.1) Background Information

As a result of being a rapidly growing economy, Turkey has been one of the fastest growing energy market in the world in last 10 years (Energy and Renewables, 2013). Turkey has been experiencing rapid demand growth in all segments of the energy sector for decades. Over the last decade, natural gas and electricity demand growth made Turkey second country, following China, and this demand growth trend is expected to progress increasingly according to the scenarios.

Due to the insufficient local fossil resources in the country; increase in the demand are mostly supplied by fossil energy products imports, so inevitably this increased energy dependence of the country day by day, risking energy security. At 2015; only 27% of the total energy demand was provided by internal resources, consequently, the rest was met by mostly gas and oil imports. Turkey progress on following steps to sustain and improve its own energy security;

- diversification of energy supply routes and source countries,
- increase the share of renewables and include the nuclear in its energy mix,
- take significant steps to increase energy efficiency,
- contribute to Europe's energy security.

Currently; total energy demand supplied by natural gas (35%), coal (28,5%), oil (27%), hydro (7%), and other renewables (2,5%). By 2023; total energy demand is expected to meet 218Mtoe and 416TWh for electricity. Turkey's Energy Policy (Republic of Turkey Ministry For EU Affairs,2016) mainly constitutes of;

- Making energy available for the consumers in terms of cost, time and amount,
- Exploiting public private facilities within the framework of free market practices,
- Discouraging import dependency,
- Securing a strong position for our country in regional and global trade of energy,
- Ensuring the availability of diversified resources, routes and technologies
- Ensuring maximum use of renewable resources,
- Increasing energy efficiency,
- Minimizing negative environmental impact while producing and using energy and natural resources.

As energy is being one of the most important subjects of Turkey-EU relations; Turkey worked diligently especially for this acquis and because of that reason; screening process of the Energy Chapter was completed in 2007. In this context; The EU legislation lays out the basis for a competitive, qualified, diverse and cost-effective energy market. Liberalization in the electricity and gas sectors expected to provide opportunities for investments by private sector actors.

Main targets of European Union energy policy is as follows;

• Forming a competitive energy market

• Energy supply security,

• Protection of the environment in the context of sustainable development.

In this context, Turkey should increase renewable energy generation and meet EU renewable goals for 2020, 2030 and 2050. As described in Table 2, on page:11 wind generation shares are far below of Turkish wind potential. Renewable generation penetration and it's impact on merit order and spot electricity prices are crucial to provide price signals for sustaining and securing new generation investments and also for wind generation technologies.

1.2) Problem Statement

Stable and affordable electricity price is one of the important objective of EU Energy Policy with securing electricity supply with reliability and reducing pollution and emissions (European Commission, n.d.). However; in restructured and liberalized electric markets price volatility is high then any other commodity; arising from widespread reasons like demand uncertainty, weather uncertainty, operations and flexibility of grid system, that presents major challenges for market participants (Keles, 2013).

Injection of high amounts of wind generation will have several serious impacts on overall energy markets. The increase of low marginal cost wind electricity will crowd out fossil fuel generation due the losses in profits (Cullen, 2013). A decrease in the conventional generation will also affect electricity supply security and increase short-term volatility of electricity prices due to the high wheather dependence of intermittent generation technology. At the same time increased wind generation also leads zero electricity prices when low demand hours meet high intermittent wind generation hours (Kyritsis, Andersson, & Serletis, 2017). In this complex market environment; appropriate regulatory arrangements needed to provide clear price signals for new wind investments in the EU-wide interconnected electricity market to meet EU Renewable Energy targets with securing RES generations and investments (European Commission, 2015).

1.3) Research Objective

The objective of this research is to estimate price impact of wind electricity generation on the wholesale price of electricity and merit order for investigating regulatory options to secure and sustain wind technology investments. As defined in existing academic literature, renewable generation is reducing wholesale electricity prices due to their lower marginal costs (Sijm, 2017). Impacts of wind generation will be assessed in Turkish electricity markets and merit order if they effectively send prices signals in Turkey to sustain new wind generation investments as RES targets being tried to achieved as defined by EU Energy Directive. Secondly; available regulatory options are investigated to support sustainable investment wind generation and securing electricity supply generated by RES.

1.4) Research Questions

What is the impact of wind energy on the merit order and wholesale prices of electricity in Turkey and is the observed impact reason to develop regulatory tools considering the sustainability of investments and securing electricity supply from renewable resources in Turkey?

After a detailed analysis of functioning and organization of Turkish Electricity market and wholesale market regulation, a literature analysis will be conducted to reveal the possible impact of wind generation on Turkish wholesale electricity prices and merit order. Secondly, available regulatory options considering sustainability and securing RES generation from existing literature are discussed.

CHAPTER 2) INTRODUCTION TO TURKISH ELECTRICITY MARKETS

2.1) Current Situation of Electricity Market in Turkey

Turkey's total electricity demand has reached 264 GWh in 2015, it was 128 GWH in 2000. According to the projections of the Ministry of Energy and Natural Resources, final electricity demand of Turkey is expected to reach at 416 GWh in 2023 (Republic of Turkey Ministry of Foreign Affairs, 2017).

As liberalization of Turkish Electricity Market progresses, we observe the steep increase in electricity supply; total electricity generation reached 261,783 GWh in 2015; doubled generation level of 2000 with 124.922 GWh.

Table 1: Electricity generation and shares by energy resources

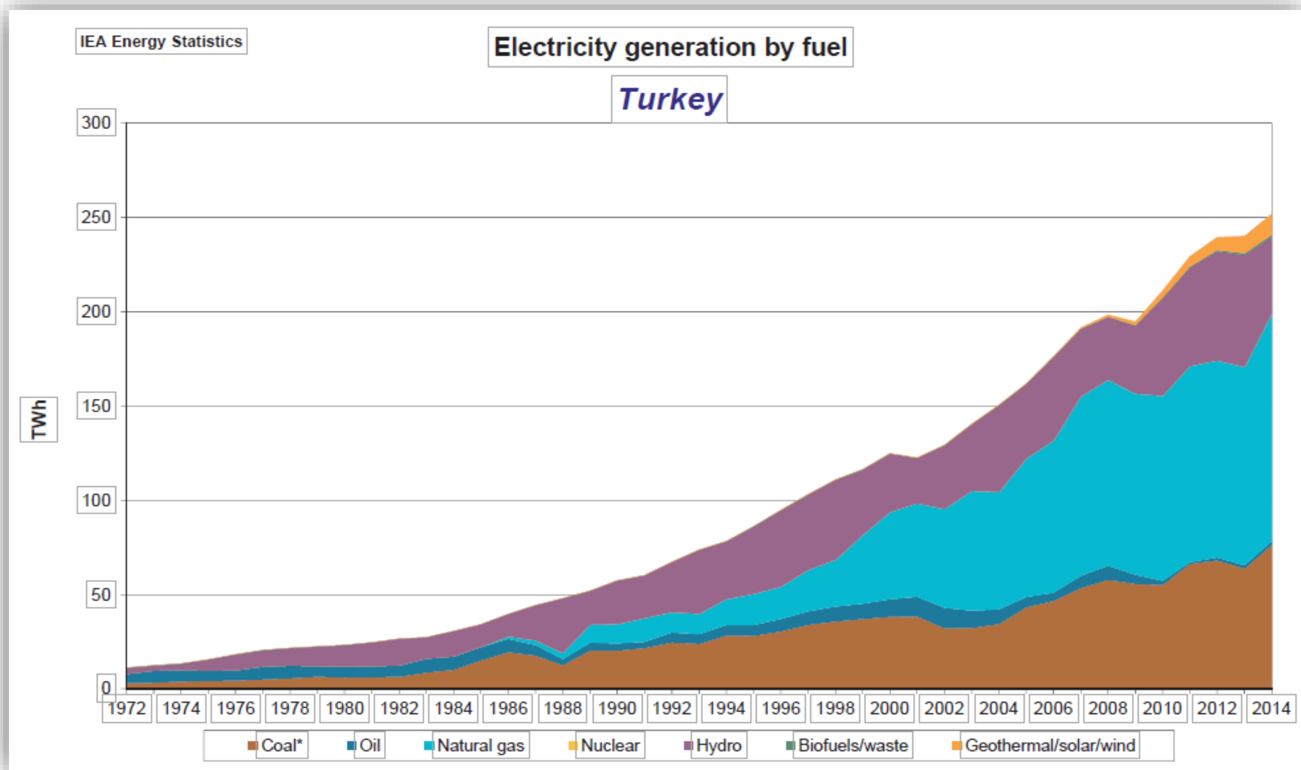
Year	**Total** (GWh)	**Coal**(%)	**Liquid fuels**(%)	**Natural Gas**(%)	**Hydro** (%)	**RES&Wastes***(%)
2000	**124.922**	30,6	7,5	37,0	24,7	0,3
2001	**122.725**	31,3	8,4	40,4	19,6	0,3
2002	**129.400**	24,8	8,3	40,6	26,0	0,3
2003	**140.581**	22,9	6,6	45,2	25,1	0,2
2004	**150.698**	22,8	5,0	41,3	30,6	0,3
2005	**161.956**	26,6	3,4	45,3	24,4	0,3
2006	**176.300**	26,4	2,4	45,8	25,1	0,3
2007	**191.558**	27,9	3,4	49,6	18,7	0,4
2008	**198.418**	29,1	3,8	49,7	16,8	0,6
2009	**194.813**	28,6	2,5	49,3	18,5	1,2
2010	**211.208**	26,1	1,0	46,5	24,5	1,9
2011	**229.395**	28,8	0,4	45,4	22,8	2,6
2012	**239.497**	28,4	0,7	43,6	24,2	3,1
2013	**240.154**	26,6	0,7	43,8	24,7	4,2
2014	**251.963**	30,2	0,9	47,9	16,1	4,9
2015	**261.783**	29,1	0,9	37,9	25,6	6,5

Source: TUIK.(2015).Transmission Statistics of Turkey. Adapted from http://www.turkstat.gov.tr/PreTablo.do?alt_id=1029

Natural gas comprised 37,9 % of total electricity generation in 2015. The portions of other energy sources used for electricity generation in 2015 was %29,1 for coal, %25,6 for hydro, %6,5 for allRenewable Sources and waste (Republic of Turkey Ministry of Foreign Affairs, 2017)[1].

[1] Renewable energy and waste includes geothermal, solar, wind, solid biomass, biogas and waste.

Figure 1. Electricity Generation By Fuel Type in Turkey



International Energy Agency.(2014).Electricity Generation By Fuel Type in Turkey 2014 Adapted from https://www.iea.org/stats/WebGraphs/TURKEY2.pdf

Figure-1; illustrates Electricity Generation in Turkey for years 1972-2014 according to fuel types utilized in total generation. The steep increase indicated by numbers above is evident with rising trend in the graphic.

2.2) Current Situation of Renewable Generation Shares in Turkey

Current Situation of Renewable Generation Shares in Turkey is as seen below; for 2016 according to the TEİAŞ-Turkish Electricity Transmission Corporation data.

Table 2: Installed RES Energy Generation Capacity by end of 2016

FUEL TYPES	INSTALLED CAPACITY	SHARE %	NUMBER OF PLANTS
HYDRO (All Types)	26.681,10	34	597
WIND - Licensed	5.738,40	7,3	148
WIND - Unlicensed	12,9	0	23
SOLAR - Licensed	12,9	0	2
SOLAR - Unlicensed	819,6	1	1.043
GEOTHERMAL	820,9	1	31
TOTAL GENERATION	34.085,80	43,3	1.844

TEIAS.(2016). *Installed RES Energy Generation Capacity by end of 2016* Adapted from http://www.teias.gov.tr/yukdagitim/kuruluguc.xls

Intermittent resources are differentiated from other conventional generators by their nature of dependence on natural factors so being exempt from the control and presenting little or any energy storage capability (PJM, 2014). This makes intermittent resources challenging as they disrupt the day-ahead, hour-ahead, and real-time planning operating procedures (Fares, 2015).

Some technical methods are developed to predict and analysis for forecasting the intermittent generation behaviour, however, they are still can not be dispatched to meet the demand of a power system. Delucchi and Jacobson (2011) addresses seven different methods to improve integrating intermittent renewable energy systems namely; solar, wind and tidal power for a reliable electricity demand management. One of the solutions related with other renewable sources is managing dispatchable renewable energy generators (such as hydroelectric, geothermal, and biomass) to balance energy deficits between fluctuating demand and intermittent resource generation.

Solar energy is significantly depended on the sun makes its generation only available during daylight hours, clouds and rain directly affect the amount generated via solar technologies. This causes stress on grid operation, day-ahead plan to control other conventional generators to compensate power output of fluctuations of solar generation. Wind-generated power is depended on wind power, and the amount of electricity produced by a plant varies due to the wind speeds, air density, and turbine characteristics. Addition to that most wind turbines operating speed is between 2,5 m/s and 25 m/s, turbines start generating electricity between these speeds, and turbines are shut down higher speeds higher than 25 m/s to prevent from damage. Same as solar, wind generation causes disruption on grid planning with the hourly load-following phase, and also distort total electric supply and demand balance operations (Wikipedia, 2017).

Table 3: Installed Wind Energy Capacity

Year	Cumulative Capacity	Increase %
2008	333 MW	(+60.9 %)
2009	801 MW	(+140.6 %)
2010	1,329 MW	(+66,0 %)
2011	1,799 MW	(+35.4 %)
2012	2,312 MW	(+28.6 %)
2013	2,959 MW	(+28,0 %)
2014	3,763 MW	(+27.2 %)
2015	4,718 MW	(+25.4 %)
2016	5.738,40 MW	(+17,7 %)

Source: Electricity Market Regulatory Agency of Turkey.(2016). Installed Wind Energy Capacity Retrieved From http://www.emra.org.tr/EN/Documents/ElectricityMarket/PublishmentsReports

Turkey's Licensed Wind Generation Capacity has reached 5.738,40 MW and by itself, it constitutes %7,3 of total electricity generation of the country in 2016. Table 2 explains the cumulative increase in capacity and ratio to previous years.

With an average annual total sunshine duration of 2,640 hours (a total of 7,2 hours per day) Turkey has the second largest potential for solar energy among European countries after Spain (Cankorel, 2016), but also the most dependent country for imported fossil fuel as mentioned above.

Solar photo-voltaic (PV) capacity has remained constant over years; installed solar PV capacity reached 819,6 MW for unlicensed generation and only 12,9 MW with licensed in 2016. As Solar energy generating technologies are diversified; principally they can be separated into two main groups as it is utilized in Turkey: 1. Photo-emissive Solar Technologies; plenary solar collectors which were 1.164.000 m2 and the vacuum-tube collectors were 57.600 m2 established in 2012. Photovoltaic panels are utilized as licensed, unlicensed facilities and off-grid systems 2. Concentrated Solar Power; there is two example power tower one is A 5 MW electricity generation capacity and a 500 MW heliostats thermal energy production system within Mersin (Kaplan, 2015).

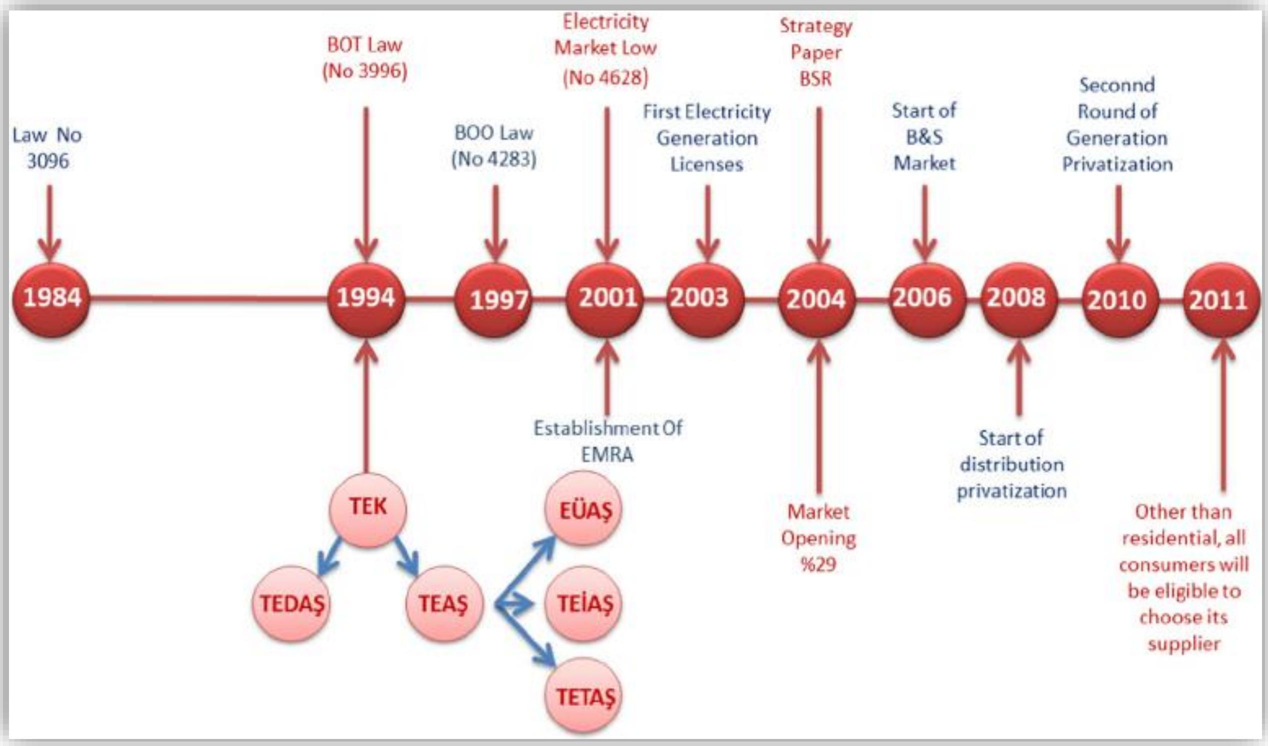
Along with the facts of lower solar investments, as an unlicensed generation (distributed generation) is also gaining more interest in the market by Ministry of Energy and Natural Resources (EMRA) regulations allows facilities with a capacity of up to 1 MW to generate electricity without pre-licensing requirements. Addition to this; in 2013 by enforcement of New Electricity Market Law (New EPK-6446 code)-will be discussed at Chapter-4; the unlicensed generation capacity has been increased from 500 kW to 1 MW with the possibility of increasing up to 5 MW by the Council of Ministry without changing the law in accordance with Photovoltaic Power Systems Program (PVPS) (Zuvin & Kimizioglu; 2016). The unlicensed facility should be connected to a consumption unit, and residual of the power which is not consumed in this unit can be sold to the network by connecting to the grid (Cankorel, 2016).

The regulatory reforms in Turkish electricity markets must be carefully reviewed in parallel within the current at global scale governance and electricity market restructuring developments. With the beginning of the 1980s through 1990s, Turkey initiated several schemes to trigger private sector investments to meet steadily increasing energy demand that is parallel to economic growth.

2.3) Historical Background of the Reforms:

We observe two main drivers factor that influence the initial of reforming and restructuring energy markets of Turkey. First one is the push of IMF and World Bank liberalization processes, as a result of stand by agreement signed between to parties in the context of exchange-rate-based macroeconomic stabilization program in 1999. Privatization of energy sector was committed by Turkey with legal amendments in the Intent Letter. The second and the most detailed factor was the European Union; as a precondition; Law No. 4054 on the Protection of Competition was enacted and Competition Authority was established in 1994 in order to join the Customs Union of EU. This initiated several major footsteps and policy reforms which were including telecommunication and energy sectors (Dilli & Nyman, 2015).

Figure 2. Milestones in Turkish electricity market reform



Source: (Colak et al, 2014)

As illustrated in Figure 2 above; privatization of Turkish Electricity sector initiated by Law No 3096 in 1984 that enabled Build-Operate-Transfer (BOT) and Transfer Operating Rights (TOR) contract types allowing private sector own/operate in electricity generation facilities. Turkish Electricity Authority (TEK) was responsible for generation, distribution, transmission as a vertical integrated governmental organization then divided into two main companies: Turkish Electricity Generation Company (TEAS) and Turkish Electricity Distribution Company (TEDAS) in 1994. In addition to the state guaranteed BOT and TOR contracts, Build–Operate–Own (BOO) contracts introduced which allows investor to continue to have ownership rights at the end of the contract (Çetin & Oğuz, 2007).

However; BOT and TOR contracts did not contribute to the development of liberalization of Turkish Electricity Markets due to the treasury guarantee factor structurally allowed owners/operators to hesitate to compete in sector, Electricity Market Law Number 4628 was legitimized in February 2001, that provided establishment of Energy Market Regulatory Authority (EMRA) as an independent regulator (Çetin & Oğuz, 2007).

Electricity Market Law Number 4628, also lead unbundling of public assets under Turkish Electricity Anonym Company (TEAŞ) into three separate companies with their separate roles as; Turkish Electric Generation Company (EÜAŞ), Turkish Electricity Transmission Company (TEİAŞ), Turkish Electricity Trading Company (TETAŞ), all companies remained as public assets (Atiyas, Cetin, & Gulen,2012).

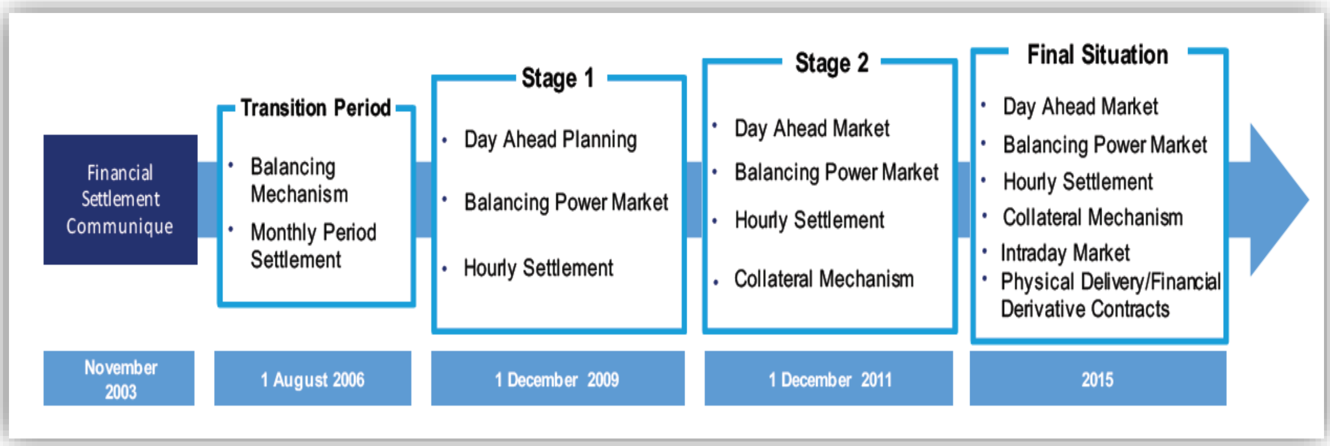
In 2004, The Strategy Paper has been published which outlines procedures for privatization of generation and distribution assets, as the steps for further liberalization of the Turkish Electricity sector. Paper states balance and settlements mechanism are necessary for providing price signals for investments and creating a spot market (Bagdadioglu & Odyakmaz, 2009). The balancing market was activated in August 2006, balancing mechanism will be discussed at Chapter 2.4.3.

Electric Market and Supply Security Strategy Paper has been declared by Ministry of Energy and Natural Resources at 2009 which clearly defines the steps for market opening and providing supply security with domestic resources to be utilized to supply electricity in middle and long term. Main subjects in this document are as follows (Dilli & Nyman, 2015).

2.4) Current Functioning of Price Mechanisms In Wholesale Electricity Markets in Turkey

The first form of competitive and a price mechanism oriented wholesale electricity market in Turkey was mainly constituted of bilateral contracts market, day-ahead market which is operated by market operator department (PMUM) and a real-time system balancing mechanism located inside TEIAS in 2009 to meet the criterias of Electric Market and Supply Security Strategy Paper (Erdogdu, 2010).

Figure 3. Market Development Stages



Source: (Deloitte Consulting LLP, 2012, p. 10)

After acceptance of The New Electricity Market Law (No. 4628) at 2012; Energy Stock Market (EPİAŞ) was established and became operational at 2015; undertook the responsibility of day ahead, intra-day and bilateral contract operations including financial conciliation services. Turkish Electricity Transmission Company (TEİAŞ) is 30% shareholder of EPİAŞ, responsible for Balancing Market operations and transmission of electricity in 21 separate regions. Borsa İstanbul has other 30% share of EPİAŞ and responsible for electricity derivatives transactions (Ersin & Arseven, 2015).

2.4.1) Bilateral Contracts

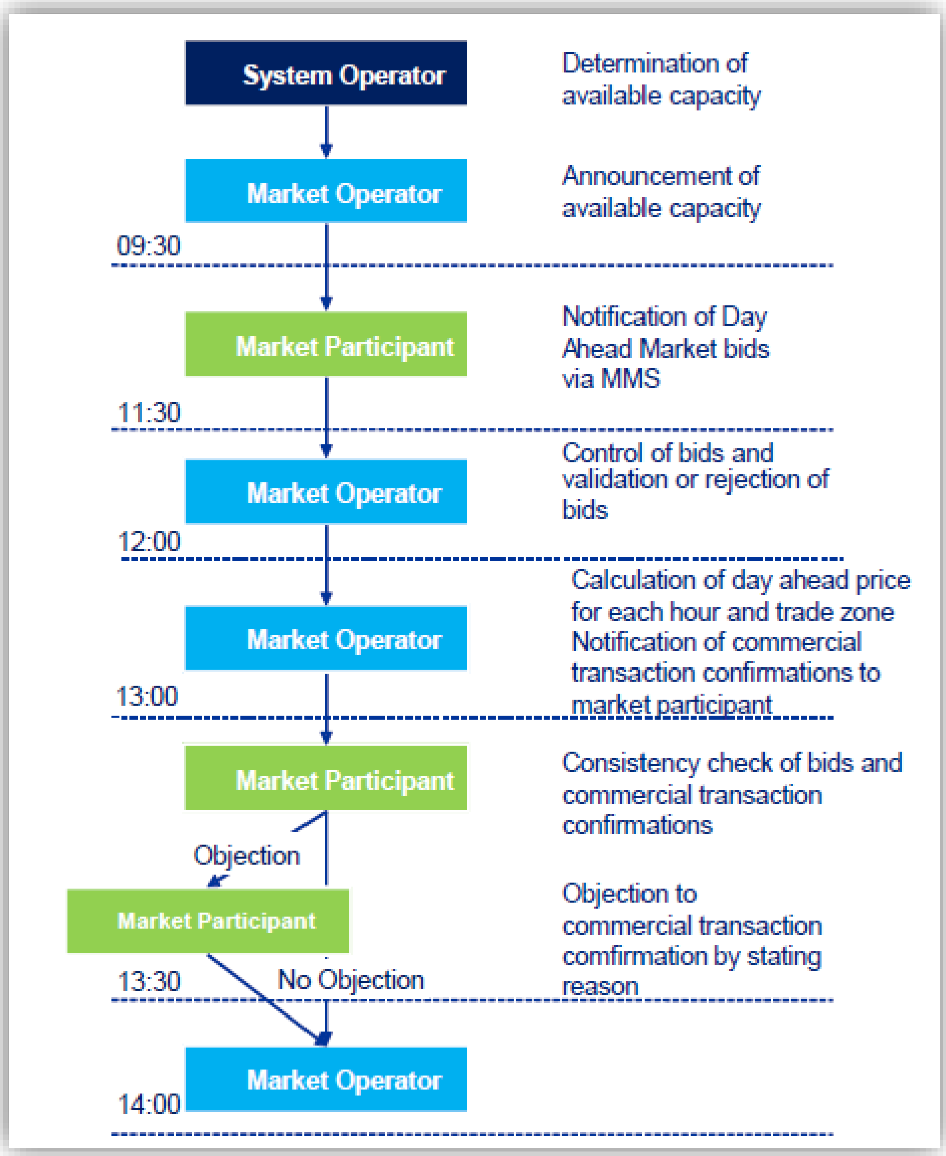
The bilateral contracts constitute % 98,6 of total electricity which is sold by TETAŞ. (Tetas, 2015). Bilateral contracts are a form of long-term power purchasing agreements between TETAŞ and build operate/transfer- transfer of operating rights plants with other free contracts between market participants and consumers (Deloitte Consulting LLP, 2012, p. 8).

2.4.2) Day-Ahead Market

The day-ahead market is being operated by the market operator (PMUM), provides buy-sell electricity transactions within 1 hour settlement period; allowing the system operator to balance the system (Deloitte; Page 11). Transactions of the day-ahead market constitute of %37,6 of total consumed electricity in Turkey in 2015 (Tetas, 2015). The day-ahead market is functioning on hourly settlement and steps are as follows:

- Market participators are notified on hourly transmission capacity bu Market Operator at 9:30
- Market participators notifies their bids to market operator at 11:30
- Market Operator states the decision to accept or decline submitted bids until 12:00.
- Market Operator calculates electricity price of following day for each hour and trading zone (There is only one Trading Zone in Turkey) and declares amount of purchase and sale transactions in the day ahead market.
- Between 12:00 and 13:00 each day, first, the price for the next day for every hour and every trade zone.
- Market participants control transaction confirmations and contacts Market Operator for any objections at 13:00 – 13:30
- Market Operator consider objections and declares latest results at 13:30 – 14:00.

Figure 4 . Day Ahead Market Process Daily procedure.



(Deloitte Consulting LLP, 2012, p. 10)

Figure-4 shows functioning and hourly settlements in day-ahead markets. Market Clearing Price is calculated through submitted bids and offers between hours 12:00 – 13:00 every day. First, Unconstrained Market Clearing Price (UMCP) is formed with the exclusion of transmission constraints then constraints are added and the Final Market Clearing Price (FMCP) is declared. (Deloitte Consulting LLP, 2012, p. 16)

Market splitting and zonal pricing possibility is an important step introduced through the Day-Ahead Market. By Balancing and Settlement Regulation (F-BSR) the system operator is authorized measure possible congestions in the transmission system, and to divide the national electricity system into trade zones to provide better signals for selecting and distribution of the location of generation plan investment on transmission system (Atiyas, Çetin, & Gulen, 2012).

2.4.3) Functioning in Balancing Power Market:

When Market Operator declared daily transaction confirmations, the system is in balance, supply meets demand on paper. But imbalances start to occur after the closing of day-ahead markets, due to several effects on the generation and on consumption. This requires an additional mechanism to re-balance supply and demand with flexible and available market participants by clearing market in real time at balancing power markets. National Load Dispatch Center (MYTM) is the system operator, responsible for balancing market transactions.

Balancing Power Market is operated through bids of market participants for consumption/generation excess or deficits occurring in the system which they can afford in 15 minutes forward. Hourly working mechanism is as follows;

- After closing of day-ahead market operations, balancing power markets are activated at 14:00.
- Market participants declare their up/down regulation bid and offer to the System Operator, regarding the hourly power supply and demand at 16:00.
- System Operator checks all declared bids and offers and compares with final supply/demand schedules and corrects mistakes if any identifies until 17:00.
- System Operator sends the orders for acceptance or cancellations of the bids at 17:00, taking account the transmission system congestions with supply quality and security criteria.

System Operator ranks declared bids/offers on balancing power market and maximum bid price is accepted as the System Marginal Price (SMP) to balance a deficit in the system. Just the opposite; the minimum bid price is accepted as the System Marginal Price (SMP) to correct when an energy excess occurs in the system. Promised generation and consumption transaction should be realized within 15 minutes after the order of system operator (Deloitte Consulting LLP, 2012, p. 21).

2.4.4) Intra-day markets:

Intra-day markets play a connecting role between day ahead and balancing power markets by allowing market participants to utilize their capabilities in the intra-day market which they might not be utilized before the closing of the day-ahead markets. Total resettlement transaction volume exceeded 156,6 GWh in the intra-day market at 2015.

2.4.5) Derivatives Market:

Derivatives market are subject to trade of financial tool such as forward contracts, futures contracts, options and swaps which allow market participants to purchase and trade any asset at a pre-defined price in future. These instruments are utilized to hedge the price and market risk of extremely volatile electricity prices. Lastly, derivatives are perfect tools to observe market for investment perspective via their price signaling ability.

After the establishment of electricity derivatives market in Turkish electricity market structure, it is expected to increased number of contracts help to provide reliable data for prices, thus more accurate forecasts will be achieved to sustain long-term supply security.

Chapter Findings:

As a result of the whole over regulation processes, public sector involvement in electricity generation is still consists %33.4 total share. The Turkish electricity grid is interconnected with the ENTSO-E Continental European system, market participants can perform cross-border trade between Turkey and the EU since January 2016 resulting improvement of the supply security and contributing a competitive and transparent sector.

Distribution companies unbundled from generation and supply roles by January 2016 this results in a %86 theoretical market opening. The single national tariff was extended from December 2015 to January 2021, which restricts to achieve fully functioning cost-based electricity market. As a result, still it is not possible to address a transparent and cost-based pricing mechanism in electricity market of Turkey (European Comission, 2016).

CHAPTER 3) THE PRICE AND MERIT ORDER EFFECT OF LARGE SCALE PRODUCTION OF WIND ENERGY IN TURKEY: A LITERATURE REVIEW.

3.1) Competitive Wholesale Electricity Markets:

Hogan (1998) states that a system operated short-term electricity market makes the basement of a competitive electricity market; when integrated with a long-term generation and distribution contracts can access to the grid by the spot-market.

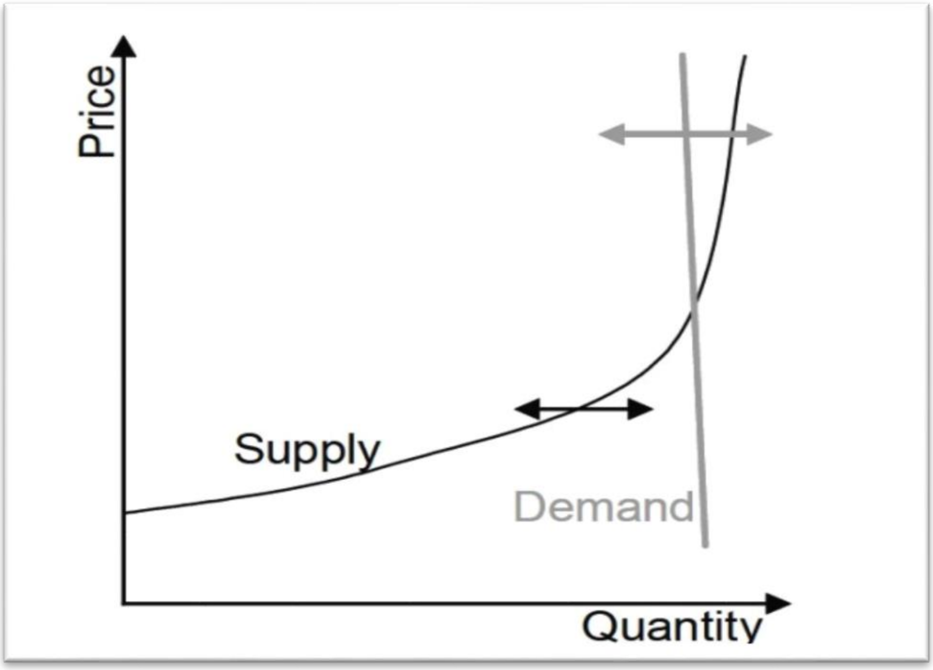
Cochran defines Competitive Wholesale Power Markets as a compound of competing independent generators and transmission system operators (TSOs-as called in Europe), where electricity, ancillary services, capacity are exchanged to be re-selled to consumers at the high-voltage level generation, transmission. Exchange of energy and related services operated at the lower-voltage distribution level is named as the 'Retail Power Market' (Cochran et al, 2013).

In the World, wholesale markets are represented in a rich variety of structures and forms, which can be under liberalized or market regimes. In this study, we focus on European wholesale market structures. According to Cornwall (2008), there are six basic form of competitive wholesale market design existing in European countries described as follows:

First one is the over-the-counter (OTC) and bilateral markets. Almost 95% of all energy is traded on OTC) and bilateral markets mostly with the day-ahead markets, at one year or longer settlement. The second one is the organized anonymous exchanges markets. In exchange markets, from day-ahead to 1-2 month settled short and medium term contracts are traded, which constitutes %1-2 of total consumed energy depending on the country. The third type of markets is transmission system operators (TSOs), acting as energy markets to allocate capacity into different price zones, the single-buyer market for balancing, bilateral contracting for re-dispatching. As another role, TSOs also manages to balance via balancing mechanisms for real-time balancing of electricity penetration. The fifth is complementary markets consist of capacity markets and ancillary services. These complementary markets target security of electricity supply in short and long terms. Lastly, retail markets are formed according to the preference of end-use as they choose their suppliers.

Due to the unstorable nature of electricity on a large scale and supply needs to be balanced with the demand very strictly; as a result 'Electricity Markets' are distinguished from all other commodity markets in this purpose. These characteristics of the market are displayed in Figure-5 below;

Figure 5: Supply and Demand in Electricity Markets.



Source: (Müsgens, 2005, p. 1)

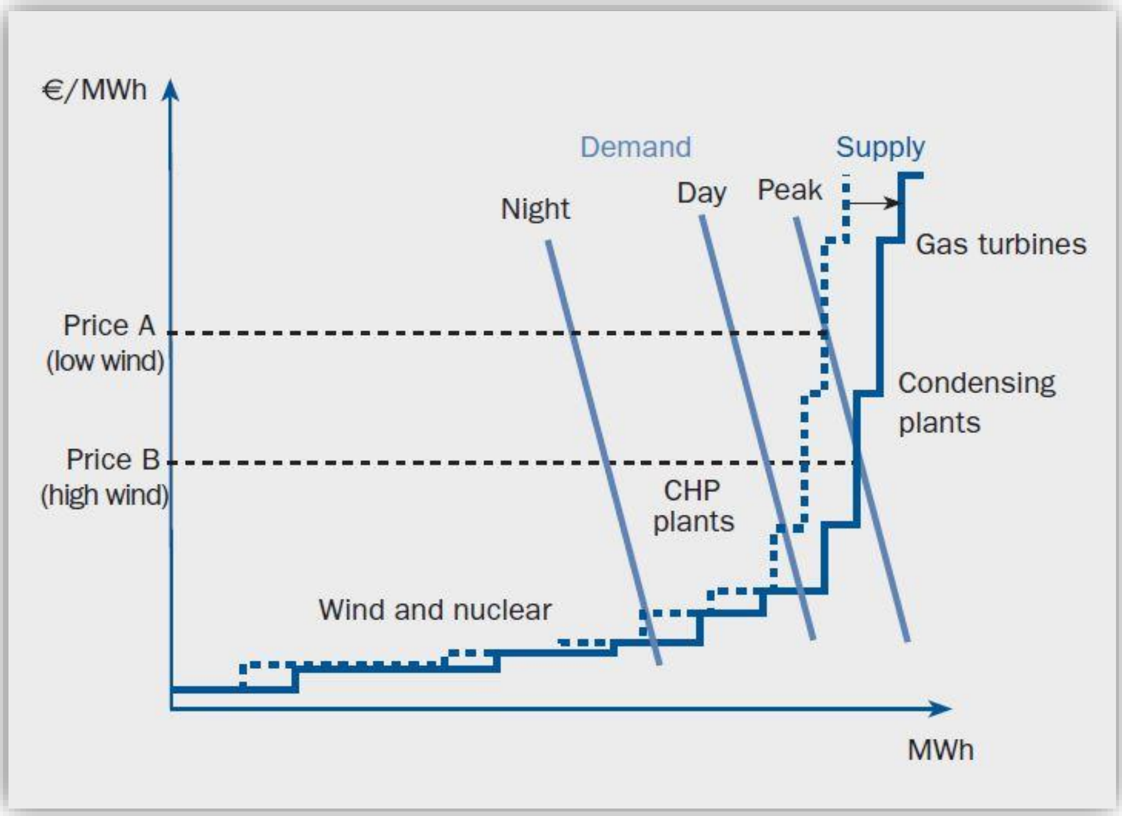
As seen in Figure 5; installed generation capacity is the supply curve is influenced by multiple variables like; fuel prices; cross-border trade and hydro storage capacity and storage availability. All these factors fluctuate with several other unpredictable facts with seasonality on an annual, monthly, weekly, daily even hourly level. Also, demand function is extremely inelastic and pretends to be affected with strong seasonalities (Müsgens, 2005).

3.2) Brief Definition of Merit Order and Merit Order Effect:

The supply function, reflects short-run marginal generating costs of all existing generation capacity in the system sorted in ascending order is called as ‘merit order’ to meet demand with the lowest generation cost first and highest in the last order (Wikipedia, 2016).

Intermittent renewable energy sources have lower marginal cost than conventional power plants due to the zero fuel costs; thus cost of generated unit MWh declines through the bottom of the supply curve. As the electricity generated from renewable sources increases, the ‘market clearing price’ will shrink below the marginal costs of all other power generators which depend on the fuels and so the fuel costs, this is called as the “merit order effect of renewables” (Erdmann, 2015).

Figure 6. Merit Order Curve.



Source: (Sensfuß, Ragwitz, & Genoese, 2008)

As seen in Figure 6; penetration of intermittent renewable generation decreases electricity price, as a result of the high price elasticity of the power demand when combined with high renewable generation periods. This is called the 'merit order effect' of wind power generation. As the wind generation supply increases, the power supply curve shifts to the right and results to lower prices.

3.3) Impact of Large Amounts of Wind Generation on Electricity Markets and Systems:

Following literature review consists of available articles focusing on the penetration of large amount of renewable generation into the market and indicate the price and cost effects of intermittent renewable generation on the electricity market and merit order while some of them focus on the issues of subsidy schemes and market designs.

Paraschiv, Erni, and Pietsch (2014) analyze the impact of intermittent renewable energies, (photovoltaic and wind), on the day-ahead electricity prices at power exchange EEX. To evaluate the policy decisions that aims the promotion of renewable energy sources in Germany and discuss their consequences on day-ahead prices. The analysis of electricity spot prices indicates that the introduction of renewable energy amplifies price changes significantly. Results suggest that renewable generation decrease market spot prices but, the feed-in tariffs increase the prices for the final consumers.

Hu, Chen, and Bak-Jensen (2010) investigated the relationship between electricity price (both the spot price and the regulation price) and the wind power generation in Danish electricity market; where more than 20% of total consumption generated by wind turbines annually. Analyze reveals the complex relationship between the spot price and generated wind power, when the wind power penetrates into the power system it drops down the regulation price.

Moreno, Lopez, and Garcia-lvarez (2012) investigated the effects of RES-E (Electricity from Renewable Energy Sources) with some other fundamental economic factors such as Gross Domestic Product per capita, measured in Purchasing Power and greenhouse gas emissions. Standards PPS on household electricity prices of 27 EU member countries; between years 1998-2009 as after EU electricity markets have been liberalized. According to their econometric panel analysis; electricity prices rise as the integration of expanding RES-E and also greenhouse gas emissions; numerically 1% increase in RES-E, results in 0.018 % price increase on the household electricity prices as the other economic variables held constant.

Bach (2009) researches market behavior and power system operation according to the quality of electricity which is generated by wind technologies and available interconnector capacity by analyzing the spot market price volatility in Denmark day-ahead- electricity market which makes %79 of its electricity trade in Nordic Pool. Despite the fact that the low wind energy generation periods spot prices remain low, there is a weak correlation between wind power and spot prices unless interconnector capacities lead to prices to decrease to zero. The study asserts Swedish congestion policy which aims single price in all areas of Sweden, distorts spot prices in East Denmark as a result of reduced physical trade capacity between two countries and offers further investigation on the cost of capacity reductions regarding the large-scale wind power integration to the electricity system.

Sensfuß, Ragwitz, and Genoese (2008) investigate the effect of renewable electricity generation on price and on overall power portfolio which is supported by feed-in tariffs in Germany, between 2011-2006. The main esteems of the study are; short-term electricity demand is inelastic, the spot market is the place where all electricity is traded on and there is no relation between the decisions of investing in renewable and or overall generation capacity. According to the analysis of the study; promotion of renewable energy in Germany leads to a decrease in day-ahead electricity prices and increase the merit order effect. The merit-order effect is bigger than the effect of net support payments that is paid by consumers thus shifting profit from companies to customers. The merit-order effect is mainly defined by the slope of the merit order curve which is sensitive to gas, coal and carbon prices and also the volume of the merit-order effect can spread abroad by the import and export of electricity.

Ketterer (2014) employs a GARCH model, to interpret wind electricity generation and the volatility of the electricity price in an integrated approach. Second, it investigates the relationship over time and analyses the impact of regulatory changes in the German market mechanism of renewable electricity on the relationship between wind power generation and the electricity price. As the result of this regulatory changes increased transparency by adding the spot and balancing market costs to Renewable Energies Act and initiation renewable energy volumes to be transacted on the day-ahead market, price volatility reduced after 2010 in German electricity markets. These regulations are also tested in the model and results suggest that new regulatory options reduce interventions on the day-ahead market leading intermittent renewable generation to be better integrated into the power system. However, according to the results of time series analysis; the strength of wind feed-in to decrease the electricity price with merit order effect has extinguished by time.

According to her results, variable wind generation decreases the prices but leads to an increase in volatility of prices. The study also proves that regulatory changes have potential to stabilize the wholesale price. The study is important for encouraging further improvement on regulations and policies are able to trigger a better integration of renewables into the power system. A framework that stabilizes the wholesale electricity price would also give incentives for investments in new generation capacity, both in renewable as well as conventional capacity.

Würzburg, Labandeira, and Linares (2013) research the size and the power of the correlation of merit order effect between electricity generated by renewable production systems and electricity prices. According to the findings; electricity prices decrease with the crowd out the effect of renewable production technologies; there is a weak evidence of a merit-order effect on electricity prices.

Nicolosi and Fürsch (2009) investigate the effect on feed-in supported intermittent wind generation on short term prices effects for 2008, long-term conventional generation capacity and market effects up to 2020 in German electricity market. Findings of the study in first hand suggests that wind generation decreases the spot prices however wind generation is not only definitive also its interaction with total load is affecting the market and changes on wind share in total load will generate system adequacy problem with more volatile electricity prices in future (2020) when low demand meets high wind generation. In the condition of high wind power generation times with low demand, ramping down of conventional power plants is economically inefficient and technically dangerous. And when low wind generation occurs when the high demand there is a system adequacy problem, adequate conventional capacity is required to supply needed electricity.

Due to the reason of volatility of intermittent generation will exceed the volatility of the overall market load and change the steepness of merit order curve in the long-run therefore set of improvement and further research offered on some issues such as optimal grid enhancements, possible renewable energy source support flexibilities, power storage options and flexible demand management (Nicolosi & Fürsch, 2009).

Munksgaard and Morthorst (2008) summarize redesigned policy measures regarding wind generation as the liberalization of Danish electricity market processed when the period of wind share significantly decreased compared to de-liberal era then investigates the impact of the redesigned tariffs on the electricity prices and new wind generation capacity investments. According to the main findings of the paper, merit order effect is 0.1-0.4 c€/kWh wind generation reduces the spot prices between 2004-2006 and redesigned tariffs are not the main reason for the recession of wind generation capacity in Denmark in liberalization period. Main drivers of the decrease of investments are related with spatial planning and the high-risk costs of new investments.

Delarue, Luickx, and D'haeseleer (2009) investigated the impact of wind generation on the cost of power generation and carbon emissions in Belgium. The study also indicates changes on merit order; when low load levels meet high wind generation, the wind generation replaces coal-fired plants and gas fired plants replaces other generation technologies on periods when high wind generation meet high load or low wind generation meet low load. But mostly, wind generated electricity replaces 50% of combined cycle gas turbine (CCGT) plant. According to the analysis, every wind power installment reduces costs nearly 56 k EUR perMWof capacity per year. Every installed wind power capacity reduces CO2 emissions 1.24 ton per MW of per year.

Mulder and Scholtens (2013) research effects of weather conditions in Netherlands and Germany; on electricity prices between 2006-2011 in Dutch electricity markets in a context of cross-border electricity trade with Germany. According to their findings; average wind speed in Germany drops electricity prices in Netherlands but wind speed in Netherlands has a direct positive proportional impact on electricity prices in Dutch electricity market. But there is no significant relationship between sunshine intensity on electricity prices. The study states that electricity prices are defined mainly according to the marginal costs of conventional gas-fired generators. However Dutch market is hardly influenced by the merit order effect of renewable energy impact on the electricity price in the Dutch electricity market is small and there is no evidence on increasing influence of renewable energy sources on the electricity price in the Netherlands for the last six years.

Kuipers (2016) analyzes North West European region, France, Germany, Netherlands, and the UK in order to find effect of variable renewable energy generation and interconnection on dispatchable runtime. As the increase in the share of more renewable energy decision was given by European Commission, increasing the size of the grid offered which does not solve backup capacity needed in member countries(European Commission, 2013). Crossborder congestion could help to integrate more renewable energy and decrease extra backup capacity investments if loads were uncorrelated among and also allow each market to utilize on other country's backup capacity in case of high residual load demand. However according to the data from 2015 markets in North West European region was strongly correlated especially for Netherlands this correlation was not in favor of cross-border trade during high loads. Also, low intermittent generation was almost on same periods, the option for utilizing other country's backup capacity was restricted. Because of electricity prices occurred lower in Germany than the Netherlands, electricity cross-border traded from Germany to Netherlands. Only on the low intermittent generation and high load periods, Netherlands exported electricity to Germany. The increase of intermittent renewable generation capacity decreased average runtime firm capacity increased electricity price volatility in Germany which risks earn back of fixed costs. The sum of residual load and foreign import named as compounded merit order effect is still not clear.

Weigt (2009) investigates the extent of replacement potential of wind energy with fossil fuels and also assesses cost saving potential of wind generation on peak, offpeak and base hours. The study shows that all wind capacity has no effect on to reduce conventional capacity and wind capacity has to be backed up. As a solution extending the grid as comprising Denmark, Poland and the Benelux may create a replacement potential for the wind for conventional generation capacity. Secondly, due to the flat supply curve on peak hours, wind generation has a drastic impact on prices and decreasing costs nearly 1 billion € per year and its cost-saving potential overruns the subsidies. On account of price sensitivity, the impact of gas and hard coal prices is stronger than lignite and nuclear, a fall in gas and hard coal prices significantly lead a drops the reductive impact of wind generation on prices. Also German electricity export will increase the prices inside its market.

Hiroux and Saguan (2009) investigates whether the renewable support schemes and electricity market designs are providing right signals as incentives to all generators in Europe. According to the results of their analysis; which target to finding the balance for signals and their risk, proper incentives, especially for wind generators, are depended to right market signals without reducing the effectiveness of support schemes. The study suggests 1) re-adjusting feed in support schemes to foster an increase of wind share and exposure more signal for producers, 2) improving the market design and signals to prevent markets from distortion 3) better balancing for integration costs and risks for investors.

Intermittent renewable generation has further impacts on electricity system not only limited to price and merit order impacts. Albadi and El-Saadany (2010) focuses on various impacts of intermittent wind generation on power systems and balancing costs. As well as distorting system reliability; intermittency of wind causes distribution and transmission losses, reduces the efficiency of thermal generation operations thus reducing emission impact of wind generation.
Also integration costs increase as the amount of wind penetration rise because of intermittent nature of wind power. The study suggests, accurate forecasting of wind generation, system robustness, capacity and ramping up abilities will play a critical role for maintaining system reliability.

Main Findings from the literature;

Several studies are conducted to observe the effect of renewable electricity generation penetration into the electricity markets on wholesale prices, merit order curve and whole electricity system. According to the academic literature on intermittent renewable penetration on wholesale electricity markets, findings mostly suggest that merit order curve shift to the right and lowers the wholesale prices with exceptional cases as in Denmark (Bach, 2009) and Germany (Nicolsi,2009) suggested a weak correlation between wind power and spot prices.

As (Sensfuß et al.,2008) indicates in his study; effect of renewable generation on prices is mostly due to the steepness of the merit order curve and wind generation transfer income from companies to customers in Germany. Also (Nicolosi & Fürsch, 2009) confirms (Sensfuß et al.,2008) on the results of the elasticity of merit order curve moreover his findings suggest when the high demand meet low wind generation, system adequacy problem occurs then adequate conventional capacity is required to supply needed electricity in Germany.

There are also other external factors influencing the renewable generation and electricity markets. As (Mulder & Scholtens, 2013) indicate the effects of weather conditions in Netherlands and Germany; there is a significant relationship between wind generation and prices but there is not any relation with the sun. Same as Senfuss indicates the fuel and carbon price changes effects the merit order effect of renewables. Cross-border trade is also an another fact, which enables one country’s generation condition to affect another country’s price level as seen between Germany and Netherlands.

As observed in most energy markets, increasing renewable generation integration into the grid decreases electricity prices. This distorts existing electricity markets systems in several aspects in a multilayered set of issues.

(Albadi & El-Saadany 2010) state negative impacts of intermittent wind generation on power systems and states increase in wind generation increase balancing costs and distorts system reliability and expose adequacy problems and also reduces effıcıency thermal generation plants which increase emission impact on the environment.

3.4) Impact of wind generation to the Turkish Electricity Market and Preferred Merit Order:

Turkish Electricity Transmission Company (TEIAS) as the authorized organization for transmission of electricity holds the right of defining and re-defining ‘ Merit Order Curve’ according to the dynamic supply-demand along with economical and technical electricity dispatch conditions.

At first glance, electricity prices are not mainly defined by merit order in Turkish electricity market. Price formation curve in Turkish electricity market is mainly defined by feed-in tariff supports, mandatory purchase contracts, fuel prices and seasonalities of hydropower.

Renewable Support Mechanism (YEKDEM, Yenilenebilir Enerji Destek Mekanizması) consists of feed-in support schemes and domestically produced renewable generation technology incentives. These supports are paid per generated kWh according to the type of RES as seen in Table 4 below and costs of this supports are allocated to sellers (Şanlı, 2014).

Table 4: Fixed Feed-in Tariff for RES Generation

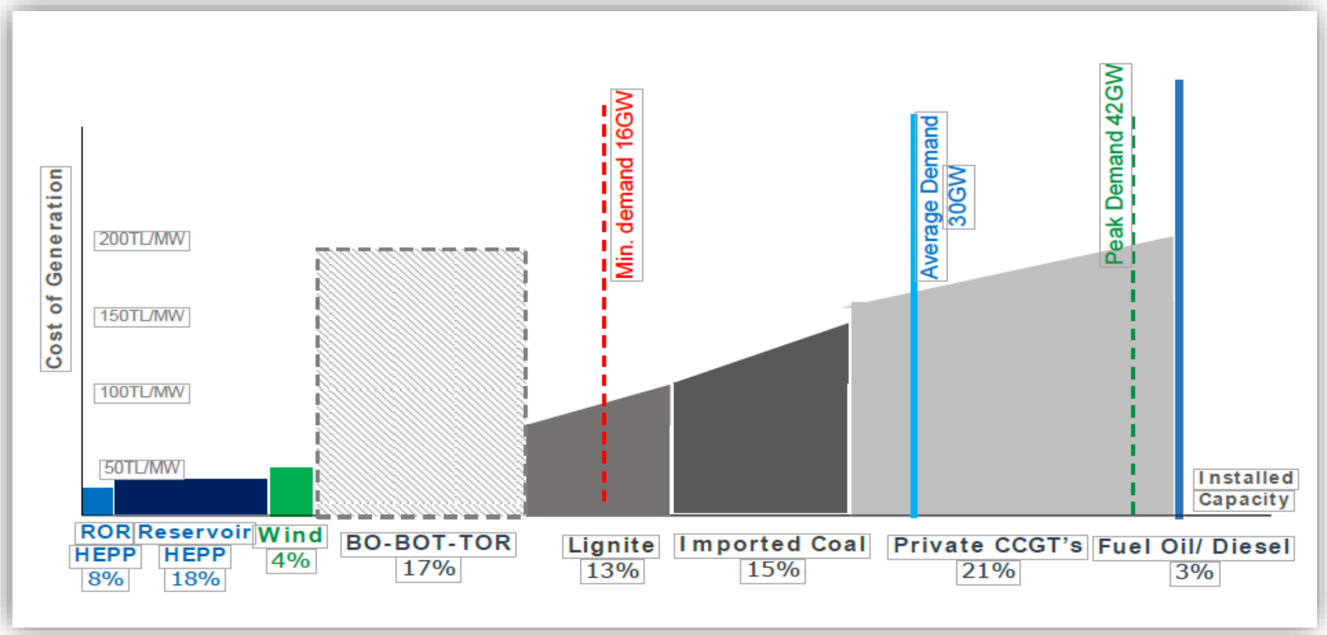
Type of RES	USD$ cent/kWh	Domestical Equipment Premium	Maximum Possible Tariff
Hydroelectricity Generation	7,30	2,30	9,60
Wind Generation	7,30	3,70	11
Geotermal Generation	10,50	2,70	13,20
Biomass Generation	13,30	5,60	18,90
Solar Generation	13,30	6,70	20

SOURCE: World Bank Group.(2015). Turkey’s energy transition milestones and challenges.

Mandatory purchase contracts are formed of Build Operate&Transfer (BO&BOT) type power plants remaining from before 2001 era, that will expire in 2019. BO&BOT plants are guaranteed by treasury and have higher priority in merit order despite the fact that they have higher marginal cost than other fossil fueled conventional high-efficient natural gas powered plants. After the termination of these BO&BOT power plants (the majority of them will be terminated in 2018-2019), these plants are going to lose their priority in merit order and will be dispatched by comparatively high-efficient natural gas and other fossil-fueled power plants. This shift of power generation is expected to affect spot electricity prices downwards.

As seen in Figure 7 below; mandatory purchase contracts signed before 2001 for Build Operate&Transfer is ending by 2019 and this will cause significant imbalances between supply and demand as they consist of 17% of Turkish generation capacity. Despite of their lower efficiency higher marginal costs they have first que in merit order curve.

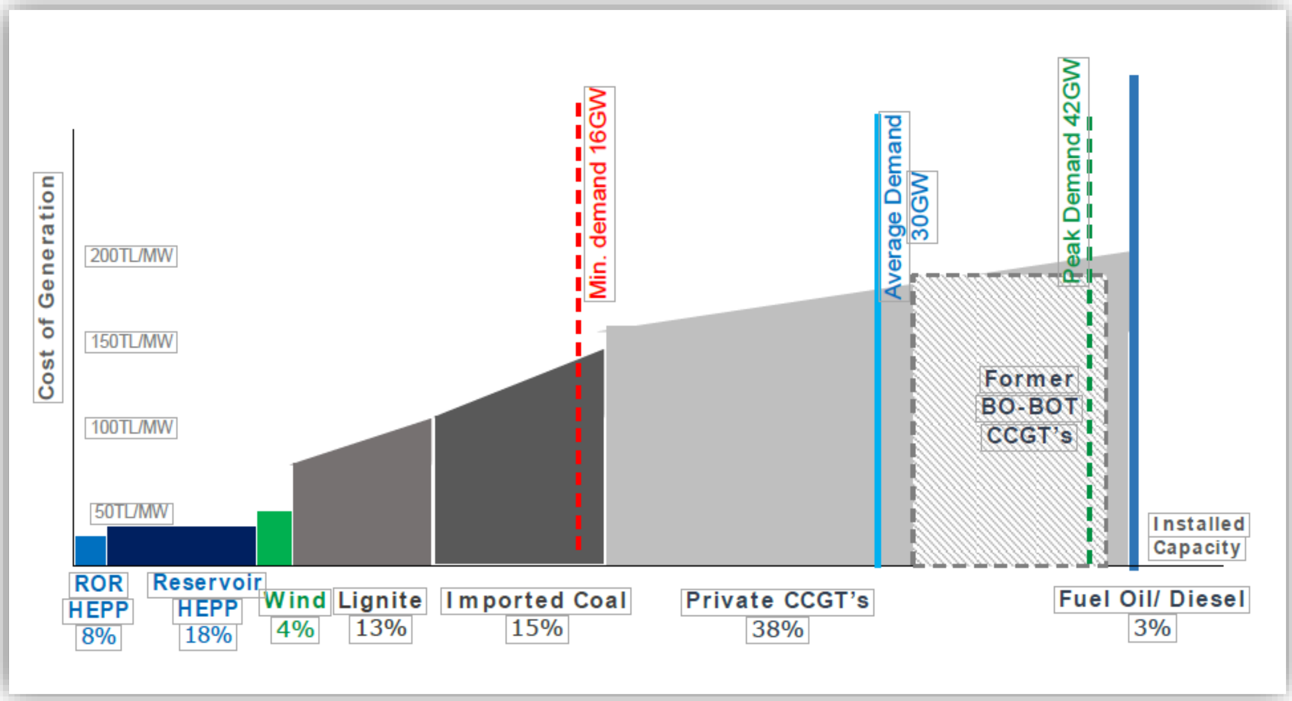
Figure 7. Merit Order Curve Before Termination of BO-BOT Plants in Turkish Electricity System



(İşbank, 2016, p. 19)

Figure 8 indicates the situation of Merit order curve in Turkish electricity markets as after the BO and BOT plants being closed, lignite, high-efficient imported coal and natural gas power plants will replace merit order and this development expected to be the most significant transition through market liberalization as shown in figures below.

Figure 8. Merit Order Curve After Termination of BO-BOT Plants in Turkish Electricity System



(İşbank, 2016, p. 19)

Natural gas fueled power plants has 38% share in electricity generation in Turkey, this makes natural gas prices main explanatory factor of electricity prices despite the rise of RES generation share. The second biggest share of generation comes from hydropower in Turkey with nearly 26% of total generation has the biggest impact on electricity prices and merit order curve after natural gas, with high volatility due to the seasonality. The share of hydropower is expected to rise with a FIT system that supports hydro investments.

Electricity prices are determined by gas and coal plants more than 90% of the time with fuel costs are in USD currency. Most importantly natural gas prices are the most important determinant of electricity prices 85% of the time thus leading to lowering gas plants electricity generation prices at same demand level. For this reason, none of the other generation types can benefit unless gas generation and coal generation replaces in the merit order curve (Garanti Bankasi, 2015, p.18).

Chapter Findings:

According to the academic literature on intermittent renewable penetration on wholesale electricity markets, findings mostly suggest that merit order curve shift to the right and lowers the wholesale prices; effect of renewable generation on prices is mostly due to the steepness of the merit order curve and demand conditions. Cross-border electricity flow and whaether conditions are also influencing merit order curves and merit order effects.

Besides the price effects of increasing intermittent renewable integration into the grid, it distorts existing electricity markets systems in several aspects in a multilayered and connected set of issues. Intermittent generation increases balancing and operating costs, and due to the nature of their intermittency, they reveal reliability problem in electricity supply and causes adequacy problems.

Insights into Turkish electricity market shows that the electricity prices are not mainly defined by merit order in Turkey. Price formation curve in Turkish electricity market is significantly influenced by feed-in tariff supports, mandatory purchase contracts, fuel prices and seasonalities of hydropower. Mandatory power purchase agreements regarding the Build Operate&Transfer (BO&BOT) plants, has priority on the merit order despite their efficiency and marginal costs are higher than other comparatively efficient conventional power generators. After the termination of these BO&BOT power plants in 2018-2019, these plants are going to lose their priority in merit order and will be dispatched by comparatively high-efficient natural gas and other fossil-fueled power plants. This shift of power generation is expected to affect spot electricity prices downwards.

As literature survey indicated, cross-border electricity trade is also another factor that influences merit order and electricity prices. Interconnection to ENTSO-E will provide increased electricity trade capacity in Turkish electricity market. In return that will also have an effect on merit order curve. The size direction of this effect is highly correlated demand and supply curves, wheather conditions are also definitive.

All these developments on merit order curve and price impact of renewable generation have an accumulated effect on supply security of electricity in Turkish electricity market, as every electricity market in the world. Following chapter investigates reasons and types of security of supply problem in the long and short run. Literature research focuses on solutions to adequacy problem in electricity markets.

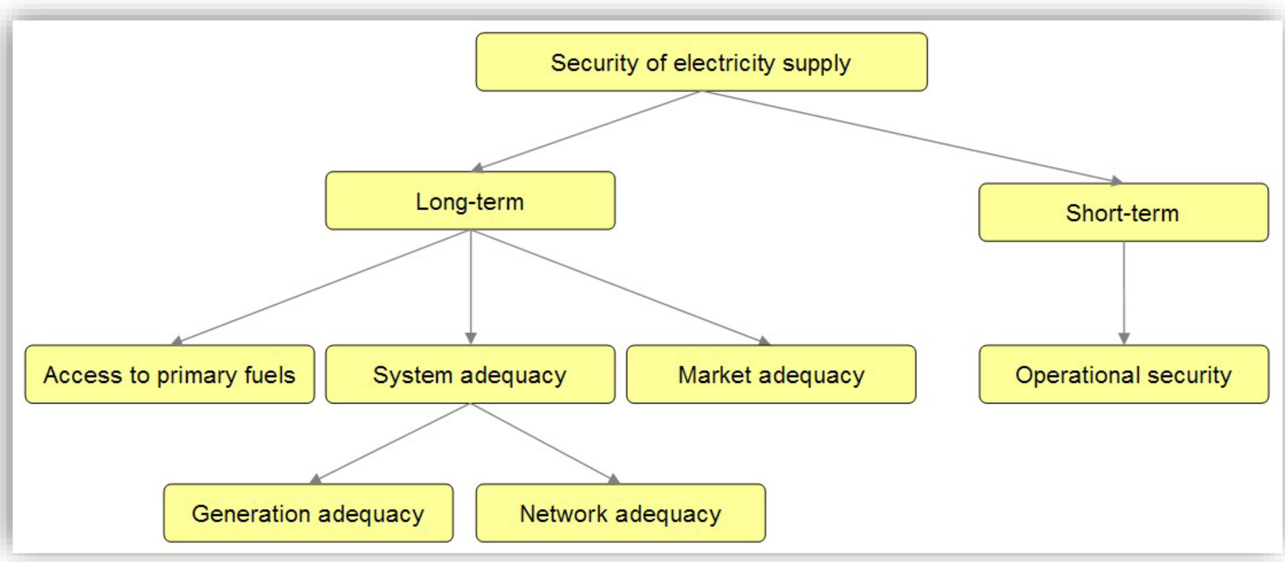
CHAPTER 4) SECURING ELECTRICITY SUPPLY WITH LARGE AMOUNTS OF INTERMITTENT RENEWABLE GENERATION IN COMPETITIVE ELECTRICITY MARKETS:

4.1) Definition and Classification of Security of Electricity Supply

Intermittent generation penetration into wholesale electricity markets reveals another aspect for resource adequacy concern, to supply sufficient capacity with reliable electricity generation in short and long run. (Milligan et al., 2016).

According to The IEA; energy security is the situation of "the uninterrupted availability of energy sources at an affordable price" (IEA, 2014, p.13). EURELECTRIC added concepts of providing quality electricity compliant with defined standards and agreements to the definition of electricity supply security (Pierre, 2006).

Figure 9. Security of Electricity Supply



Source: (Pierre, 2006, p.16)

As described in Figure-9; existing literature allocates energy security in two main directions as Short-term and Long-term Energy security (Pierre, 2006);

Short-term energy security concerns responsiveness of the energy system to the dynamic supply-demand changes in the market. System operators provide short-term security of supply by balancing supply and demand in seconds which requires appropriate regulations on ancillary services with sufficient technical reserves. Short term security of supply can be named as operational security depends on system flexibility (Pierre, 2006, p. 20).

Long-term energy security concerns the sustainability and adequacy of new investments to supply required energy demand correlated with economic growth and also environmental aspects. Long-term security of electricity supply and system reliability is achieved by following adequacies as briefly described below (Pierre, 2006, p. 16);

- **System adequacy;** is the key function of the electricity system, depending on **generation adequacy** and **network adequacy** for sustainably transmitting/distributing every MWh of electricity to consumers that are generated by producer plants (Pierre, 2006, p. 18).

- **Generation adequacy** indicates the satisfaction of demand both in low and high load conditions with available capacity. Generation adequacy is ensured with following sub-dimensions, (Roques, 2008);

(i) optimized generation capacity with complete optimal system reliability design criteria;

(ii) minimized investment volume with an optimized investment timing of minimizing reduced effect of transitory regulations on supply security;

(iii) optimized generation mix, considering peaking and baseload units and also and fuel mix.

- **Network adequacy** indicates the existence of full-functioning infrastructures for transmission, distribution and cross-border interconnection to answer supply and demand activities in the market. Proper revenue from this infrastructure services is essential to sustain and develop the system with investments (Pierre, 2006, p. 19).

Market adequacy: As a keystone market condition, linking all producers with consumers is an essential market duty (Pierre, 2006, p. 20).

Access to primary fuels: Electricity producers have right to prefer any fuel type according to economic rational without being restricted by any means of political decisions (Pierre, 2006, p. 16).

Following literature research will be organized to cover existing regulatory options for short and long-term security concerns for adequacy matters focusing the European electricity markets.

4.2) Literature Review for Strategies Considering Security of Electricity Supply:

Literature considering the security of electricity of supply has evolved since the electricity sectors reform processes have started to transform electricity systems. Roques (2008) argues the general acceptance of long and short term distinction of supply security and states the existence of short-term price signals and adequacy measures have a significant effect on long-term adequacy and security.

Ela et al. (2016) discuss the significance and difficulties related with operational flexibility of electricity system for the short-run term with considering large amount of intermittent renewable generation focusing on existing regulations experienced in the United States. In the dynamic market environment, drastical changes on volume of voltage and electricity frequency insist effective management of operational flexibility. For this reason several types of designs have emerged to support flexibility, however, the way and the depth of this incentivization is highly disputed; in the study performance of flexible ramping products and pay-for-performance regulating reserves are investigated.

Frequent scheduling with settlement intervals, centralized scheduling with efficient dispatch and make-whole payments are addressed as existing traditional tools utilized to provide short-term operational flexibility, however as the rapidness for power adjustments and power range needs amendments to handle increased variable generation integration, new types of methods have emerged. Improved scheduling strategies and methods can lead provide needed flexibility options with existing market conditions. Pay-for-performance regulation and primary frequency response markets, support flexibility with extra incentives. Flexible ramping, demand response and energy storage options promises potential to incentivise the resources for better flexibility specialy coping with intermittent generation variability (Ela et al.,2016)

For long-term adequacy issue, mainly there are two broad approaches, which are also contradicting with each other; **‘‘energy-only market’’** strategy; defends long-term efficiency and risk can be handled only by demand in market conditions by **‘‘scarcity pricing’’** without a regulatory intervention and the **‘‘capacity mechanism’’** strategy; intervention of regulatory by **‘‘capacity mechanism designs’’** that ensures the security of generation as the ‘‘reliability product’’. Reliability product is generated by producers, by achieving adequacy in long-term and firmness in mid-term; as they receive extra yield in return (Batlle & Rodilla, 2010).

Hogan (1998) argues the role of a transparent and proper scarcity price mechanism in the energy-only designs if scarcity price mechanism has the ability to provide more effective incentives for investments and operations which make it possible without regulatory interventions. Also, this model creates another form of a problem, called as the ‘missing money’, results from the imperfections in the market design that depress spot electricity prices and concludes to inadequate incentives to invest in new capacity. Addressing the imperfections in the market design helps to eliminate the inadequate incentives and solving missing money problem but that does not eliminate the necessity of proper regulatory interventions at all.

Wen, Wu, and Ni, (2004) argue several aspects of supply security such as energy-only markets, price caps and capacity design in competitive markets. His findings suggest that energy only market model has risks in economic and political context as the practical experiences like market failure case of California proves the fact that the model unable to deal with rising demand in a sustainable way. Secondly, he argues price cap tool and states that price cap model is necessary but only for energy-only markets. Then he investigates existing capacity mechanisms in U.S. markets, namely capacity obligation model, administrative payments for capacity and explicit capacity adder payment model then states the necessity of these capacity mechanisms to ensure resource adequacy in long term for competitive markets also addresses their disadvantages. Lastly, he suggests that maintenance scheduling is critical object to provide necessary capacity in short-term operations and defends the maintenance scheduling duty can be undertaken by generation companies.

Capacity mechanisms are regulatory intervened solutions as mentioned above. In application, capacity mechanism shows great variety with principles according to the countries. The study will suggest types of capacity mechanism aims to secured electricity supply and later focus on design principles for better market designs achievable with capacity mechanisms in competitive electricity markets.

Broadest categorization of available mechanisms has been introduced in ‘Final Report of the Sector Inquiry on Capacity Mechanisms’ from European Commission, states that 35 different types of capacity mechanism implemented in 11 member European countries, mainly divided as 'targeted' and 'market-wide' capacity mechanisms.

Table 5: Types of Capacity Mechanisms in Europe

Targeted Capacity Mechanisms		***Market-wide Capacity Mechanisms***	
Volume Based Mechanisms	*Price Based Mechanisms*	*Volume Based Mechanisms*	*Price Based Mechanisms*
- Strategic reserves - Tenders for new capacity - Demand Response * (*interruptibility schemes)	- Targeted capacity payment	- Central Buyer Model - De-central obligation schemes	- Market-wide capacity payment

Source: Own table

Volume (quantity) based and price-based mechanisms are common in both in targeted and market-wide mechanisms. In volume (quantity) based mechanisms, the regulatory organization provides the amount of required ‘‘reliability product’’. As expected, in price-based mechanisms, the regulatory organization defines the price of the required ‘‘reliability product’’ (Batlle, 2010).

Targeted Capacity Mechanisms:

In targeted mechanisms; additionally demanded and supplied extra amount of electricity in the market is ordered centrally and also the price is defined centrally by the capacity mechanism (European Comission, 2016, p.38). Strategic reserves, tendering for new capacity and demand response are volume based mechanisms due to the reason, supported quantity of electricity is set in the beginning. But targeted capacity payments are considered as price-based mechanisms as the electricity is supported by payments for requested a specific type of generation (European Comission, 2016, p.152).

Strategic reserve: Reserve mechanisms are strategic tools which exist to secure system via reserved ready and available capacity. If prices peak in a certain demand situation, reserved capacity is conducted and the system is balanced via reserves (European Comission, 2016, p. 145).

Strategic reserves has the capability to recover missing money problem if supported by proper regulations and also ensure system without distorting it. However, strategic reserves are not proper regulations for electricity markets which require additional new generation capacity investments (European Comission, 2016, p. 145).

Tendering for new capacity: is an investment financing mechanism -which can be a power purchase agreements, works with the principal of plant owner pays back the finance support by pre-defined extra capacity supply as demanded forward when the plant begins production.

Despite reserve capacity is not a mechanism for attracting investments, tender for new capacity is a suitable tool to trigger investments also investing in the desired location. On the other hand; tender mechanisms are not successful to solve long-term adequacy and are likely to worsen existing regulatory and market imperfections (European Comission, 2016, p. 145).

Demand-response schemes can be named as interuptibility schemes which are the subcategory of strategic reserve mechanism. Operators are paid for the response of their supply according to the demand conditions both if it rises and falls (European Comission, 2016, p. 149).

Demand response mechanisms do not solve capacity shortages and should be managed through a support scheme indicating value added to TSO to efficiently secure the system. In the long term aspects transparency is necessary for technical specifications when selecting operators by TSO's to prevent from over-renumerating them (European Comission, 2016, p. 152).

Targeted capacity payment: As a property of a price-based capacity mechanism, the price of capacity is defined by centrally in targeted capacity payment mechanism and it is paid to a producer in the condition of generating from a defined technology or with specific criteria like the location of production.

Targeted capacity payments protect some generation plants from being shut down however they can risk other generation plants activities which are not supported same as the tender and reserve models risk the non-eligible ones for this support. Targeted capacity payments are the least efficient version of a capacity mechanism, due to the reason of their crowding out effect for ineligible producers that risk long-term adequacy by risking their activities and disrupting alternative technology preference of investors by allocating investments in a specific type (European Comission, 2016, p. 154).

Market-wide Capacity Mechanisms:

Market-wide capacity mechanism principle depends on payments to all producers as they supply generation to secure the system reliability. The main difference is capacity is defined as a product and does not mean electricity. Mechanisms perform under price and quantity based principles same as in targeted capacity mechanism (European Comission, 2016, p. 152).

Central buyer mechanism: On central buyer mechanism, the price is defined by bids by capacity providers on a central bidding auction, for a centrally defined quantity of capacity.

The mechanism is useful for overcoming capacity shortages if its design does not disrupt market functionality. The flexibility of the product design is essential to prevent from inefficient outcomes with the complexity of implementation of the mechanism (European Comission, 2016, p. 152).

De-central obligation: Electricity producers and capacity providers are obliged to make a contract for securing the required capacity according to the demand conditions in this mechanism. There is not a bidding activity in de-central obligation mechanism however the price for demanded capacity is defined with supply and demand elasticity.

The de-central obligation is capable of overcoming capacity shortages and useful to address a systemic, market-wide missing money problem, but not proper provide capacity if it is demanded in certain place or type of generation. Unlike central buyer mechanism, capacity is not defined centrally. This mechanism is present in France (European Comission, 2016, p. 152).

Market-wide capacity payment: Capacity providers receive a centrally defined payment for meeting all existing demand in the market. The mechanism is present in Ireland.

In market-wide capacity payment mechanism, crowding out effect does not occur on generation technology preferences as it occurs with targeted capacity payments but it may act as a barrier for new investors into the market. Lastly, market-wide capacity payments are not cost effective and fail to set out the value of capacity. (European Comission, 2016, p. 161).

As the evaluations stated above, all mechanisms have their own advantages and disadvantages, mechanisms can be useful when the problem and exact conditions of the market are well defined. If the concern is biased long-term adequacy, volume-based, market-wide scheme and technology neutral capacity mechanisms are most fitting solutions to ensure future investments and create reliable income for their investors. Lastly, if the concern is biased short term, strategic reserve mechanism is likely to be the most suitable solution, as it gives the control capability on existing capacity for hold on hold off in the market (European Comission, 2016, p. 209)

4.3) Developments with Capacity Mechanism Design and Implementation in the European Union

Hawker, Bell, and Gill (2017) evaluate the capacity mechanism developments in EU member countries that are contradicting with European Internal Energy Market target. As targeted single competitive electricity market which aims to achieve adequate price signals also reflecting the scarcity for new investments and increased cross-border electricity flow which is a tool for providing extra capacity during peak demand, capacity mechanisms has a negative impact on cross-border electricity flow by disrupting competitiveness in prices and leading to decrease in new investments. The study suggests set of EU-wide comprehensive solutions to neutralize the effects of the capacity mechanism. These solutions are allowing interconnection into national capacity mechanisms, a single capacity mechanism in EU and financial risk hedging management for resolving the capacity adequacy issue.

The Clean Energy for All Package (Winter Package)

The European Commission presented "The Clean Energy for All Package" proposal which is also known as "The Winter Package" in direction of a competitive integrated electricity market aligning with transition requirements of decarbonization and clean energy generation. The proposal will be legally binding from 1 January 2020.

Proposal defines properties of an optimal capacity mechanisms, as follows;

- Allowing all internal and cross-border capacity generators also special attention to new investors,
- trigger a competitive pricing for minimizing the cost of procured capacity;
- supporting interconnection investment and reliability incentivization;
- for preventing from disrupting trade allowing electricity scarcity pricing.

On Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the internal market for electricity document (European Commission, 2016, p. 53), in **Chapter IV - Resource Adequacy**: ***Resource adequacy*** issue is defined in ***Article 18 as*** follows*;*

Article 18 - Resource Adequacy:

1. Member States ought to screen resource adequacy on their land according to the ***'European resource adequacy assessment'*** which is a methodology developed by ENTSO-E and ACER that states the criteria for allowance of a new capacity mechanism establishment that is introduced at Article 19.

2. Member States are responsible for diagnosing the cause of an adequacy scarcity if it is due to a regulation which is implemented.

3. Scarcity pricing, interconnection development, energy storage, demand response and energy efficiency tools will be utilized and a proper schedule plan will be declared for addressing to prevent regulatory disruptions by the Member States.

At ***Article 23*, the design principles for capacity mechanisms** are explained as follows:

Article 23 - Design principles for capacity mechanisms (European Commission, 2016, p. 57),

1. Member States are allowed to implement capacity mechanisms if the precautions described in *Article 18(3)* fails to respond the adequacy needs.

> *18(3).* The Member States obliged to declare a schedule for accepting measures to overcome any defined regulatory disruptions. Member States ought to progress on scarcity pricing, interconnection improvement, handling regulatory disruptions, utilizing storage of energy, demand response and improve energy efficiency.

2. Member States ought to deal and negotiate with its interconnected neighbor before integrating a national capacity mechanism.

3. Capacity mechanisms should not disrupt the market and prevent cross-border trade from any restriction. The capacity amount should not be larger than the adequacy need.

4. New generation investment which is taken in operation after 1 January 2020; can accompany in a capacity mechanism with the condition of having lower emissions below 550 gr CO2/kWh. After 1 January 2025, capacity suppliers which are emitting over 550 gr CO2 per will not be allowed to accompany in capacity mechanisms.

5. Member States are obliged to install any form of capacity mechanisms only with the condition of 'European resource adequacy assessment' result indicates a resource adequacy problem existence.

Also ***Article 24-Existing mechanisms****;* stated that after 1 January 2020; the Member States ought to modify their existing mechanisms according to the criteria defined in Articles 18, 21 and 23 of this New Regulation.

Chapter 4 Findings:

Literature suggests a rich variety of regulations aims to ensure short and long-term security of electricity supply all over the world. However, there is not a one size fit solution that works for every country and market condition. For contributing Turkish Energy Acquis alignment to European Union Energy Policy, we have investigated 'Final Report of the Sector Inquiry on Capacity Mechanisms' and forward-looking "The Clean Energy for All Package" proposal, particularly Chapter IV: Resource adequacy for understanding future regulative projections considering resource adequacy and capacity mechanism issue.

For proposing a possible generation adequacy and security of supply solution, following brief facts are derived from existing literature considering the security of supply situation of Turkish electricity system.

Turkish electricity system is an "energy only" market without a capacity mechanism thus generator's only income is electricity generation yields and there is also no price cap regulation. This constitutes the 'missing money' risk during a capacity shortage period if prices skyrocketed. Despite demand-side participation theoretically is possible in the Turkish day-ahead market, it does not exist in practice. Consequently, price signaling for new investment decisions is only attracted by price spikes (Dastan and Selcuk, 2016).

Actually installed capacity Turkish electricity market was 70 GW exceeds peak demand that can reach to 41 GW with significant difference and supply/demand capacity rate was 69% in 2014. Numbers indicate an oversupply situation (IEA, 2016, p.152). On the other hand, some thermal plants are mostly out of service due to maintenance and repair it is possible to miss peak demand period (Dastan and Selcuk, 2016).

CHAPTER 5: CONCLUSIONS

This thesis aims to analyze the possible impacts of a large amount of intermittent wind generation on the merit order and wholesale electricity prices in Turkey and possible electricity supply security measures are discussed to prevent negative impacts of intermittent wind integration into the electricity system.

The study investigated structure, organization and functioning of Turkish wholesale electricity market. Turkish electricity market and the system have experienced intensive reforming process through liberalization which was started by IMF and World Bank at 2001 and evolved to another stage with European Union alignment process at 2001. Turkish electricity market adopted several measures policies and regulations and transformed into a competitive market which includes day ahead, intra-day, balancing, and derivatives market. However, the theoretical market opening rate is %86 and pricing mechanism still is not considered as cost-based.

Merit order mechanism in Turkish electricity market is investigated, it is concluded that merit order is significantly influenced by feed-in tariff supports, mandatory purchase contracts, fuel prices and seasonalities of hydropower. As stated in Chapter 3, Turkish electricity market is mostly relying on bilateral agreements with a %95 ratio of total trade capacity. Mandatory power purchase agreements remaining from pre-liberalization era linked with Build Operate&Transfer (BO/BOT) plants; are the other issue preventing Turkish price mechanism from to be a price based market organization. Build Operate&Transfer (BO/BOT) plants operate on an old fashioned and inefficient generation technology Despite their higher costs, they have privilege on the merit order and sorted before low-cost generation technologies.

According to comprehensive literature research focusing on impacts of increasing intermittent renewable penetration on whole electricity systems and market mechanisms, for Turkey, it expected that renewable generation will decrease prices when mandatory power purchase agreements end at 2018-2019 and low-cost generation technologies replace on merit order curve with them. Also, cross-border electricity trade and whaether conditions in neighboring countries will affect prices according to the steepness of demand and supply curves.

Also, intermittent generation increase causes adequacy problems in electricity supply and risks electricity system reliability problem both in short and long terms. In Chapter 4, a detailed literature research is conducted to define electricity supply problem, it’s types and relationship between intermittent renewable generation. The literature research focused on solutions to adequacy problem in electricity markets.

According to the literature review, energy-only markets as current Turkish electricity system are not capable of overcoming missing money problem and providing price signals which are crucial for sustaining new investments in generation. However, there is not a perfect solution for supply security of electricity and regulations are subject to change according to the country and market conditions. Findings of the evaluation suggest that while volume-based, market-wide scheme and technology neutral capacity mechanisms are best tools for long-term adequacy, strategic reserve mechanism is advised for short-term adequacy problem.

Lastly, latest proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the internal market for electricity of European Commission is investigated that is going to be binding 2020 for considering design principals for the allowance in case of the proper capacity mechanism.

BIBLIOGRAPHY

1. Ministry of Foreign Affairs of Turkish Republic.(2015). Retrieved from http://www.mfa.gov.tr/turkeys-energy-strategy.en.mfa
2. Energy and Renewables.(2013). Retrieved from http://www.invest.gov.tr/en-US/sectors/Pages/Energy.aspx
3. Republic of Turkey Ministry For EU Affairs.(2016). Retrieved from http://www.ab.gov.tr/index.php?p=80&l=2
4. European Commission.(n.d.). Retrieved from https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union
5. Keles, D. (2013). *Uncertainties in energy markets and their consideration in energy storage evaluation* (Vol. 4). KIT Scientific Publishing.
6. Cullen, J. (2013). Measuring the environmental benefits of wind-generated electricity. *American Economic Journal: Economic Policy*, *5*(4), 107-133.
7. Kyritsis, E., Andersson, J., & Serletis, A. (2017). Electricity prices, large-scale renewable integration, and policy implications. *Energy Policy*, *101*, 550-560.
8. European Commission. (2015). Launching the public consultation process on a new energy market design {SWD(2015) 142 final}. Retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52015DC0340
9. Sijm, J. P. M. (2017). Cost and revenue related impacts of integrating electricity from variable renewable energy into the power system-A review of recent literature. *Policy Studies*, *2016*, 2015.
10. Republic of Turkey Ministry of Foreign Affairs. (2017). *From Rep. of Turkey Ministry of Foreign Affairs*.Retrieved from http://www.mfa.gov.tr/turkeys-energy-strategy.en.mfa
11. International Energy Agency.(2014).Electricity Generation By Fuel Type in Turkey. Retrieved from https://www.iea.org/stats/WebGraphs/TURKEY2.pdf
12. PJM.(2014). Intermittent Resources Subcommittee. Retrieved from http://www.pjm.com/committees-and-groups/subcommittees/irs.aspx
13. Fares, R. (2015). Renewable Energy Intermittency Explained: Challenges, Solutions, and opportunities. Retrieved from https://blogs.scientificamerican.com/plugged-in/renewable-energy-intermittency-explained-challenges-solutions-and-opportunities/.
14. Delucchi, M. A., & Jacobson, M. Z. (2011). Providing all global energy with wind, water, and solar power, Part II: Reliability, system and transmission costs, and policies. *Energy policy*, *39*(3), 1170-1190.
15. Intermittent energy source. (2017, June 16). In *Wikipedia, The Free Encyclopedia*. Retrieved June 16, 2017,

from https://en.wikipedia.org/w/index.php?title=Intermittent_energy_source&gettingStartedReturn=true#cite_note-IEA2005WindVar-28.

16. Cankorel, T. (2016) Turkish Solar Update. Retrieved from http://www.renewableenergyworld.com/articles/2016/01/turkish-solar-update.html

17. Kaplan, D. (2017). Renewable Energy Turkey O*pportunity?*

https://www.rvo.nl/sites/default/files/2015/10/Renewable%20Energy%20Turkey.pdf.

18. Zuvin,S., & Kimizioglu,E. (2016). Solar Energy Incentives and Licensing Procedures in Turkey. Retrieved from

http://www.mondaq.com/turkey/x/476838/Renewables/Solar+Energy+Incentives+And+Licensing+Procedures+In+Turkey

19. Dilli, B., & Nyman, K. J. (2015). Turkey's Energy Transition. Milestones and Challenges. *ESMAP Paper No. ACS14951, World Bank, Washington, DC*.

20. Colak, I., Bayindir, R., Fulli, G., Tekin, I., Demirtas, K., & Covrig, C. F. (2014). Smart grid opportunities and applications in Turkey. *Renewable and Sustainable Energy Reviews*, *33*, 344-352.

21. Çetin, T., & Oguz, F. (2007). The politics of regulation in the Turkish electricity market. *Energy Policy*, *35*(3), 1761-1770.

22. İŞBANK.(2016).*Energy Sector Investment Report 2016.* Retrieved from http://rapor.isyatirim.com.tr/2_20160624100821219_1.pdf

23. Atiyas, I., Cetin, T., & Gulen, G. (2012). *Reforming Turkish energy markets: political economy, regulation and competition in the search for energy policy*. Springer Science & Business Media.

24. Bagdadioglu, N., & Odyakmaz, N. (2009). Turkish electricity reform. *Utilities Policy*, *17*(1), 144-152.

25. Erdogdu, E. (2010). A paper on the unsettled question of Turkish electricity market: Balancing and settlement system (Part I). *Applied Energy*, *87*(1), 251-258.

26. Deloitte Consulting LLP.(2012). *Turkish Electricity Market Review.* Retrieved from https://dec.usaid.gov/dec/GetDoc.axd?ctID=ODVhZjk4NWQtM2YyMi00YjRmLTkxNjktZTcxMjM2NDBmY2Uy&pID=NTYw&attchmnt=VHJ1ZQ==&rID=MzUxMTQ1

27. Ersin, B.T., & Arseven, B. (2015). Overview of Electricity regulation in Turkey. Retrieved from https://www.morogluarseven.com/news/overview-electricity-regulation-turkey-2015-2

28. Türkiye Elektrik, Ticaret ve Taahhüt Anonim Şirketi. (2015). *2015 Yili Sektor Raporu*. Retrieved from http://www.tetas.gov.tr/File/?path=ROOT%2f1%2fDocuments%2fSekt%c3%b6r+Raporu%2fTETA%c5%9e+2015+Y%c4%b1l%c4%b1+Sekt%c3%b6r+Raporu.pdf

29. Deloitte Consulting LLP.(2012). *Turkish Electricity Market Review*. Retrieved from http://hydropower.ge/user_upload/Turkish_Electricity_Market_Review_Report_Deloitte_Turkey.pdf

30. European Bank for Construction and Development.(**2015)** *STRATEGY FOR TURKEY*. Retrieved from http://www.ebrd.com/ebrd-turkey-strategy.pdf

31. European Commission.(2016). *Turkey Progress Report 2016.* SWD(2016) 366 final. Brussels. *Retrieved from https://ec.europa.eu/neighbourhood-enlargement/sites/near/files/pdf/key_documents/2016/20161109_report_turkey.pdf*

32. Hogan, W. W. (1998). Competitive electricity market design: A wholesale primer. *December, John F. Kennedy School of Government, Harvard University*.

33. Cochran, J., Miller, M., Milligan, M., Ela, E., Arent, D., Bloom, A., ... & Gómez-Lázaro, E. (2013). *Market evolution: Wholesale electricity market design for 21st century power systems* (No. NREL/TP-6A20-57477). NREL (National Renewable Energy Laboratory (NREL), Golden, CO (United States)).

34. Cornwall, N. (2008). Achieving electricity market integration in Europe. *Competitive Electricity Markets: Design, Implementation and Performance*, 95-138.

35. Merit Order. (2016, November 16). In Wikipedia, The Free Encyclopedia. Retrieved November 16, 2016, from https://en.wikipedia.org/wiki/Merit_order

36. Erdmann, G. (2015). Economics of electricity. In *EPJ Web of Conferences* (Vol. 98, p. 06001). EDP Sciences.

37. Paraschiv F, Erni D, Pietsch R. The impact of renewable energies on EEX day-ahead electricity prices. Energy Pol 2014;73:196–210.

38. W. Hu, Z. Chen and B. Bak-Jensen, "The relationship between electricity price and wind power generation in Danish electricity markets", Proc. IEEE Asia-Pacific Power and Energy Engineering Conference (APPEEC)

39. B. Moreno, A.J. Lopez, M.T. Garcia-lvarez, The electricity prices in the European Union. The role of renewable energies and regulatory electric market reforms, Energy 48 (2012) 307e313.

40. Bach, P. E. (2009). Effect of Wind Power on Spot Prices. *Renewable Energy Foundation, London, UK.*

41. Sensfuß, F.; Ragwitz, M.; Genoese, M. (2008): The Merit order effect: A detailed analysis of the price effect of renewable electricity generation on spot market prices in Germany.Energy Policy, Volume 36, Issue 8, August 2008, Pages 3076-3084.

42. Ketterer, J. C. (2014). The impact of wind power generation on the electricity price in Germany. *Energy Economics*, *44*, 270-280.

43. Würzburg, K., Labandeira, X., & Linares, P. (2013). Renewable generation and electricity prices: Taking stock and new evidence for Germany and Austria. *Energy Economics*, *40*, S159-S171.

44. Nicolosi, M., & Fürsch, M. (2009). The impact of an increasing share of RES-E on the conventional power market—the example of Germany. *Zeitschrift für Energiewirtschaft*, *33*(3), 246-254.

45. Munksgaard, J., & Morthorst, P. E. (2008). Wind power in the Danish liberalised power market—Policy measures, price impact and investor incentives. *Energy Policy*, *36*(10), 3940-3947.

46. Delarue, E. D., Luickx, P. J., & D'haeseleer, W. D. (2009). The actual effect of wind power on overall electricity generation costs and CO 2 emissions. *Energy Conversion and Management*, *50*(6), 1450-1456.7

47. M. Mulder, B. Scholtens, The impact of renewable energy on electricity prices in the Netherlands, Renew. Energy 57 (2013) 94e100.

48. Kuipers, D. F. (2016). Merit order effect across borders.

49. Weigt, H. (2009). Germany's wind energy: The potential for fossil capacity replacement and cost saving. Applied Energy, 86(10), 1857-1863.

50. Hiroux, C., & Saguan, M. (2010). Large-scale wind power in European electricity markets: Time for revisiting support schemes and market designs?. *Energy Policy*, *38*(7), 3135-3145.

51. Albadi, M. H., & El-Saadany, E. F. (2010). Overview of wind power intermittency impacts on power systems. *Electric Power Systems Research*, *80*(6), 627-632.

52. Garanti Bankasi.(2015) . *Electricity Market Report 2015-2025 Projections***.** Retrieved from https://www.garantiinvestorrelations.com/en/images/pdf/2015-Electricity-Market-Report.pdf

53. Milligan, M., Frew, B. A., Bloom, A., Ela, E., Botterud, A., Townsend, A., & Levin, T. (2016). Wholesale electricity market design with increasing levels of renewable generation: Revenue sufficiency and long-term reliability. *The Electricity Journal*, *29*(2), 26-38.

54. International Energy Agency. (2014).Energy supply security: The emergency response of IEA countries 2014. Paris: Retrieved from https://www.iea.org/publications/freepublications/publication/energy-supply-security-the-emergency-response-of-iea-countries-2014.html

55. Pierre, I. (2006). Security of Electricity Supply–Roles, responsibilities and experiences within the EU [Electronic resource]. *Eurelectric–Union of the Electricity Industry.–Brussels, Belgium*.

56. Roques, F. A. (2008). Market design for generation adequacy: Healing causes rather than symptoms. *Utilities Policy*, *16*(3), 171-183.

57. Ela, E., Milligan, M., Bloom, A., Botterud, A., Townsend, A., Levin, T., & Frew, B. A. (2016). Wholesale electricity market design with increasing levels of renewable generation: Incentivizing flexibility in system operations. *The Electricity Journal*, *29*(4), 51-60.

58. Batlle, C., & Rodilla, P. (2010). A critical assessment of the different approaches aimed to secure electricity generation supply. *Energy Policy*, *38*(11), 7169-7179.

59. Hogan, W. W. (2005). On an "Energy only" electricity market design for resource adequacy. *California ISO*.

60. Wen, F. S., Wu, F. F., & Ni, Y. X. (2004). Generation capacity adequacy in the competitive electricity market environment. *International journal of electrical power & energy systems*, *26*(5), 365-372.

61. European Commission.(2016). *REPORT FROM THE COMMISSION Final Report of the Sector Inquiry on Capacity Mechanisms* .SWD(2016) 385 final.Brussels. Retrieved from http://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:52016SC0385

62. Hawker, G., Bell, K., & Gill, S. (2017). Electricity security in the European Union—The conflict between national Capacity Mechanisms and the Single Market. *Energy Research & Social Science*, *24*, 51-58.

63. European Commission.(2016). *Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the internal market for electricity*.COM(2016) 861 final/2 - 2016/0379 (COD).Brussels. Retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2016:861:FIN

65. Dastan, S. A., & Selcuk, O. (2016). Review of the security of supply in Turkish energy markets: Lessons from the winter shortages. *Renewable and Sustainable Energy Reviews*, *59*, 958-971.

66. International Energy Agency.(2013). *Energy Policies of Countries Turkey 2016 Review*. Retrieved from https://www.iea.org/publications/freepublications/publication/EnergyPoliciesofIEACountriesTurkey.pdf

67. IEA. (2016). Electricity Generation By Fuel Type in Turkey 2014. Retrieved June 16, 2017, from https://www.iea.org/stats/WebGraphs/TURKEY2.pdf

68. Electricity Market Regulatory Agency of Turkey.(2016). Installed Wind Energy Capacity Retrieved From http://www.emra.org.tr/EN/Documents/ElectricityMarket/PublishmentsReports

69. Müsgens, F. (2005). *The Economics of Wholesale Electricity Markets* (Doctoral dissertation, Universität zu Köln).

TABLE OF CONTENTS

List of Figures……………………………………………………………………………….…………4

List of Tables…………………………………………………………………………….……….4

Abbreviations……………………………………………………………………………………..5

CHAPTER 1: INTRODUCTION………………………..……………………………….……..6

1.1.Background Information…..…………………………………..…………………….. ……6

1.2. Problem Statement…..…………………………………………..…………………………...7

1.3. Research Objective…..…………………………………………………………………….8

1.4. Research Questions…..……………………………………….……………………………8

CHAPTER 2: ORGANIZATION AND FUNCTIONING OF TURKISH ELECTRICITY MARKETS..9

2.1. Current Situation of Electricity Markets in Turkey…..……………………………………9

2.2. Current Situation of Renewable Generation Share in Turkey……………..……………………10

2.3. Historical Background of the Reforms……………………………………………..….13

2.4. Current Functioning of Price Mechanisms In Wholesale Electricity Markets in Turkey………..15

2.4.1. Bilateral Contracts………………………………………………………………...16

2.4.2. Day Ahead Market……………………………………………………….……..16

2.4.3. Funtioning in Balancing Power Market……………………………………….……..18

2.4.4. Intra-day markets…………………………………………………………………18

2.4.5. Derivatives Market…………………………………………………………………..19

Chapter 2 Findings ……………………………………………………………………………19

CHAPTER 3: WHOLESALE ELECTRICITY MARKETS AND RENEWABLE PENETRATION…………………………………………………………………………..…20

3.1. Competitive Wholesale Electricity Markets…………………………………………………...20

3.2. Brief Definition of Merit Order and Merit Order Effect……………………………………...…21

3.3. Impact of Large Amount of Wind Generation on Electricity Markets and Systems…………….22

3.4. Impact of wind generation to the Turkish Electricity Martket and Preferred Merit Order…...….27

Chapter 3 Findings………………………………………………………………………….30

CHAPTER 4) SECURING ELECTRICITY SUPPLY WITH LARGE AMOUNT OF INTERMITTENT RENEWABLE GENERATION IN COMPETITIVE ELECTRICITY MARKETS……………………………………………………………………………………32

4.1. Definition and Classification of Security of Electricity Supply……………………………..…...…32
4.2) Literature Review for Strategies Considering Security of Electricity Supply……………………..…..33

4.3) Developments with Capacity Mechanism Design and Implementation in European Union….....38

Chapter 4 Findings……………………………………………………………………………………40

CHAPTER 5: CONCLUSIONS………………………………………………………..……......…41

BIBLIOGRAPHY……………………………………………………………………….……………43

List of Figures

Figure 1: Electricity Generation By Fuel Type in Turkey..…………………………………………….…10

Figure 2: Installed RES Energy Capacity Source.……………………..…………………………..13

Figure 3: Supply and Demand on Electricity Markets ………………..…………………………..…....15

Figure 4: Day Ahead Market Process Daily procedure……………………………………………16

Figure 5: Supply and Demand on Electricity Markets…………………………………………….…20

Figure 6: Figure 6. Merit order Curve…………………………………………………………..21

Figure 7: Merit Order Curve Before the Termination of BO/BOT Plants in Turkish Electricity System………………………………………………………………………………………...28

Figure 8: Merit Order Curve After the Termination of BO/BOT Plants in Turkish Electricity System………………………………………………………………………………………...28

Figure 9. Security of Electricity Supply…………………………………………………………32

List of Tables

Table 1: Electricity generation and shares by energy resources.…………………………..……......9

Table 2: Installed RES Energy Generation Capacity by end of 2016…….…………………..……........11

Table 3: Installed Wind Energy Capacity……………………………..…………………………….11

Table 4: Fixed Feed-in Tariff for RES Generation……..…………………………………..…………27

Table 5: Types of Capacity Mechanisms in Europe…………………………………………….……….34