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FACULTY OF ENGINEERING AND NATURAL SCIENCES

Price Forecasting and System Direction Determination in Turkish Balancing Power Market

Capstone Project Proposal

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LIST OF ABBREVIATIONS

BPM	Balancing Power Market
BC	Bilateral Contracts
DAM	Day-ahead Market
IDM	Intraday Market
FERC	Federal Energy Regulatory Commission
OFGEM	Office of the Gas and Electricity Markets
CRE	The Energy Regulatory Commission
AEEGSI	Italian Regulatory Authority for Electricity Gas and Water
OECD	Organisation for Economic Co-operation and Development
TUSIAD	Turkish Industry & Business Association
SQL	Sequential Query Language
GPU	Graphics Processing Unit
GDP	Gross Domestic Product
PCI	Per Capita Income
ARX	Autoregressive with Exogenous input
EPF	Electricity Price ForecastingM
RFR	Random Forest Regression
SVM	Support Vector Machine
ANN	Artificial Neural Network
LSTM	Long Short-Term Memory
RNN	Recurrent Neural Network

BLSTM	Bidirectional Long Short-Term Memory
LPG	Liquefied Petroleum Gas
OSB	Organized Industrial Zone
EPİAŞ	Energy Markets Management Inc.
TEİAŞ	Turkish Electricity Transmission Corporation
PTF	Market Clearing Price
HES	Hydroelectric Power Plant
BOTAS	Turkish Oil Pipelines Corporotion
YAL	Up Regulation Instructions
YAT	Down Regulation Instructions
EÜAŞ	Electricity Generation Corporation
MOE	Merit Order Effect
ARIMA	Autoegressive Integrated Moving Average
ARMA	Autoegressive Moving Average
ARIMAX	Autoegressive Integrated Moving Average With Explanatory Variable
ARMAX	Autoegressive Moving Average With Exogenous Variable
GDP	Gross Domestic Product
VaR	Value at Risk
CFR	Cash Flow at Risk
PaR	Profit at Risk
ETRM	Energy Trade Risk Management
EPEX	The European Energy Exchange

TWh	Terawatt Hour
MW	Megawatt Hour
kWh	Kilowatt Hour
CNN	Convolutional Neural Network
PCA	Principal Component Analysis
GRU	Gated Recurrent Unit

1. OVERVIEW

Price Forecasting and system direction determination in Turkish Balancing Power Market: The fundamental of Turkish spot power markets had been established at the end of 2011 first with Day-Ahead and Balancing Power Markets. The Intraday Market followed this and was established in 2016. For generation and retail companies managing the imbalances over Balancing Power Market is crucial. In that context the expectation is analyzing/understanding the fundamentals of the Turkish generation fleet, especially renewables, assessing the relationship between the system direction and generation fundamentals, and creating models for system direction and price forecasting in balancing power market [capstone project description website].

Energy Systems Engineering and Industrial Engineering departments have worked together to approach this problem more reliably. The Capstone group project group consists of five students from two different departments. Kadir Taha Yüceler (1604548) and Taha Bin Huraib (1721248) participate in the Industrial Engineering department and are responsible for data science applications. Ekin Yüksel (1600422), Güney Yurtsever (1730530), and Özlen Pınar Toprak (1609760) are from the Energy Systems Engineering department and responsible for finding parameters that affect the balancing power market and how these parameters affect it.

1.1 Identification of the need

In 2001 the Turkish energy market entered a state of reconstruction. Focusing on transparency and competition were the major milestones that contributed to this market. The market saw a trend that paved the way for private companies to take more control from the government. Concurrently the balance of supply and demand took a much more important role. Determining the prices and the amount of supply and demand took precedence and proved vital. As it is with the standard definition of supply and demand, lower levels of electricity supplied by power plants cause the price of electricity to increase. An inverse relationship is what governs the direction of the prices. Unfortunately, the introduction of external variables and various unforeseen situations adds to the nuances and further complicates the problem.

One of the main purposes of electricity supply companies can be described as forecasting the prices of electricity ahead of time. Electricity prices are formed by the relationship between electricity supply and demand in the non-stable competitive electricity market [1]. The accurate prediction of consumer consumption allows companies to take better actions. As an example, if the prediction of demand is less than that of the actual demand, then power shortages could occur. On the contrary, overestimating the demand would lead to higher energy prices and would incur negative losses to the company. The prediction process depends on various models and mathematical analyses. In order to obtain an advantage in the energy market, electricity suppliers prefer to create their trading strategies and predict the market price before the actual trade time (real-time) with some powerful forecasting models [1].

On the other hand, forecasting the market price predictions before real-time is not easy for all energy sources. When we evaluate natural gas and coal, these are examples of non-renewable energy sources and it is easier to forecast the prices in advance, because natural gas and coal, do not work due to constantly changing weather conditions, they proceed more stably. On the other hand, it is more difficult to forecast the price of renewable energy resources in advance. When we consider wind and solar energy, these types of energy resources depend on the weather conditions for this reason the amount of electricity that they generate can changeable every day. While making price forecasting in advance, many unstable and changing conditions such as the weather should be examined and subsequently price forecasted.

As mentioned earlier, Day-Ahead Market and Balancing Power Market were introduced in 2011 to predict the prices of energy beforehand [2]. In addition, the Intraday Market was established 2016 to further help with the prediction process. The process of dealing with and combating imbalances is especially important for suppliers as well as retailers. This thesis's main goal is to analyze the effect of renewable energy sources and understand their impact on the market while predicting the direction of the Balancing Power Market and developing an accurate prediction model. On the other hand, in another detailed explanation, the purpose of making this price forecasting model is that the price forecast methods made in the market are mostly for non-renewable energy sources, such as natural gas and coal. As long as there is not a major problem the amount of electricity produced by non-renewable energy sources continues day by day in a stable way without much change. Not being affected by external factors such as weather conditions ensures continuous electricity generation for these non-renewable energy sources.

However, since these forecast models for renewable energy resources are not developed in today's market, we wanted to focus on this and our aim is to make price estimates by using appropriate mathematical models over the renewable energy sources that are difficult to forecast, depend on weather conditions.

1.2 Definition of the problem

Before introducing the problem, we should first take a look at some of the most pertinent terms that affect the energy market.

Merit Order: The merit order is a way of ranking available sources of energy, especially electrical generation, based on ascending order of price (which may reflect the order of their short-run marginal costs of production) together with the amount of energy that will be generated. (GATES Enerji Ticaret A.Ş (2020))

Balancing Power Market (BPM): It is an organized wholesale electricity market that is operated by the system operator, where the reserve capacity obtained by output power variation can be realized within fifteen minutes to balance supply and demand in real-time.

Bilateral Contracts (BC): These are commercial agreements between real and legal persons, subject to private law provisions, regarding the purchase and sale of electrical energy or capacity.

Day-Ahead Market (DAM): It is an organized wholesale electricity market that is established for electricity energy purchases and sale transactions on the basis of a settlement period to be delivered one day later and operated by the Market Operator.

Intraday Market (IDM): It is an organized structure that serves as a bridge between the Day-Ahead Market and the Balancing Power market, contributing to the balancing and sustainability of the Electricity Market, where continuous trade is carried out until 90 minutes ago.

When we look at figure 1 below, we see the day-ahead market, the intraday market, the balancing power market, and bilateral contracts. We see that the ratio of the volumes of these markets in comparison to past and current markets in Turkey. Within the years, we can see which market has more volume in which years.

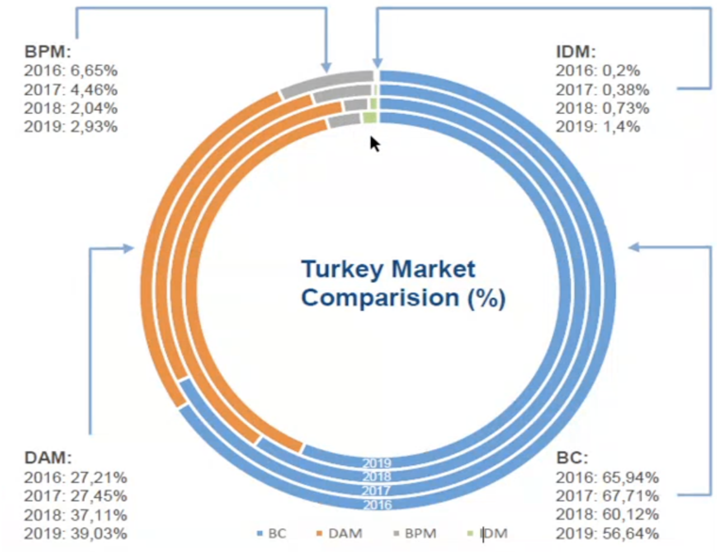

Figure 1. Turkey Market Comparison according to GATES Enerji Ticaret A.Ş (2020).

As seen in figure.1. The most important variable is the BC market. IDM, on the other hand, represents a small part. However, it continues to increase every year. When we examine figure.1. compared to years, it can be seen that Bilateral Contracts were used more frequently in the beginning. Following the bilateral contracts, the Day-Ahead Market, the Balancing Power Market, and finally the Intraday Market takes place. However, over the years, this positioning and market volumes in the market have changed. The use of Bilateral Contracts and the use of the Balancing Power Market also decreased. The Day-Ahead Market has had an increase in the usage area. In addition, although before the intraday market was in the market with a very small rate, its current position is much more than in the past. The value and usage area of the Intraday Market will increase day by day. Bilateral Contracts and the Balancing Power Market will decrease day by day.

If we consider how the electricity trading system around the world is working, first we need to examine the Scandinavian Market which covers Norway, Sweden, Finland, and Denmark. Scandinavian Pool, also known as the Nord Pool, is a kind of voluntary or net pool that allows physical Bilateral Agreements. In this market, electricity can be bought and sold within or outside of the pool, by the framework of bilateral agreements between market participants. Generators, distributors, suppliers, industrial consumers, and traders can also join the Nord Pool anytime. There are five transmission system operators in total. Two of them are located in Norway and the rest in Sweden, Finland, and Denmark. They are all active operators and cooperate with each other to facilitate trade and promote competition.

Except for Denmark, the other Scandinavian electricity markets are 100% open. Usually, large end-users in the retail market make contracts with suppliers. Here are the common types of contracts and they are briefly explained as follows:

- Contracts, where the price can be changed with short notice,
- Contracts which are fixed-price contracts,
- Spot contracts with an increment rate without the spot price, and the contracts with an increment rate based on the spot price.

When we compare the Scandinavian market and the Turkish market:
In the Scandinavian market, mostly buying and selling transactions take place around Bilateral Agreements and contracts. Although the Bilateral Agreements were highly demanded in the Turkish market before, there are still some actions going on at smaller volumes. Turkey has formerly used much of these Bilateral Agreements before. Today, the Day-Ahead Market plays the biggest role meanwhile the Intraday Market is developing, and its share is increasing day by day. On the other hand, the use of Bilateral Agreements is decreasing day by day in Turkey's electricity market.

Another example to be given from the world market, we wanted to examine the electricity market of Greece as they are one of our neighbor countries.
The system operator in Greece is called a Greek Transmission System Operator. This Greek Transmission System Operator is responsible for both system and market operations. Within the framework of the Electricity Trade Law, participants can buy and sell electricity in the market. To give more insight, the Greek Electricity Law states that each supplier must also be a producer and have sufficient capacity for electricity production. The market, which is called System Trade Arrangements, is a kind of central pool where all electricity is bought and sold.
Parties must sign a Price Differences Contract in order to eliminate financial uncertainty arising from transactions or payments to them at a single market price determined by the central market.

One of the most important differences between the Greek market and the Turkish market is that the system and market operators in the Turkish market are dependent on the different departments. In Turkey, the market operator's department is Energy Exchange Istanbul (EXIST) and the system operator's department is Turkish Electricity Transmission Company. But in the Greek market, this system and market operations are working in the same department.

Finally, we examined the Electricity Trade Regulations of England and Wales, which have an important place in the world market.

The New Electricity Trade Regulations, which is created to replace the Pool of England and Wales, are based on reciprocal trade and a balancing mechanism between manufacturers, suppliers, traders, and customers. The parties accept Bilateral Agreements and so that, in any event of a shortage or excess in the long-term agreement on amounts, differences can be corrected in a shorter-term market. For the realized imbalance amounts, payment is made over the imbalance price determined in the Balancing Mechanism.
In order to determine the physical balance of the system, participants inform the National Transmission Company, which is the transmission system operator, on their expected physical conditions, namely the planned production amount and the measured demand for each half-hour trading period. Final notifications of physical conditions are made while the balancing mechanism is opened.

When we look at the England and Wales electricity market, we can see that these two markets and also Turkey have used Bilateral Agreements. At the same time, we see that there is a Balancing mechanism to compensate for market irregularities in all these three-country markets. Again, all three markets have a system operator and are aware of the demand measured by the planned amount of production.

As important as markets are, the variables affecting the merit order also play an equally important role. As mentioned above, the merit order is the ranking of available resources in an ascending manner based on the marginal cost of each resource. In today's world, conventional energy sources such as fossil fuels and natural gas, are less susceptible to price fluctuations since their inputs are more stable and do not depend on external variables. On the other hand, renewable energy sources such as solar and wind energy solely depend on day-to-day changes in weather conditions. Renewable power plants produce energy independently from market prices. Thus, they are more likely to fluctuate and be more inconsistent. Renewable energy sources' low operating costs impact the balance of the market and also have the potential to negatively impact the profitability of the market. The incurred losses become a bigger problem, due to the fact that the marginal cost of renewable sources is zero. On the contrary, the network's frequency (50 Hz) and optimal voltage curves cause undesirable effects. Consequently, all of the aforementioned uncertainties add to the ambiguity of the system. Having defined the balance market and by reviewing the literature and the methods developed and implemented, the definition of the problem started taking a clear form.

As we approach real-time, we want to develop a model that accurately forecast the price formed in the equilibrium market based on the conditions of a particular day and day-ahead market forecasts. Our model can be formally written as a function that takes two inputs (Day-Ahead Market, real-time variable inputs) Let us denote the prior as g and the former as x_t with y being our target, the function could then be written as:

$$f(g,x) = y \tag{1}$$

The aim of this project is to develop a price, demand forecasting model by focusing on renewable energy sources and examining the day-ahead electricity generation and output of these renewable energy sources by taking into account the changeable weather conditions.

1.3 Standards and Constraints

Today, political decision makers undertake the regulation of electricity markets, especially through regulators. Legal regulation in terms of authorization documents, licenses and regulations issued by regulators for market actors; It can be said that it implements administrative regulation in terms of determining its performances and standards, and lastly, price regulations especially in order to prevent unfair competition. The purpose of the regulations is to reduce the financial risks of companies and increase the quality of service and thus maximize profits.

Considering that the aim of the regulations is to increase competition and to provide high quality and low-cost services to consumers, it can be said that the number of participants in the electricity market has increased significantly since 2003 and this target is approached. According to the report of the EPİAŞ, the number of participants in 2020, which is 1105, generally consists of private production enterprises and wholesale and retail sales companies [5]. Current 2020 participant data are shared in the table below.

License Type	Number of Public Institution Participants	Number of Private Sector Participants
Production	4	1101
Supply	0	151
Distribution	0	21
OSB Production	0	1
Transmission	1	0
Officer Supply	0	63

Table 1. Number of Participants by License Type in 2020 [6]

Electricity Market Balancing and Settlement Regulation was last updated by the Energy Market Regulatory Authority on 28 July 2020. The purpose of this regulation is; to determine the principles and procedures for balancing active electrical energy supply and demand and settlement. This Regulation; It covers the procedures and principles regarding balancing the duties, powers and responsibilities of the balancing mechanism and the parties to the settlement and the active electricity energy supply and demand, and the financial settlement of the receivables and debts resulting from the participation of the licensed legal entities in the balancing mechanism and settlement.

The Regulation Balancing Mechanism includes the electricity futures market and the Day Ahead market, Intraday Market and real-time balancing activities that are complementary to Bilateral Agreements. According to the regulation, the Market Operator is EPİAŞ and the System Operator is TEİAŞ. in the Regulation registration obligation and registration rules of the market participants, registration process, updating registration information, electricity futures market, Day Ahead Market, Intraday Market, Balancing Power Market, notifications and information to be provided by the system operator for settlement, issues regarding losses, settlement of activities in the markets, settlement of energy imbalances, payment transactions, objections and correction procedures and provisions [7].

Table 2. shows which market participants are involved in which electricity market areas by license type. Some of the participants are from the private sector and some are from public institutions. We can also see

in which part of the electricity market the participants operate according to their license type. There are different license types such as production, procurement, distribution and OSB production, transmission, and employee supply.

Country	Regulation Area	Regulator Name	Description
Usa	Energy sector	Federal Energy Regulatory Commission, FERC	Organizing electricity transmission and wholesale between states, regulating mergers and acquisitions of electricity companies, monitoring and researching energy markets, regulating the sector as a whole and supervising compliance with the rules.
England	Gas and Electricity Market	Office of the Gas and Electricity Markets, OFGEM	Giving an activity license, determining the standards, deciding on disagreements that may arise between the actors operating in the sector.
France	Gas and Electricity Market	The Energy Regulatory Commission, CRE	Regulating electricity and natural gas networks is to ensure that users (businesses, local authorities, consumers and producers) do not discriminate, access the natural monopoly of transmission and distribution infrastructure, and ensure supply security.
Italy	Gas, Electric and Water Market	Italian Regulatory Authority for Electricity Gas and Water, AEEGSI	Determining the tariffs, defining service quality standards and regulating technical, legal or other restrictions in accordance with competitive market conditions, protecting the interests of users and consumers.
Turkey	Electricity, Gas, Oil and LPG	Republic of Turkey Energy Market Regulatory	To make regulations regarding the production, transmission, distribution and sale of energy.

Table 2. Electricity Sector Regulators by Country Source according to RAP [8].

When developing any prediction model that relies on data to find patterns, the biggest constraint could be regarded as the process of data collection and preparation. As an example, if we decide to use a sequential model, which we will most likely use, the time-intervals between the input points have to be of equal length. The second constraint could be the computational power needed to run our models. If we decide to use a deep-learning approach, cloud computing and other alternatives should be considered. This of course all depends on the complexity of the model. The constraints could be summarized to be the following:

1. Availability of data
2. Data quality
3. Scope of Data cleansing
4. Computational constraints

The consensus in our team is that none of these constraints would cause a major risk to the success of our project. The data will be provided by GATES energy company, and the process of cleansing and cleaning the data could be performed in a reasonable amount of time by using simple SQL queries. Computational constraints could be overcome by using cloud computing services such as Google Colab, which is a service that provides state of the art GPUs for deep-learning applications.

As with regards to the environmental, social, economic, health, and ethical effects. In our case only two of them have consequences, they could be summarized as the following:

Environmental effects	The better prediction of demand would lead to more accurate levels of production, contributing to a lower carbon footprint.
Economic effects	A better analysis of the market will allow distributors to provide energy at lower costs.

1.4 Conceptual solutions

In the related literature we observed that academics divided the forecasting energy market into four exclusive time intervals listed in following order;

1- Very short term forecasting (minutes)
2- Short term forecasting(24 hours to 1 week)
3- Medium term(1 week to couple of months)
4- Long term(months to years)

In any given data science and data related project, the most important procedure before developing and designing an architecture, relevant input points i.e., parameters have to be determined beforehand. Regarding the inputs needed for our model, we first studied the relevant literature and pre-determined the most important parameters used in Energy markets. According to Gultekin (2009), the most important parameters that affect energy demand in the long term could be summarized to be the following:

1. Population
2. Number of households
3. Average household size
4. Urbanization rate
5. Percentage of population that uses electricity
6. Technological progress
7. Number of electric tools per person
8. Price of electricity
9. Price of alternative energy sources
10. Climate conditions
11. Geographical features
12. Time
13. Gross domestic product (GPD)
14. Percentage of multiroom housing
15. City and village revenues
16. Per capita income (PCI)
17. Employment data

In addition to these parameters, we consulted an expert and asked for their advice in determining the most important parameters affecting our problem(very short term), they could be summarized to be the following:

1. At the end of the Day-Ahead Market, is there a difference in the Intraday Market predictions made by solar and wind power plants?
2. Is there a fault in the system (a plant that is not producing electricity)?
3. Is there a difference in the demand of the system?
4. Renewable energy power output

Once the parameters have been determined, the problem takes the form of modeling. Upon reviewing the literature, we come to realize that Autoregressive with Extra Input models (ARX) are most widely used [9]. Moreover, a good starting point for research in this domain would be the Electricity price forecasting (EPF) review article by Weron in 2014. In the related literature there are numerous methods of EPFs, most notably there are five main modelling approaches [9]:

1. Multi-agent
2. Fundamental
3. Reduced form
4. Statistical

5. Computational Intelligence

Different authors have also implemented a wide range of other methods under computational intelligence and compared their results. The following are some of the methods used [9]:

1. Random Forest Regression (RFR)
2. Support Vector Machine (SVM)
3. Artificial Neural Networks (ANNs)
4. Long Short-Term Memory (LSTM)

In our project we are aiming to solve and analyze a problem that relies on sequential data. When it comes to sequential data, our problem could be formulated as predicting the output at some time *t* given the data up to time *t* [11]. In other terms, our goal is to find the probability of the desired target variable for each *t* in the prediction horizon, with the knowledge of all the previous timestamps, this probability formula could be formulated as the following:

$$P(x_t \mid x_{t-1}, \ldots, x_1) \tag{2}$$

As mentioned earlier, our model will most likely have to take small intervals of time as input in a vectorized form and output the desired target variable. The vectorized form of the input would refer to the different parameters discussed earlier. If we decide to use a deep learning approach, our aim would be to maximize the predictive capability of the model by adjusting different weight parameters. Conceptually, we will not only be looking at how the model performs on unseen data, but we are also interested in determining the effect of different variables by performing sensitivity analysis like operations. Let us denote the target variable as *J*. Then the change in this variable with respect to the weights ($[w_1, w_2, \ldots, w_n]$) of the input variables (parameters discussed earlier) could be written as:

$$\nabla J = [\partial J/\partial w_1 , \partial J/\partial w_2, \ldots, \partial J/\partial w_n] \tag{3}$$

Equation.3. measures the sensitivity of the change in the target variable *J* with respect to change in its inputs / arguments. Which is also known as the gradient. The gradient above is also the main method by which neural networks adjust their weight, by analyzing the change in each input variable with respect to the final output *J*, the network then performs the gradient descent algorithm, and finds the optimal weights [12]. One of our goals is to analyze the effect of renewable sources on the system's direction. Unfortunately, the use of deep learning models do not give us an insight into the contribution of each parameter. Thus, the use of more statistical methods and simpler linear regression techniques can give us an insight to the sensitivity of the model with regards to each parameter. For example, we could deploy a multi-parameter linear regression formula and observe the weights given to each variable. Another approach could be the use of Principal component analysis (PCA) to reduce the number of variables. Thus, allowing us to filter out the most important variables. Covariance matrices could also be utilized.

As of now, we have not decided on which model to use. The model used could change depending on the progress of the implementation, but the latest developments in the field of deep learning, and with the advent of big data, makes the prospect of using a variant of multilayer perceptron such as recurrent neural networks and their more complex variants more appealing. LSTMs in particular, have proven to be capable of accurately predicting time-series data with high dimensional vector spaces as inputs. It is also worth noting that LSTM based recurrent neural networks (RNNs) are the most widely used deep learning approach in modeling sequential and time-series data [13]. One of the standards we aim to consider for our benchmarks is a study by Toubeau et al. (2018) [14], in which the use of Bidirectional Long Short-Term Memory (BLSTMs) is considered for short-term multivariate predictive scenarios. Additionally, we will also consider the use of more statistically oriented methods to serve as a benchmark for our problem.
An extensive review and explanation of the methods will be explained in the upcoming sections.

2. WORK PLAN

In this section Work Breakdown Structure, Responsibility Matrix, Project Network, Gantt Chart is created.

2.1. Work Breakdown Structure (WBS)

A WBS was created to visualize the hierarchical division of work.

1. Electricity System Forecasting (ESF)
    - 1.1. Analysing the literature
        - 1.1.1. Check the previous problems
        - 1.1.2. Study the previous methodologies
        - 1.1.3. Identify the parameters used in prediction
    - 1.2. Analysing the Energy Market
        - 1.2.1. Check the world energy markets
        - 1.2.2. Check the energy sources
        - 1.2.3. Turkish Electricity Market (reference price)
        - 1.2.4. Determine parameters affecting price in the electricity market
        - 1.2.5. Energy supply, security, policies
        - 1.2.6. Electricity market's risk
    - 1.3. Data Science Applications
        - 1.3.1. Collect the data for energy pricing
        - 1.3.2. Data preparation (arranging & cleaning)
            - 1.3.2.1. Fill in missing data (clean the data)
            - 1.3.2.2. Improving the existing data set
            - 1.3.2.3. Data normalization
            - 1.3.2.4. Convert columns to arrays (NumPy) to feed into the model
            - 1.3.2.5. Train-test split procedure
        - 1.3.3. Data visualization
        - 1.3.4. Start modelling the data
            - 1.3.4.1. Proof of concept for different architectures
            - 1.3.4.2. Choose the architecture with highest predictive capabilities on validation set

1.3.5. Hyper parameter optimization
1.3.6. Model evaluation
1.3.6.1. Determine correct evaluation metrics
1.3.6.2. Test model on test dataset using correct metrics

2.2 Responsibility Matrix (RM)

A Responsibility Matrix is created to map the tasks (Tasks / Activity) on a table according to responsible team members.

Tasks	Taha	Kadir	Özlen	Güney	Ekin
Check the previous problems	R	R	R	R	R
Study the previous methodologies	R	R	S	S	S
Identify the parameters that used in prediction	R	R	R	R	R
Check the world energy markets	S	S	R	R	R
Check the energy sources			R	R	R
Turkish Electricity Market (reference price)	S	S	R	R	R
Determine parameters affecting price in the electricity market	R	R	R	R	R
Energy Supply, security, policies			R	R	R
Electricity Market's Risk			R	R	R
Collect the data for energy pricing	R	R	S	S	S
Data preparation (arranging & cleaning)	R	R			
Data visualization	R	R			
Start modelling the data	R	R			
Hyper parameter optimization	R	R			
Model evaluation	R	R			

R: Responsible
S: Support

2.3. Project Network (PN)

A Project Network was created to determine the chronological order of the tasks and predecessors.

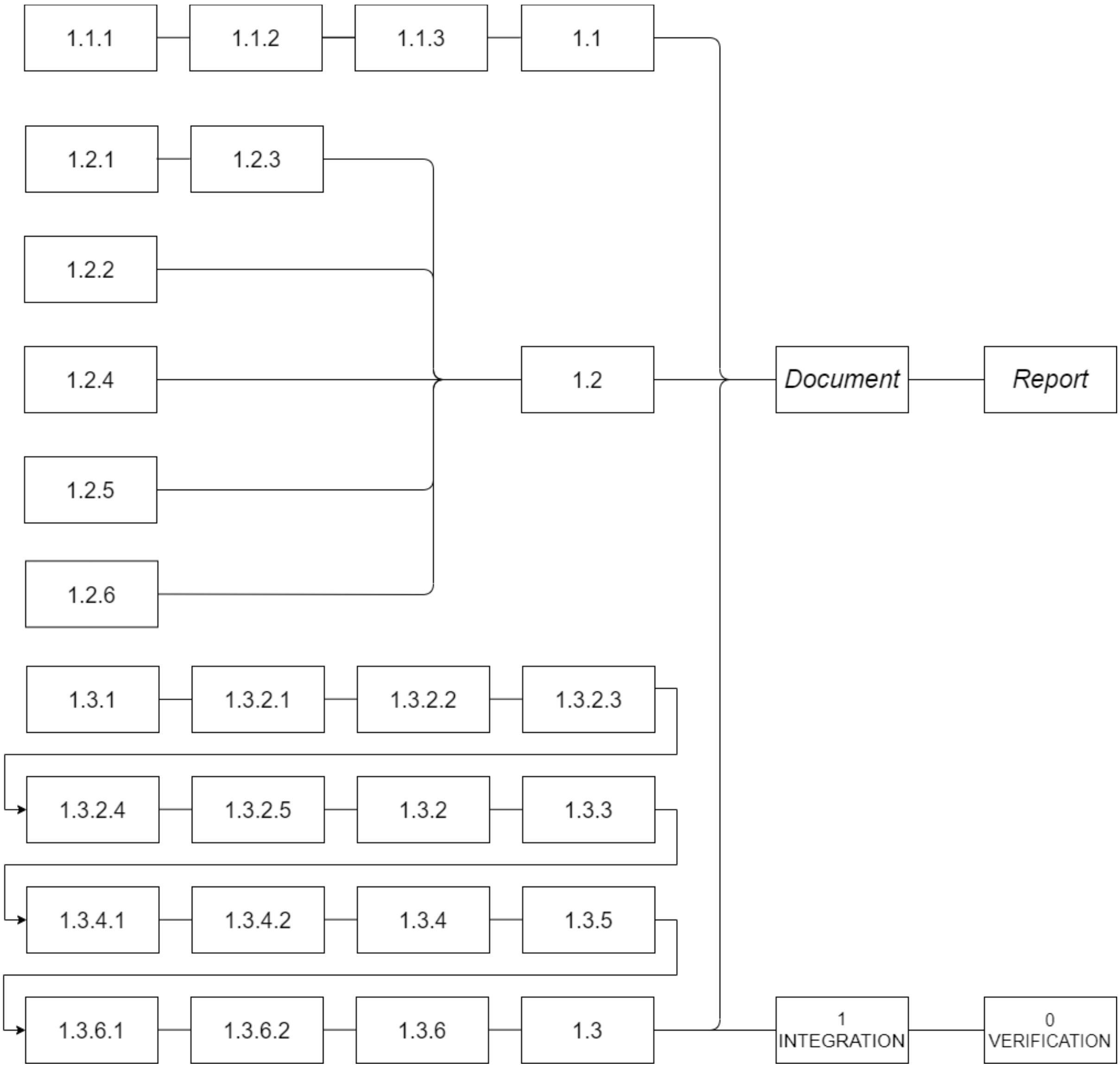

Figure: Project Network Diagram

2.4. Gantt chart

The Gantt chart is provided to visualize and schedule the plan.

WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Taha	1.1.1	1.1.2	1.3.1	1.3.2		1.3.3	1.3.4	1.3.5	1.3.6	1.3					
Kadir	1.1.1	1.1.2	1.3.1	1.3.2		1.3.3	1.3.4	1.3.5	1.3.6	1.3					
Özlen	1.1.1	1.1.3	1.1	1.2.1		1.2.3		1.2.4	1.2.5						
Güney	1.1.1	1.1.3	1.1	1.2.2		1.2.3		1.2.4	1.2.6						
Ekin	1.1.1	1.1.3	1.1	1.2.1	1.2.2	1.2.3	1.2.4		1.2.6						
Integration											1				
Verification												0			
Documentation											Draft		Report		
Presentation													Draft	Present	*Exhibition*

3. DESIGN PROCESS

Risk Table

RISK LEVEL		**Severity** of the event on the project success		
		Minor	Moderate	Major
Probability of the event occuring	Unlikely	VERY LOW	LOW	MEDIUM
	Possible	LOW	MEDIUM	HIGH
	Likely	MEDIUM	HIGH	VERY HIGH

VERY LOW	This event is very low risk and so does not require any plan for mitigation. In the unlikely event that it does occur there will be only a minor effect on the project.
LOW	This event is low-risk; a preliminary study on a plan of action to recover from the event can be performed and noted.
MEDIUM	This event presents a signficant risk; a plan of action to recover from it should be made and resources sourced in advance.
HIGH	This event presents a very signficant risk. Consider changing the product design/project plan to reduce the risk; else a plan of action for recovery should be made and resources sourced in advance.
VERY HIGH	**This is an unacceptable risk. The product design/project plan must be changed to reduce the risk to an acceptable level.**

Failure Event	Probability	Severity	Risk Level	Plan of Action
Inadequate data	Unlikely The data will be provided by GATES A.Ş.	Major To achieve a sufficient result enough data is crucial	Medium	Contact with the firm to get enough data to feed the system.
Low data quality	Unlikely Almost all data is recorded by the firm and the market operators	Major Data quality is another crucial factor for forecasting	Medium	Edit the data to achieve suitable dataset. (add labels, intervals, etc.)
Improper analytics	Possible Since there are numerous techniques, some problems may occur	Major This can seriously affect the direction of the project	High	Consider the literature reviews and study the techniques to select the most suitable one.
Selecting unsuitable forecasting method	Unlikely The accuracy of the models will be compared to find the best one	Major Improper method can change the result of the project	Medium	Compare the accuracy results of different machine learning models and focus on the most convenient one.
Incorrect data editing	Possible If the data is too complicated, some problems can occur	Major Data editing part can suspend the whole project	High	Always keep the original dataset to be prepared of incorrect editing. Moreover, save the different versions of the dataset.
Changing dataset for each machine learning model	Possible The working principle of the algorithms are different	Major It can directly affect the performance of the models	High	As mentioned before, keep the datasets for different machine learning algorithms to prevent confusion.
Overfitting the training data	Possible The model can overfit the training data	Major Since it is hard to collect same amount of data it is hard to realize	High	Prepare additional test sets to check if it is overfitted or good fit. Apply cross-validation or increase data. Additionally, model complexity should be reduced.

Underfitting the training data	Possible If the model is unsuitable, underfitting can occur	Minor It can be easily realized through accuracy rates	Low	Perform feature engineering. Check the data to clean the noise of it. Increase the complexity of the model.
Lack of communication between Energy and the Industrial engineering departments	Unlikely The group members hold regular information meetings	Major Lack of communication directly affect the success of the project.	Medium	Select a specific communication channel. Actively share information and necessary documents. Try to increase commitment and motivation.
Lack of literature	Likely Most of the academics studied on Day-Ahead Market	Moderate Reviewing previous works can provide conceptual infrastructure	High	Try to find common features in related topics and improve the core knowledge about the project.
Wrong parameters selection	Possible Wrong parameters selection may produce incorrect result.	Major To set up the right system by using the correct data and parameters.	High	New parameters that were not use before should be selected.
Analyzing renewable sources incorrectly	Possible Wrong price forecasting	Major Analyzing incorrectly can affect data and price	High	It is necessary to analyze in detail again.

3.1. Energy Systems Engineering

3.1.1. Definition of the problem

3.1.1.1. Energy Resources

The energy demand is increasing rapidly thanks to technological developments, industrialization, and the increase in the world population. Energy is necessary for increasing the welfare of societies, it is used in almost every field in daily life. In short, energy, which is defined as the ability to do work, can be found in different types such as mechanical, heat, electricity, chemical, and nuclear. It can be transformed from one species to another with appropriate methods and can be classified in different ways. Energy sources are generally classified according to their use and convertibility. According to the classification made and according to their use, energy sources are renewable and non-renewable; and also according to their recyclability, they are classified as primary and secondary energy sources.

The form of energy that has not any change or transformation is known as primary energy. Primary energy sources are oil, coal, natural gas, nuclear, hydraulic, biomass, tidal wave, sun, and wind. The energy obtained as a result of the conversion of primary energy is known as secondary energy. Electricity, gasoline, diesel oil, diesel, petroleum gas, and liquefied petroleum gas are among these types of secondary energy sources. Non-renewable energy sources are divided into two as fossil sourced and core sourced. While coal, oil, and natural gas are considered as non-renewable energy sources from fossil sources, uranium and thorium are included in the non-renewable energy resource group originating from the core. Hydraulics, solar, wind, geothermal, biomass, wave tide, hydrogen are all examples of renewable energy sources.

In the literature, there are many studies about energy resources in the world and Turkey. This project will focus on the more detailed information about renewable energy sources in Turkey and their effect on renewable sources of electricity prices will be investigated.

3.1.1.1.1 Primary Energy in the World

When we look at energy usage in the world, China has an important role in the energy market. In 2019, China became the world's largest producer of hydroelectric, wind, and solar power. It continued to be the world's largest energy producer and largest energy consumer in 2019, as well as being the world's largest coal producer in 2019. China produces about half of the coal in the world. The energy that China gets from total coal production is greater than the combined oil, natural gas, and coal production of the USA. While 17% of the energy consumed in the world comes from coal, 58% of China's total energy consumption comes from coal.
On the other hand, the USA continues to be the world's largest oil producer for the last 3 years in a row. The USA produced 17% of the world's oil and 23% of natural gas in 2019. In 2019, the rate of carbon emissions continued to decline for the USA and many other developed countries, but China's rate of carbon emissions increased. USA energy production increased by 6% in 2019, the biggest increase came from oil and natural gas, while coal production continued to decline significantly. The USA has been the country with the highest increase in oil production in the last 3 years in a row.

In general, China accounts for 18% of the world's population, 16% of the world economy, produces 20% of the world's energy resources, and consumes 24%. The USA constitutes 4% of the world population, 24% of the world economy, produces 16% of the world's energy resources, and consumes 16%.

In the global distribution of proven oil reserves, the Middle East is still the region with the highest oil reserves with 48.1%. Most of the proven oil reserves are found in Venezuela (17.5%). Next is Saudi Arabia (17.2%) and Canada (9.8%). The serious increase in oil production continues in Central and South America.

As for the increase in renewable energy and natural gas production; It constitutes 75% of the increase in global energy production in 2019. The energy produced from renewable energy sources increased by 41% in 2019, thus the amount of energy produced from renewable energy sources surpassed nuclear energy for the first time.[15]

3.1.1.1.2 Primary Energy in Turkey

In terms of installed energy power in Turkey; At the end of 2018 installed capacity was 88,551 megawatts (MW) after that, Turkey has reached the level, at the end of 2019 and it was 91 267 MW. In December, the licensed and unlicensed Solar power plant with a total installed power of 101 MW was commissioned. An increase of 36 MW was realized in the installed power of wind power plants last December. An increase of 17 and 3 MW was observed in renewable energy and hydroelectric power plants, respectively. No change was observed in the installed power of geothermal and domestic / imported coal power plants. The installed power of the fuel oil and natural gas power plants decreased by 133 MW and 27 MW, respectively.

49.1% of the power plants that became operational in December, which were the power plants with renewable resources. Thus, the renewable resource rate exceeded 49% for the first time. Hydroelectric power stations, of Turkey's total, installed electric power constitute 31.2%. The share of wind and solar power plants is only 14.9%.

Considering how electrical energy is produced from sources in Turkey; about 26.2 terawatt-hours of total electricity production in Turkey in December 2019 (TWh) was approximately 27 TWh in January 2020.

Wind power plants reached the second-highest monthly production value with 2.38 TWh in January 2020 and 2.64 TWh in August 2019. Another remarkable point is that renewable energy plants, which have an average share of 44.5% in electricity generation throughout 2019, were realized at 36.3% in the first month of 2020 and below 43.9% in the same period of 2019.
Gross electricity consumption in Turkey decreased by 0.16% in 2019 and it was 303.7 TWh. According to the Turkey Electricity Transmission Company (TEİAŞ) in 2018 gross electricity consumption data level was 304.2 TWh. It can be thought that the slowdown in the sector was effective in this decrease in gross electricity consumption.[16]

3.1.1.1.3. Renewable Energy around the World and Turkey

Renewable energy sources are thought to be an alternative to fossil fuels, and today various studies are carried out on the development of renewable energy technologies. Commonly used renewable energy sources; hydraulic energy, geothermal energy, biomass energy, solar energy, and wind energy. Turkey is a country rich in diversity and the potential of renewable energy sources. Our country has 8% of the world's potential in geothermal energy, which is not available in many countries, an important solar energy potential due to its geographical location, an important hydraulic energy potential due to its location features, and important wind energy potential.[17]

1. Hydraulic Energy

One of the widely used renewable energy sources is hydraulic energy. The most common use of this energy is to accumulate water in reservoirs by building dams on rivers and to generate electrical energy in the turbine by utilizing the potential energy of the accumulated water. Hydroelectric power plants are generally used for this purpose.
The total installed capacity of hydroelectric power plants in Turkey is 30,534 MW. In 2019, 88,850,170,000 kilowatt-hours of electricity were produced by Hydroelectric Power Plants. The number of theoretical hydroelectric potential in Turkey is 433 billion kWh. The technical evaluable potential is 216 billion kWh. The technical and economical one is calculated as 160 billion kWh. HES has over 600 businesses in Turkey. Technical hydropower potential has been developed in Turkey by 42%. [18]

2. Geothermal Energy

Geothermal energy is the natural heat of the earth and it is defined as the thermal energy contained in the hot fluid (water vapor, gas) under pressure and hot dry rocks accumulated in the depths of the earth's crust. This energy is used for electrical energy generation or heating purposes. According to the research in the world, respectively, of the countries, most benefiting from geothermal energy, the United States, the Philippines, Indonesia, Mexico, Italy, and New Zealand, in recent years, Turkey's installed geothermal power is set to increase rapidly.

Turkey has great potential in conjunction with the presence of Alpine-Himalayan orogenic igneous and geothermal angle due to the large volcanic activity. Due to active faults and volcanism in our country, there are more than 600 geothermal resources in the Northwest, Central Anatolia, East, and Southeast Anatolia regions, especially in the Aegean Region.

Considering the 600 geothermal resource areas in Turkey as our theoretical potential geothermal potential is estimated at 31,500 MW. Drilling works have been carried out in only 124 out of 600 source areas until today. This situation shows that the geothermal exploration studies in our country are insufficient and more drilling studies are required to make the possible geothermal reserve visible. Geothermal energy applications in Turkey; mostly for residential heating, greenhouse heating, and thermal spring purposes. Although there are high-temperature areas for electricity generation, production remained at a low level.[19]

3. Solar Energy

Solar energy is very powerful energy resulting from the fusion reaction that converts the hydrogen gas in the sun's core to helium. Technologies such as solar collectors, solar power plants, and solar cells have been developed to benefit from this energy that comes to our world through solar rays. Thanks to these technologies, solar energy can be used as heat energy directly or indirectly by converting it into electrical energy.

According to the research, it has been determined that the countries that benefit most from solar energy are Germany, China, Japan, Italy, and the USA. The biggest developments in the world took place in 2013 and 2014 when the solar power plant installed powers of China and Japan were evaluated. It is seen that China's installed solar energy power has grown by 54.1% and Japan's installed solar energy power has grown by 70.78%. This is due to the decrease in production costs as a result of the widespread production of solar panels in China, and the fact that Japan turns to renewable energy sources due to the nuclear disaster it has experienced.

The total installed capacity is 6493 MW of Solar Power Plants in Turkey. In 2019 9,620,335,000 kilowatt-hours of electricity were produced by Solar Power Plants.

Although there is a significant potential for solar energy in Turkey, it is not being utilized enough energy from the sun. The high cost of electricity generation prevents the commercial use of this energy. Solar energy in Turkey is widely used in hot-water heating systems. Solar cell production in the future world and the decrease in the contribution of fiscal incentives and electricity from solar energy is expected to increase its production activities in Turkey.[20]

4. Biomass Energy

Biomass energy is an energy source obtained from plant and animal origin substances containing carbohydrate compounds. Today, fuels such as bioethanol, biodiesel, and biogas are obtained by using biomass energy resources. Bioethanol and biodiesel is a type of fuel produced using various plants or animal oils. Biogas, on the other hand, is mainly methane and carbon dioxide gas formed as a result of the fermentation of organic substances (plant and animal wastes, urban and industrial wastes) in an oxygen-free environment. In recent years, the world has focused on renewable energy crops agriculture. According to the research, it has been determined that the countries using the most bioethanol and biodiesel in the world are the USA and Brazil.

Biomass energy potential in Turkey is still high but nowadays there are no many projects or actual work. At the end of 2018, there are 122 biomass-fueled (biogas, thermal, landfill gas, and wastewater) power plants that have received a production license from EMRA (energy market regulatory authority), and their total installed and operational power is 714 Mw and 517 Mw, respectively.

Besides, it is estimated that the amount of animal waste biogas corresponding to Turkey's potential is 17-23 TWh. Our country cannot adequately utilize biomass resources despite having significant potential. In Turkey, organic waste, biomass, and energy from biogas for obtaining public and private sector investment has increased recently.[21]

5. Wind Energy

Wind energy results from the different heating of solar radiation on the ground surfaces. Different warming of the seas and air causes the formation of a pressure difference, and this pressure difference causes the movement of the air. This movement of air from high pressure to low pressure is known as wind. Wind energy is used to generate mechanical energy or electrical energy. The mechanical energy obtained is generally used for irrigation in homes and farms. Wind Power Plants are used to generate electrical energy from wind energy. According to the research of wind power installed capacity of the high country respectively, China, Germany, and the USA. Turkey's installed capacity of wind energy is determined by rapid development over the last decade. For wind turbine plants to be economical investments, the average wind speed at 50 m altitude on the land where the turbine will be installed should be at least 7 m / s.
When considering the terrestrial wind potential and sea level wind potential; at 7 m / s and over the 7 m/s, there are 48000MW for the terrestrial wind potential in Turkey, on the other hand, there are 5300 Mw for the sea level wind potential.

The total installed capacity is 8,405 MW of Wind Power Plants in Turkey. In 2019, 21,749,838,000 kilowatt-hours of electricity were produced by Wind Power Plants. Some of the 229 power plants taken into operation have not yet reached the installed capacity equal to the installed capacity of the license, and the construction continues. In this context, with the activation of the full capacity of the power plants, some of which were commissioned, an additional wind turbine with a capacity of 753 MW will be activated and the installed power will reach a capacity of 9,158 MW. Also, the license capacity of 71 power plants, of which no units have been commissioned yet but progress has been made, is 662 MW. In this context, the partially commissioned and completed all of the progress of construction projects in Turkey is seen to rise to 9,820 MW of wind power installed capacity.

In the first half of 2020, despite the Covid-19 epidemic, the installed power level that can be commissioned reached 232 MW. With this number of Turkey's wind installed capacity reached 8288 MW. The first 6 months of total electricity derived from wind is 11 million 506 thousand 233 kilowatt-hours when accessing this amount accounted for 8,52's percent of the total electricity generated from wind energy in Turkey. On April 10,36's percent of the electricity produced in Turkey was produced from the wind.[22]

After describing the issue of energy sources in Turkey in detail, we wanted to also describe the Turkish markets in Turkey's electricity market, for understanding our project's problem better.

3.1.1.2. Turkish Electricity Markets

Turkey's electricity energy market structure shows a rapid change and development since the early 2000s. With the developing technology, a system has been established in which renewable energy sources are included in the system and all stakeholders on the supply or demand side of the large or small scale are also included in the system. Due to the market structure, while trying to achieve supply-demand balance, pricing processes must be completed in an optimum manner. Pricing processes are affected primarily by supply and demand balance, competition conditions, state or private sector strategic planning or investments, political, economic, social events, and other physical factors.

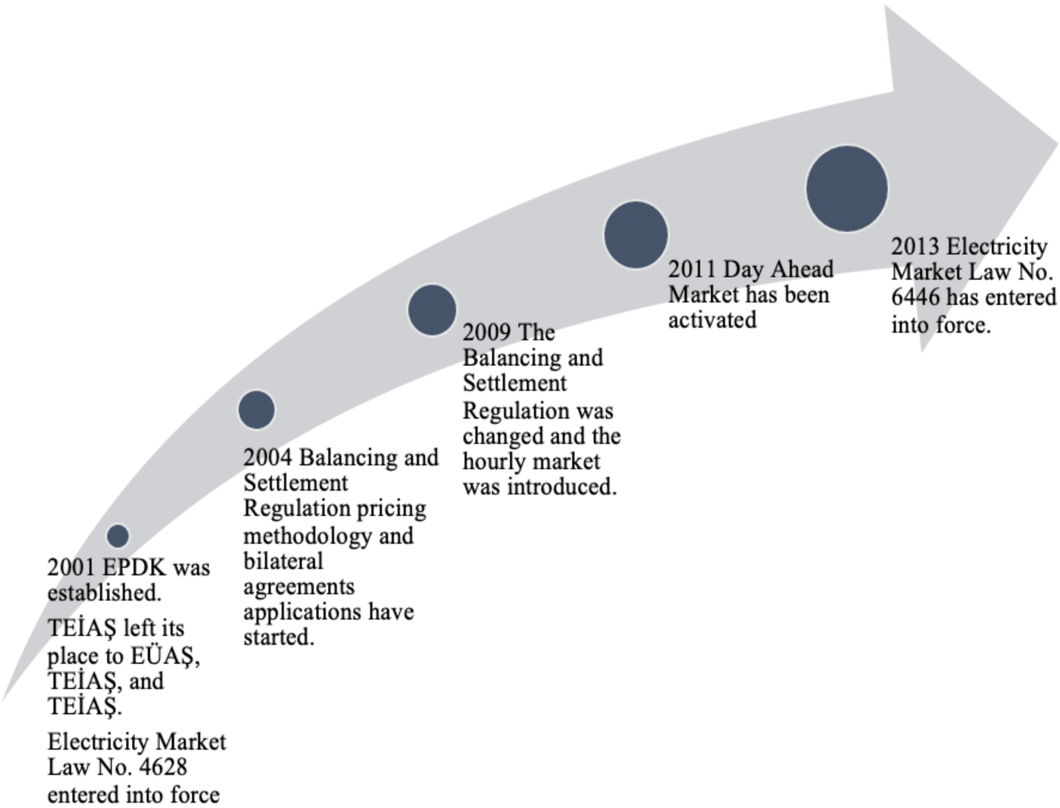

Figure 2. The electricity market reform process in Turkey

The electrical energy market structure aims to regulate production and distribution costs in an optimum manner, to ensure energy supply security, to reduce leakage losses, and to realize investment costs quickly and with private sector dynamics.

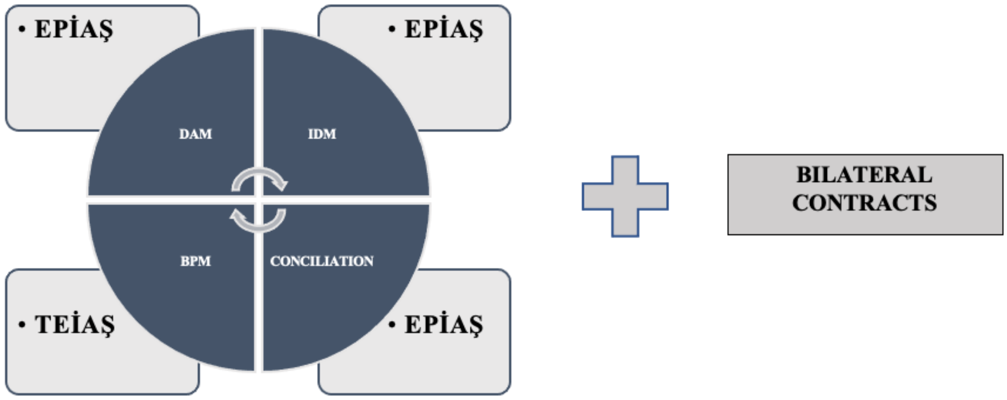

Figure 3. Turkish Electricity Markets

As shown in Figure 3. the electricity energy market structure can be examined in four parts as long-term Bilateral Agreements, a Day-Ahead Market, an Intraday Market, and a Balancing Power Market.

1. Bilateral Contracts

Bilateral Contracts maintain their importance in determining the reference price for the day-ahead market in today's market. Bilateral Contracts are based on price risk protection and long-term supply security due to their market structures. In other words, in terms of supply-demand balance, it is a market structure where trade takes place within the framework of long-term forecasts and price fluctuation is low.

1-Turkey precipitation, increasing installed capacity and TL's depreciation against the US dollar	5-Decrease in hydraulic energy production as a result of low precipitation
2- the effect of low HES production with the effect of depreciation in exchange rate	6-BOTAS ending subsidies applied in natural gas tariffs
3-Increasing production due to investments, resulting in a downward impact on the price of oil prices	7-HES generation triggered by above-normal rainfall, high production in public HESs
4-Decrease in electricity generation due to decrease in natural gas supply	8-A strong loss of demand that affects the world like a pandemic

Table 3. Factors causing the change of PTF, market-clearing price, in recent years

PTF, market-clearing price, is the hourly price of electricity generated by matching the bids in the Day-Ahead Market according to supply and demand curves. Many parameters affect market clearing price as shown in Table 3.

2. Day-Ahead Market (DAM)

With the balancing and settlement regulation made in 2004, the Day-Ahead Balancing system was later switched to the Day-Ahead Market system in 2011. Participation is voluntary. It is a market where the prices and quantities offered are determined on a daily, hourly basis. While determining the Day-Ahead market prices, Bilateral Agreement prices are taken as reference.

3. Intraday Market (IDM)

The Intraday Market, which started operating on 1 July 2015, is also a market where participation is not mandatory. Generations of renewable energy sources, especially wind power plants, are difficult to predict regarding Day-Ahead compared to other power plants. Daily and hourly estimates of the production of renewable energy facilities are much less inaccurate than the estimation results made the day before.

In the Intraday Market, especially the imbalance costs arising from the production estimates of renewable energy sources or sudden malfunctions are less than the Day-Ahead market. The Intraday Market is a market where Day-Ahead and continuous trade is conducted in coordination with the balancing power market. In the Intraday Market, offers are made hourly and can be updated up to two hours before physical delivery.

4. Balancing Power Market (BPM)

It is operated under the responsibility of TEİAŞ, and the Day-Ahead Market offers are balanced in real-time depending on the supply-demand balance. However, it is the responsibility of the Balancing Power Market to resolve any real-time system imbalances that arise. The aim in this market is to ensure that the system is set in immediate balance and adjusted to ensure sufficient supply quality, rather than trading. The offers placed in the Intraday Market also affect the system marginal prices. Because players who have fallen into an energy imbalance have the opportunity to reduce imbalance costs to make purchases and sales in the Intraday Market. Thus, on the one hand, the system imbalance is corrected and on the other hand, high risks that may occur in the Balancing Power Market are prevented.

As shown in Figure 4, it shows hourly information about the system's direction's needs whether the system is in energy surplus or deficit [23]. According to these needs, several instructions are given to the system by the system operator, TEİAŞ. These instructions are called YAL and YAT. To balance the system, when there is an electrical deficit in the direction of the system, then YAL, up-regulation instructions, is instructed. If there is an excess of electricity in the direction of the system, the YAT, down-regulation instructions is instructed.

Date	Hour	System's Direction
01/01/2021	00:00	↓ Energy Deficit
01/01/2021	01:00	↓ Energy Deficit
01/01/2021	02:00	↓ Energy Deficit
01/01/2021	03:00	↓ Energy Deficit
01/01/2021	04:00	↓ Energy Deficit
01/01/2021	05:00	↔ Balanced
01/01/2021	06:00	↔ Balanced
01/01/2021	07:00	↓ Energy Deficit
01/01/2021	08:00	↑ Energy Surplus
01/01/2021	09:00	↑ Energy Surplus
01/01/2021	10:00	↑ Energy Surplus
01/01/2021	11:00	↑ Energy Surplus

Figure 4. Hourly information about system energy surplus.

It is desired that the market-clearing prices in the Day-Ahead Market and the real-time system marginal prices emerging in the Balancing Power Market are always close to each other. The Intraday Market also serves to achieve this goal. In cases where there is no Intraday Market, imbalance costs appear much more pronounced, with the inclusion of the Intraday Market into the system, market-clearing prices and system marginal price changes have started to move closer to each other. In order to reduce this difference, the following activities can be done: More effective use of smart grid structures and power plants that can be put into operation quickly, bringing the trade in the Intraday Market closer to real-time.

As a result, Turkey has taken important steps towards the liberalization of the electricity market and has created market structures and supports each other. The purpose of the market structures created is to increase private sector participation and mutual trade volume and to generate benefits for end-users. In doing so, the imbalance costs that may occur should be avoided. At this point, supply-demand balance and pricing estimation strategies are extremely important for each market structure. Although the supply-demand balance factor is the main component in pricing, many different parameters in new market structures also affect price setting strategies. The type, effect size, and periods of the factors affecting the price vary according to the characteristics of the market structure.

3.1.1.3. Determining the reference price in the Turkish Electricity Market

In the Turkish electricity market, the reference price is determined by the merit order method. With this method, it is aimed that the system produces electricity at the most affordable cost. The basis of the method is based on minimizing the costs of thermal power plants with high production costs and maximizing the production of renewable energy sources whose marginal cost is considered zero. Simply, electricity generation plants are ranked from cheapest to most expensive according to the cost of production, and plants that will meet the correct demand from the cheapest to the most expensive according to the energy demand in the relevant hour are commissioned in order. The last power plant that meets the demand, that is, the most expensive power plant that is activated at the relevant time in the system, determines the reference price for the relevant time of the system.

The fact that the amount of energy produced from renewable energy sources varies greatly shifts the merit order point. More use of renewable energy sources creates lower electricity prices. Situations such as changing the hours covered by block bids, changing the number of block bids accepted on request, also shift the merit order point.

Factors affecting the price of electricity can be seen in Figure 5. in key factors, operational factors, strategic factors, and historical factors can be divided into 4 separate categories.

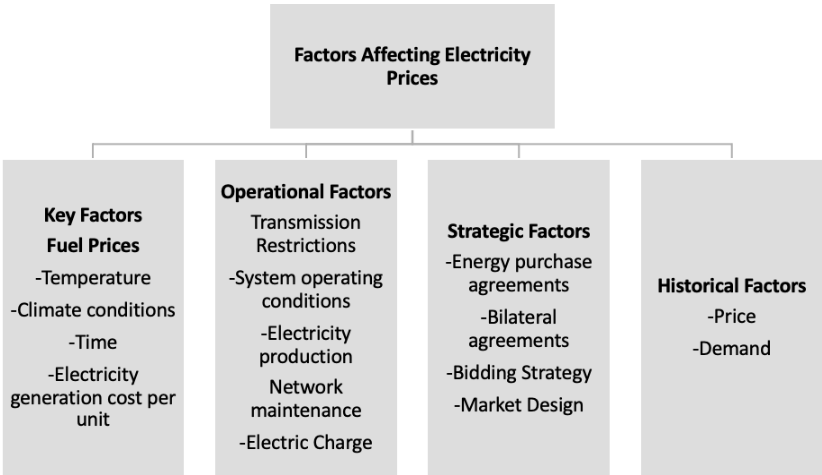

Figure 5. Factors Affecting Prices in Competitive Electricity Markets

We think we can better understand our problem, once we understand the energy sources, markets, how to determine the price of electricity, factors affecting the price and terms in the Turkish electricity market. That's why we gave a piece of information about these subjects above and now if we explain the subject of the project in detail;

3.1.1.4. Problem

If the problem is named in general; Price Forecasting and System Direction Determination in the Turkish Balancing Power Market. In order to determine the orientation system of Turkey, the first spot electricity market price forecasting was established in 2011. Later, Day-Ahead Market and Balancing Power Market were also established. The Intraday Market followed and was founded in 2016. As stated in the introduction part, predicting electricity prices in advance is one of the main roles of electricity distribution companies. Electricity prices consist of the relationship between electricity supply and demand in the competitive electricity market [24]. For example, if the demand forecast is less than the actual demand, power outages may occur. However, if the demand forecast is overestimated than the actual demand, it can lead to an increase in energy prices and adversely affect the company. The estimation process is carried out with various models and mathematical analysis. Electricity suppliers try to create trading strategies and predict the market price before the actual trading time with powerful forecast models in order to gain an advantage in the energy market. [24].

While making these estimates, the estimated energy type is also very important. Because today, inputs of traditional, non-renewable energy sources such as fossil fuels and natural gas are less sensitive to price fluctuations because they are more stable and do not depend on external variables. Therefore, they do not fluctuate or differ greatly unless there is a problem in the price forecast determined before the real-time.
On the other hand, renewable energy sources such as solar and wind energy depend on daily changes in weather conditions. Renewable power plants generate energy regardless of market prices. Therefore, they are more likely to fluctuate and be more inconsistent. Because of this fluctuation and inconsistency, it is more difficult for renewable energy sources to estimate the price determined before the real-time. Renewable power plants want to produce and generate electricity, no matter how high or low the price, as long as the weather conditions are favorable. The low operating costs of renewable power plants affect the market balance and can also negatively affect the profitability of the market. As a result, due to all the mentioned uncertainties, uncertainties and imbalances may occur in the energy market.

The main purpose of this thesis is to analyze the effect of renewable energy sources on the energy market and to predict the direction of the balancing market to minimize the uncertainties and imbalances that may occur. To understand the effects of renewable energy sources on the market by developing an accurate prediction model. The purpose of doing this is to manage the imbalances in the Balancing Market, which is very important for production and retail companies.
Taking this into consideration, in other words, the main purpose is to analyze the foundations of the Turkish generation fleet, especially renewable energies (wind and solar), better understand, evaluate the relationship between the system direction and production principles, and create models for system direction and price estimation in balancing the energy market.

3.1.1.5. Importance of price forecasting

Forecasting the price of electricity has many benefits to both the producer and the consumer. Therefore, the importance of this issue is quite high in the electricity market. For a fairer market, the electricity market should be economical and give its participants confidence. Market participants ' use of the price estimation method when creating price quotes. It helps to increase their stability and make it easier to manage risks.

- Demand forecasting in electricity distribution networks is the future projection of distributed electrical energy made by distribution companies for a certain period under different scenarios.
- A good network should be safe, reliable, and economical. Demand forecasting is used to fully meet these conditions.
- The fact that market participants increase their profitability while making their price offers and that they can manage risk more easily guide the prediction studies.

3.1.2. Review of technologies and methods

3.1.2.1. Merit Order Approach in Price Structuring

Merit Order provides an understanding of the role and relationship between different energy sources in the formation of supply based on demand in the electricity market. Under the influence of multi-factor market conditions and EÜAŞ power plants, natural gas power plants, and hydroelectric power plants with reservoirs play a determining role in the formation of the market price. In the case of the electricity market, variable costs for electricity generation are marginal costs. We can think that marginal costs are equal to fuel costs. The system should consist of different technologies to minimize the total electricity generation cost and ensure market integrity.

Despite the high investment cost, renewable energy sources constitute the lowest marginal costs. Therefore, they are at the bottom or left of the curve, followed by nuclear and thermal power plants. There is oil at the top or right of the curve as they create the highest marginal cost. Bids from large hydroelectric power plants are generally considered strategic and vary based on the amount of water available.[25]

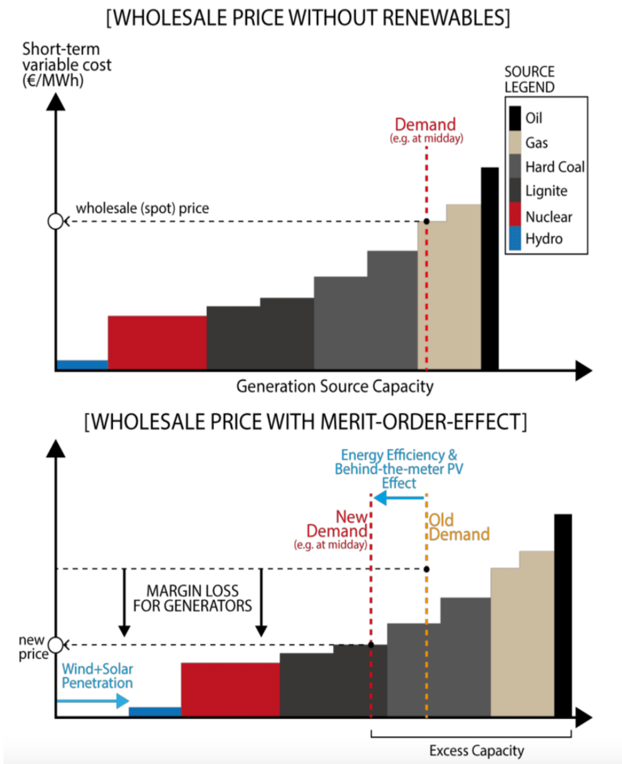

Figure 6. Definition of the merit order effect (MOE) using the demand and supply curve (merit order curve) in the day-ahead electricity market. [26]

Figure 5: Definition of the merit order effect (MOE) using the demand and supply curve (merit order curve) in the day-ahead electricity market. [11]

3.1.2.2. Forecasting the price

Forecasting the electricity prices has been done for many markets in the past and is still being done. Studies for forecasting prices in the literature are usually based on past period prices. Markets, where forecast models are applied, have different structures. For this reason, factors such as the characteristics of the market, the geographical location of the country or region in which the relevant market operates, the resource structure, climate conditions, and at what stage of electricity market reform practices affect price modeling.

3.1.2.3. Parameters affecting price forecasting

It is important to know the factors that affect the forecast as well as to forecast a price. Healthier results are achieved when acted upon by factors. As mentioned above, the country in which the markets are located, the geography in which they are located, their cultural and characteristic features are important. Thus, many dynamic factors can be counted. In general, we can categorize the factors affecting the price forecast into two parts: long-term and short-term.

The main factors affecting the long-term electricity price estimation:

1. Electricity demand
2. Coal prices
3. Natural gas and oil prices
4. Renewable installed power capacity increases
5. Capacity factors
6. Storage capacity

The main factors affecting the short-term electricity price estimation:

1. Time factor
   - Working time
   - Leisure Time
   - Sleeping Time
2. Economic factor
3. Weather
   - Temperature
   - Humidity
   - Wind speed and wind chill index
   - Precipitation
   - Cloud cover and light intensity
4. Random or Occasional Spikes

In addition to long-term and short-term factors, merit order also indirectly affects the price forecast. Merit order consists of conventional and renewable power plants. Therefore, factors affecting power plants also affect the merit order. Additionally, the balance created by merit order is affected by two different factors that may cause the curve to shift:

1- Change of electricity demand according to installed power; Situations of shortage or surplus can be effective on price.
2- The changing marginal costs of power plants using different technologies are reflected in the price change over the production they adjust.

3.1.2.4. Electricity markets around the world

1- EPEX Spot

The European Energy Exchange, otherwise known as EPEX SPOT, is an electrical energy exchange used in some countries and operates in the following countries. UK, Luxembourg, Netherlands, Austria, Belgium, Denmark, Finland, France, Germany, Norway, Sweden, and Switzerland.

EPEX SPOT operates day-ahead energy markets for these countries. This European energy exchange calculates the offer and demand curves and their intersection for each hour of the next day. If information is given about the most up-to-date data, the volume of electricity traded in EPEX SPOT markets in 2019 reached 593 terawatt-hours (TWh). [27]

2- Nord Pool Spot

It has the distinction of being the first northern country to regulate and operate the Norwegian electricity market. The energy law that it enacted in 1990 has been a regulation based on other northern countries.
With the energy law enacted in the Scandinavian countries in 1990, the foundations of liberalization in the energy market were laid and the spot electricity market operated by "Statnett Marked Nordik" in 1993, following the decision taken in the Norwegian Parliament for electricity energy trade in 1991. In 1996, Norway and Sweden agreed to establish a joint electricity market, and as a result of this agreement, Statnett Marked expanded its field of activity to include Sweden and took the name "Nord Pool Spot ASA". He then joined Finland in 1998 and Denmark Nord Pool ASA in 2000, respectively. On the other hand, Nord Pool is a kind of voluntary or net pool that allows for physical bilateral agreements. Electricity can be bought and sold on or outside of the pool within the framework of bilateral agreements between market participants. Manufacturers, distributors, suppliers, industrial consumers, traders, and intermediaries can join the pool.

3.1.2.5. Electricity price forecasting examples around the world

Just as the electricity market is universal, its problems are universal as well. For this reason, many people have tried many methods to realize price forecasting in different parts of the world. When we examine the samples, we can understand that more of the ARIMA model is being used. Below there are examples of price forecasting for the Spanish, California, and Nordic electricity markets.

First of all, Contreas, Espinola, Nogales, and Conejo [28] have conducted trials for both the Spanish and California electricity markets. They used the ARIMA method to predict the hourly price of electricity in the markets. At the end of the study, the average error for the Spanish Electricity Market was around 10%, while the average error for the California Electricity Market was 5%.

Second of all, Zhang and Cheng [29] preferred to use daily data for the Nord Pool Electricity Market. It realized price estimation using multi-layer sensors and ARIMA methods. In his study, he used system price, system volume, regional price, and reserve variables and delays as parameters. At the end of the study, the error obtained by multi-layer detection was 5.85%, while the error obtained by the ARIMA method was 6.37%.

3.1.2.6. Electricity price forecasting examples in Turkey

In literature, some studies include daily, weekly, monthly, days, weeks, and months of different seasons that are subject to price forecasting in one or more electricity markets by one or more methods. As with the examples in the world, the price was estimated in the Turkish electricity market with more multilayer sensors and seasonal rigging models.

Firstly, Özgüner [30] used parameters of hourly load, system pre-day price, and system marginal price to be able to forecast prices. As a method, he chose a multi-layer feed-forward artificial neural network and multiple linear regression to continue his research. In doing this work, he created different models of artificial neural networks for price estimation. During his study, he used the 1 the year of 2011 as data by dividing it into weeks.

Secondly, Kölmek [31] obtained 9504 hours of data in the period 12/01/2009-12/31/2010 and estimated the pre-day price of the system using artificial neural networks and autoregressive integrated moving average methods. In the study, it was concluded that the estimates made with artificial neural networks according to the average absolute percentage error criterion performed higher than the estimates made with the autoregressive integrated moving average model.

3.1.3. Standards and constraints

From the point of view of this study, changes in the market and electricity prices during the period of research, as well as the fact that the Turkish electricity market is still in the process of reform, can be considered an important constraint.

3.1.3.1. Parameters affecting price in the electricity market

Fluctuations during the day and week in the time series include seasonal characteristics. The decrease in the load and price point is evident at the weekend, especially on Sunday. However, official holidays, holidays, or unusual situations that will affect the supply-demand balance generally disrupt the seasonality in the series.

The effect of climatic conditions in Turkey is emerging more clearly in some of the special years. 2014 was drier than 2015 and prices were higher. Rainfall and water resources, power generation systems connected to relatively less affected by the drought which countries the Netherlands and Germany's price were less than the rates for Turkey. However, the types, efficiency, and external dependency of each country's power generation plants are critical in determining the market prices in these countries. For example, France makes significant use of nuclear resources in electricity generation, while the Netherlands realizes gas and coal-based production. The Netherlands and Turkey in the global exchange of electricity is no doubt that gas prices will significantly affect the market price. The natural gas supply shortage experienced in date 13.02.11 in Turkey and a number of manipulative reasons, market prices 2000TL / MWh levels seen but this was not permanent.

On the other hand, if we give an example of other factors that affect the electricity price, while long-term political factors are effective at the level of bilateral agreements, they have an indirect effect on average prices in Day-Ahead and Intraday Markets. However, as reasons such as the commissioning of a new power plant and planned breakdown-maintenance services can be known Day-Ahead, they show their effect in the Day-Ahead market. Factors such as production imbalances of renewable energy power plants, malfunctions in the power plant required to be commissioned according to the offer, affect the Intra-Day market prices. Ultimately, the unbalanced loads in all market types for some reasons are settled by balancing through the balancing power market.

3.1.3.2. Energy Supply

The field of study of the energy economy is energy markets, energy market regulatory institutions and their regulations, energy transportation and storage, energy conversion, total energy resources, and the resources subject to trade among them. Here, the relationship between the country's energy resources and economic activities and the results of the use of energy resources are examined. For example, such as how economic growth affects energy demand, how problems in energy supply affect production, how energy can be used more efficiently, in which situations individuals and companies increase their energy demand, in which situations they reduce it, and how effective are energy markets are sought answers.

In this situation, the factors determining the energy demand are energy prices, economic growth, demographic factors, technology, price and income elasticities of energy demand, while the factors determining the energy supply are energy prices, supply flexibility, countries' stock status, seasonal conditions, production and transportation costs, international relations, investment projects of energy companies and projections of international organizations on energy.

While some studies show that economic process ends up in a rise in energy demand, some studies state that economic growth happens only as a result of additional energy is consumed. In different words, there's no agreement regarding the direction of the relation link [32]. Erol and Yu [33] examined the connection between energy consumption and value of England, France, Italy, Germany, Canada, and Japan between 1952 and 1982, two-way for Japan, unidirectional from energy consumption to GDP for Canada, Germany and for Italy, they found a one-way causality from GDP to energy consumption.

The increasing population and urbanization rate increases energy demand. On the other hand, technology affects energy demand in both directions. Higher technologies developed are machines, tools, etc. that use less energy will now be needed to do the same amount of work, as it will make the assemblies more efficient. On the other hand, with the developed technologies, machines, tools, etc., which were not in our lives before, will be put into use which will increase energy demand. Income and price elasticity of energy demand varies according to the country's economy, the country's foreign dependency on energy, time, and which energy source is in the situation.

Energy prices are the most important factor affecting energy supply. Rising energy prices following the law of supply increase the amount of energy supplied. Countries' stock status is negatively related to energy supply. Increasing stocks decrease supply. Seasonal conditions increase the energy supply depending on the location. Natural disasters, extreme temperatures, colds, or droughts increase the supply. Increasing production and transportation costs decrease energy supply.

3.1.3.3. Energy Supply Security and Its Importance

Today, energy has become one of the basic requirements of a country's social and economic development. Without energy, even some basic daily needs cannot be met. Therefore, energy supply security also means national security. However, some risks may cause interruptions in the energy supply. These are physical (technical failures, accidents, wars, natural disasters), economic (big fluctuations in energy prices, oil embargoes), and social (strikes, social movements, internal disturbances) risks. [34].

In another classification, risks are divided into two as short term and long term. While short-term risks consist of physical, political, and technical risks that cause sudden interruptions in energy supply, long-term risks consist of supply-demand imbalance, resource scarcity, investment inadequacy, and infrastructural problems, which are more predictable and take longer to resolve than short-term risks. [35].

The executive mechanism should take precautions against these risks and provide the energy needed by the society and the economy to consumers in sufficient quantity and quality, low cost, uninterrupted, timely, and environmentally friendly. Even if the price of the energy offered to consumers is low, it is insufficient in terms of quantity and quality, or on the contrary, the provision of quality and sufficient energy at high prices will not meet the expectations. Even if all these are met, the energy in question must be met when the consumer needs it.

In cases where price fluctuations are high, macroeconomic indicators (such as the balance of payments, unemployment, inflation, growth) will be negatively affected. However, few countries on earth are self-sufficient in terms of energy, because energy resources are not evenly distributed across the earth. Therefore, countries must strengthen these weak points as much as possible with supply security measures.

Another negative point in terms of supply security is the price of these resources. Prices increased rapidly with the global financial crisis, which was particularly effective in 2008-2009. The high volatility of the prices is also a disadvantage. Prices, which are easily affected by international military-political turmoil and economic fluctuations, do not give confidence to their consumers and negatively affect the production process.

3.1.3.4. Energy Supply Security Policies

Countries realizing the importance of energy supply security have developed various policies in this regard. In the short term, it is necessary to make investments in energy supply in parallel with economic development and environmental needs, and in the long term, to give flexibility to energy systems to respond to sudden changes in supply and demand. On the other hand, it is necessary to increase resource diversity, increase energy (such as oil and gas) storage capacity, ensure price security, give importance to energy saving and efficiency, and use foreign policy tools [36].

One of the most important policies for energy supply security is resource diversification. Under normal conditions, it is desired that the shares of energy resources in consumption are as equal as possible and not to be dependent on a specific energy source. The aim is to avoid the risks that may occur in the event of any supply interruption.

3.1.4. Conceptualization

If we explain more conceptually how to do this project; First of all, it is very important to understand the concepts and the subject of the project. Firstly, we focused on the definition of the subject and researched it. When we explain the subject in more detail, we will make a price forecasting in the Balancing Power Market by considering renewable energy resources. Wind and solar energy can be given as examples of these renewable energy sources.

We realized that the markets for which we will make this price prediction are the Balancing Power Market. After determining the power plant types and markets that we will work on, it is also very important to determine the parameters that affect these power plants and the market forecast price. If we give an example from a few parameters that we have determined: electricity demand, capacity factor, storage capacity, the time factor, economic factors, weather conditions… All of these parameters are factors that affect the price estimation. In this project, it is very important to determine the necessary parameters for proper modeling and to determine all parameters that may have an impact on this project from every angle. For this reason, all possibilities should be taken into consideration, starting from these parameters, especially when determining the mathematical model. Each research is very important to select and use suitable mathematical models for these parameters and to find suitable solutions for the parameters. According to the literature studies conducted for selecting the suitable models, we saw a few examples of models used in other countries' electricity markets. There are different types of modeling, such as linear time series like ARMA or nonlinear time series, artificial neural network models, and these models can be used in the electricity market for price forecasting. In this project our aim to choose the most suitable model according to the parameters that we have determined and the data that we will use for price forecasting in the Balancing Power Market.

3.1.5. Risk assessment

3.1.5.1. What is Risk?

It is the possibility of damage, injury, loss, or any other negative consequences. It is possible to prevent or reduce its effects by taking precautions. There is also a risk in the electricity market from past to present. The liberalization of the electricity and gas markets in the early 1990s led to the opening of new markets for spot and derivative products all over the world. Electricity exchanges, formed by the liberalization of electricity markets, have similarly made it possible to trade spot electricity and electricity derivatives, and trade of other securities and collaterals on stock markets in the financial market.

Besides, the abolition of restrictive orders in the electricity market created a competitive environment in markets where the risk of losing formerly belonged to a monopoly was low. This competitive environment has brought along new risks. Electricity cannot be stored and is purchased mainly for consumption. Liberal electricity markets are much more volatile than other collateral or commodity markets. Therefore, the electricity market is exposed to significant risks arising from fluctuating market conditions. This situation manages the risks arising in the increasingly competitive environment; has made it the focus of market participants all over the world.

3.1.5.2 Types of Risks in the Electricity Market

Risk in electricity markets has different reasons. According to Wangensteen [37], there are three main sources of risk in the electricity market, these risk sources are also seen in all liberal markets.

These risks are:

1. Market risk: This risk depends on price fluctuations caused by changes in supply and demand.
Many different risks can be mentioned within this market risk. First, there is price risk and this is related to uncertainty in future spot prices. On the other hand, Financing risk is the risk of a business being unable to provide the money and credit required to operate, develop, or increase the cost of the loan it provides. The financing risk in the electricity trade arises from the daily financial settlement of the electricity trade in the spot electricity market, which we call the day-ahead market. Also, the Volume risk is related to the future volume of electricity and arises from weather-dependent consumption. It is the probability of inaccurate estimates that result in the cost of imbalance that arises when the electrical energy supply or withdrawal to the system is different from that reported to the system operator.

For example; If a power plant is out of operation due to a malfunction or a large consumption facility starts to operate/stop working suddenly, deviation of the Load Forecast Plan due to various reasons (weather, etc.), unexpected changes in the open position at hand.

Liquidity risk arises from the periodic low liquidity experience in some markets. This situation restricts the movements to close or change position at any time. Volume risk and price risk are not completely independent. Because as the demand increases, the price tends to increase.

2. Strategic risk: It is linked to political decisions and includes external changes. For example, energy law changes, concessions, rules for power exchange, emission trade promotion, interest rates, and foreign exchange inflows. Regulation risk is also very important, it refers to the risks related to the sanctions, financial losses, and/or loss of reputation that the company may be exposed to as a result of changes in legislation, regulations and standards, relevant laws, regulations, communique, and other regulations. On the other hand, Operational Risk can be defined as the risks arising from people, systems, processes, or methods during the operation. Operational risks in electricity trading are as follows: Operation Management Risk arising from Authorization Inadequacy, System Risk arising from software problems, Transaction risk arising from people, and methods ...

3. Technical risk: associated with outages of production and storage facilities. .[38]

3.1.5.3. How can these risks be resolved?

When the major risks mentioned above occur, it is also very important to solve them. There are certain methods to solve and manage these risks. In addition to these methods, suitable models are also developed to solve these risks. Optimum models are also used in order to minimize the risks that may occur while estimating the price.
If we talk about certain solutions in risk management; For example, three options can be used depending on the time to focus on controlling price risk;

• In short-term risk analysis to determine when VaR (Value at Risk) open positions will be closed,
• CFR (Cash Flow at Risk) in the medium-term cash flow regulation
• PaR (Profit at Risk) is a method that can be used to manage volume and price risk in the long run.

As another example, the buyer or seller can trade in the Futures Options Market in order to eliminate the counterparty risk regarding their energy trade.

On the other hand, Operational and Operational Management Risks are risks that can be controlled by dividing the business. The most important issue in this context is the determination of correct job descriptions and the authorization and limitation of the right people under these definitions and the establishment of a reporting system. ETRM (Energy Trade Risk Management) helps to minimize system-related errors and facilitate operational work by integrating programs, systems, and departments. .[39]

3.1.6. Evaluation Planning

Linear time series (ARMA, ARIMA, ARMAX, and ARIMAX) models, nonlinear time series models, artificial neural network models, and wavelet transform types of these models for price prediction in electricity markets find application areas for different country markets. Some of the common features of studies that make price estimates with different methods are to be able to compare the forecast performance depending on the market and the period and to be able to identify models that give low estimation error. In this study, Turkey's electricity market to create a system of Balancing Power Market direction and price forecasting models made a comparison of data obtained with the correct parameters are parameters must be selected.

As the justification for the price estimation made in the literature, the fact that market participants increase their profitability and make risk management easier while making their price offers guides the estimation studies. In our study, we talked about how electricity price estimates are applied in the world and talked about the errors that occur and may occur in the applied system. We aim to create a direction and price forecasting model for the Turkey Electricity Market which is the most appropriate and least error with the system.

3.2. Industrial Engineering

3.2.1 Definition of the problem

For the Industrial engineering team, the definition of the problem could simply be summarized as designing a model that is highly predictive of the balance market's price and system's direction. The importance of the balanced market resides in its ability to balance supply and demand in real-time. When we approach real-time, we want to develop a model that accurately predicts the balance market depending on a given day's conditions and the day ahead market predictions. Our model could formally be written as a function that takes two inputs (day-ahead market, real-time variable inputs)
Let us denote the prior as *g* and the former as *x* with *y* being our target, the function could then be written as:

$$f(g,x) = y \tag{4}$$

The model will also have to consider renewable energy sources and their energy output such as the amount of energy a wind turbine generates in a given day as inputs. In addition, the analysis of independent inputs and their specific effects on the system will be considered. The development of a price prediction model that uses renewable energy source's energy output and a set of other explanatory input variables as inputs for the prediction of the balancing market and energy prices at very short time-intervals.

Upon reviewing the literature, we came to the conclusion that deep learning algorithms are only used in 3 very recent papers in the electricity price forecasting. Unfortunately, all the papers work on the day-ahead market[ugurlu,1]. In section 3.7.2 we will review some of the papers that deal with the different models that aim to predict the prices and electricity loads at different time intervals. Our initial conclusion is that there is a significant gap in the related literature with regards to energy price forecasting at very short intervals. There also is a gap in the balancing market forecasts. Our project will hopefully positively contribute to the literature.

3.2.2. Review of technologies and methods

Although the topic of balancing market has received relatively little attention by academic scholars. We will try to list some of the methods used for similar problems. Before listing the technologies used in the electricity industry, a review of some of the most important prediction models is necessary. In the domain of pattern recognition and data science, there exists two main supervised leaning problems:

1. Classification: the prediction of a label (discrete).
2. Regression: the prediction of a continuous quantity(continuous).

In our project, we will be solving a supervised regression problem. Here are some of the most widely used Regression techniques in Machine learning:

1. Linear regression: By far the most important statistical tool. This technique maps a set of independent variables (X) to a set of dependent variables(Y).

2. Polynomial regression: Although similar to linear regression, this technique can take the higher powers of input variables. This technique can easily over fit if high powers are used in the presence of little data[bishop].

3. Logistic regression: A technique mostly used for binary classification problems, but could also be used for regression tasks. Logistic regression becomes a classification algorithm only after adding a decision rule.

4. Principal Component regression (PCR): A technique that uses principal component analysis to perform regression tasks in the presence of many independent variables.

5. Support Vector Regression: This method can solve both linear and non-linear regression problems.

Above were only a few of the regression techniques used in Machine learning. Having said all that, our main focus should be the review of methods related to time-series problems in the electricity market. The leading paper in Electricity price forecasting (Weron,2014) listed some of the most widely used approaches which are the following[10]:

1. Multi-agent
2. Fundamental
3. Reduced-form
4. Statistical
5. Computational Intelligence

In the literature, academics have looked into implementing a wide range of other methods under the umbrella of computational intelligence and compared their results. The following are some of the methods used [9]:

1. Random Forest Regression (RFR)
2. Support Vector Machine (SVM)
3. Artificial Neural Networks (ANNs)
4. Long Short-Term Memory (LSTM)

The techniques mentioned above are mostly statistically oriented and are more widely used in the paradigm of machine learning rather than deep leaning. The latest developments in the field of deep learning, the advent of big data, makes the prospect of using a variant of multilayer perceptrons such as recurrent neural networks and their more complex variants more appealing. The main reason why RNNs in particular have proven to be capable in predicting time-series data is the fact that these models have a concept of *'memory'!.* They achieve this, through the repeated(recurrent) use of the same weight matrix in each time-stamp. Although the vanilla version of these architectures are almost never used, Long Short-Term Memory (LSTM) based recurrent neural networks are among some of the most powerful techniques in time-series forecasting tasks. LSTMs are by far the most widely used deep learning approach in modeling sequential and time series data.

In this section, we will give a brief introduction to some of the deep learning architectures we plan to experiment with. As mentioned in part 1.4, there exists a myriad of methods dealing with different forecasting problems. Here, we will limit ourselves to the three most widely used architectures in time-series forecasting and analysis. By increasing order of complexity, firstly, we will give a brief introduction to RNNs. We will then discuss their major problem in dealing with long input series. Secondly, we will introduce an improved version, a cell type that increases the gradient flow by introducing more parameters. Finally, we will discuss how LSTMs vastly increase the computational prowess of the aforementioned models and how they reign supreme in dealing with sequential data and time-series analysis.

1.RNNs

Unlike traditional ANNs, RNNs have the capability to deal with varying size sequential inputs; this alone makes the prospect of using them for time-series data more compelling. RNNs work by recurrently (recursively) feeding the hidden layer's output back into the model as an additional input for the next input point. The reason why RNNs are efficient as they are is because of the fact that the same weight matrix W is used across every single time-stamp. The figure below will illustrate the simplified version of the RNN architecture[11].

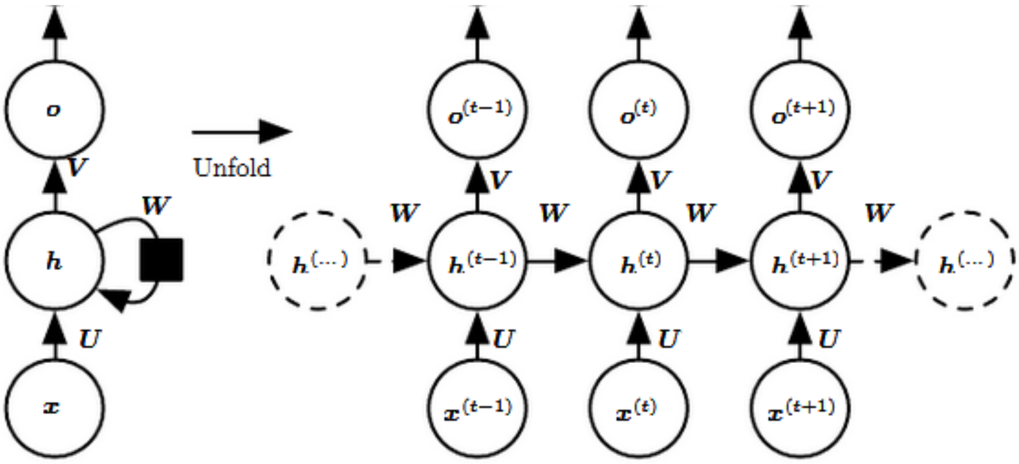

Figure 7. Unfolded RNN

As seen in figure.7, the d-dimensional input space x_t is multiplied by the same weight matrix U and is fed to the hidden layer h_t as an input. Additionally, the previous layer's hidden output h_{t-1} multiplied by the weight matrix W is also fed into the hidden layer h_t.

There exist many different notations for describing the model above, but for the sake of simplicity, we will try to keep it constant with the figure above.

$$a_t = b + Wh_{(t-1)} + Ux_t \quad (5)$$
$$h_t = tanh(a_t) \quad (6)$$
$$o_t = c + Vh_t \quad (7)$$

In conclusion, the model works by taking linear combinations of different inputs and sends them through a non-linearity -mostly *tanh* in the case of RNNs. The model can unfold as many times as necessary, giving it the increased flexibility over traditional ANNs.

Although RNNs may seem sufficiently complex, they suffer from a major drawback, known as the exploding gradient[40]. Deep learning networks depend on very long chains of partial derivatives multiplied with each other. Imagine the need to multiply the same weight matrix multiple times, the multiplication of many factors less than one multiplied many times will converge to zero. Thus, the model will not be able to adjust its weights. To overcome the gradient flow problem, different architectures have been proposed—most notably LSTMs in 1997 and GRUs in 2014.

2-GRUs

Although introduced much later in 2014 by Kyunghyun Cho et al. [41], it was introduced as an attempt to simplify LSTMs and reduce the computational power needed for training. The main idea behind this architecture is to add more parameters and allow for a better gradient flow. Here, we will be looking at a simplified version of the GRU. The main take point is the addition of a "forget gate" that determines how much of the previous hidden layer's information should be kept. Many different notations exist, but we will try to keep it brief:

First, let us change denote $Wh_{t-1} + Ux_{t-1}$ *as* Z_g. Then we can pass Z_g through the tanh activation function and obtain *g*.

The hidden layer h_t then become:

$$h_t = [(1-\beta)*g + \beta*h_{t-1}]\ \beta \in [0,1] \tag{8}$$

When $\beta = 1$ *then* $h_t = h_{t-1}$ *then "pure memory"*

When $\beta = 0$ *then "vanilla RNN"*

The above formulation was for the scalar case. Now let us look at the vectorized notation. We will use the Hadamard operator with the forget gate "f".

$$h_t = (1-f) \odot g + f + h_{t-1} \tag{9}$$

3-LSTMs

LSTMs were introduced in 1997 to overcome the vanishing gradient problem by the addition of three gates to the already existing RNN architecture.

a. Forget gate
b. Input gate
c. Output gate

As mentioned above, LSTMs highly resemble GRUs but are more complex and require increased computational power. The main take away point behind LSTMs is that the addition of extra parameter and taking their linear combination and passing it through an activation function vastly improves the flow of the gradient and allows the model to learn and adjust its weight through very long input sequences.

For our implementations, we will first try to use RNNs, then GRUs, then LSTM; this is because the computational complexity of these methods is as the following:

LSTM > GRU > RNN

Figure 8. will illustrate the difference between LSTMs and GRUs[42].

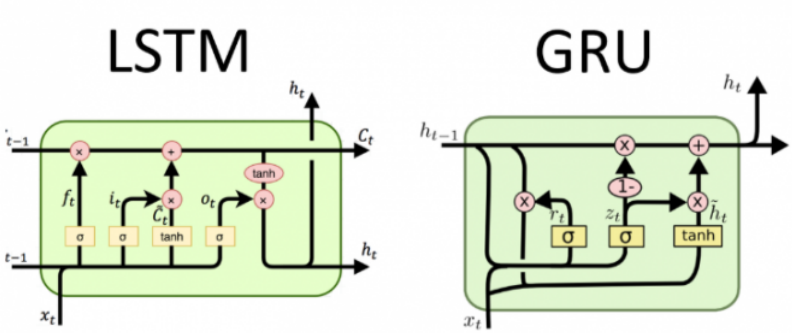

Figure 8. LSTM vs. GRU architecture comparison

Regarding the problem we have at hand, predicting the energy system's direction over very short intervals of time. Different papers have tried to solve this problem through the use of both statistical methods and computational engineering. Although, it is worth noting that most of these methods were used to predict the load variable not the price. Table 4. will illustrate our extensive literature review on the topic.

Paper	Method	MAPE	Time-Interval	Data set
Ugurlu et.al, 2018[43]	LSTM	0.22	2-hour ahead	Turkish
Tian et.al,2018[44]	CNN	0.0472	Hourly	Northern Italy
Tian et.al,2018[44]	LSTM	0.0480	Hourly	Northern Italy
Tian et.al,2018[44]	CNN+LSTM	0.0396	Hourly	Northern Italy
Pramono et.al, 2019[45]	LSTM + CNN	2.02	Hourly	Switzerland
J. del Real et.al 2020 [46]	CNN+ANN	1.4934	Hourly	France
J. del Real et.al 2020[46]	ANN	2.8351	Hourly	France
Abderrezak et.a.l 2014[47]	Exponential smoothing	0.491	Half-hour	France
Son & Kim. 2020[48]	LSTM	0.07	Monthly	South Korea

Yamin et al. 2004[49]	ANN	10.93	Hourly	California/USA
Dong et.al. 2011[50]	EMD-SA-ARIMA	12.6922	Half-hour	New south wales / Australia
Setiawan et.al. 2009[51]	SVM	4.3	5-minute	Australia
Shrivastava & Panigrahi, 2013[52]	Custom ELM	7.88	Hourly	Ontario/Canada

Table 4. Literature Taxonomy

We would like to briefly discuss the paper by Tian et.al and display their improvisation in concatenating the LSTM network with a CNN based architecture. Figure. 9 will illustrate the model

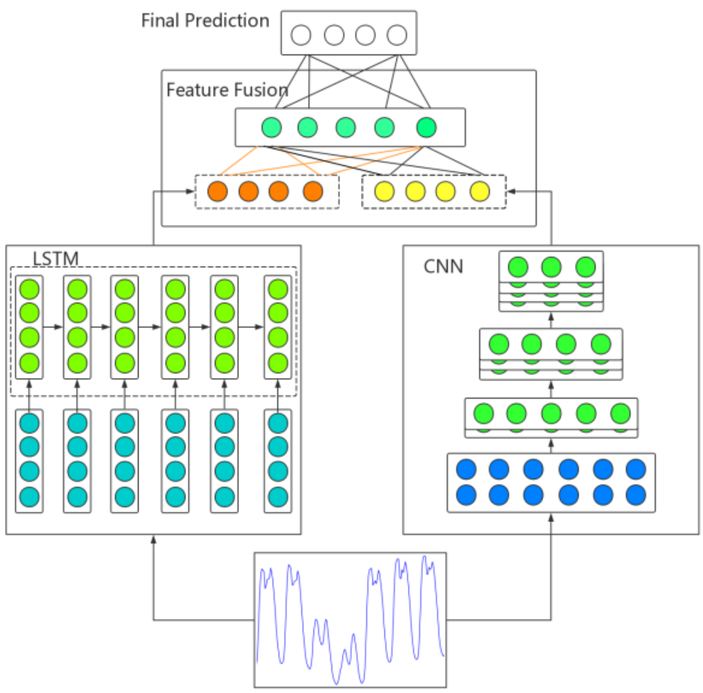

Figure 9. Concatenated CNN + LSTM

As seen in Fig 9. above, the CNN architecture is used to analyze more spatial and the locality of the data; this is the reason why CNNs are most widely used in image recognition problems. The LSTM, on the other hand, will analyze and detect long-term dependencies. Finally, the hidden states of both models are concatenated, and a fully connected layer is added for the prediction operation to take place[44]. This custom architecture was shown to provide accurate energy load predictions over hourly periods.

The second architecture worth describing is that of J. del Real et.al, which utilizes both CNNs and ANNs for the prediction of hourly demands[46].
Fig 10. below is a graphical representation of their model.

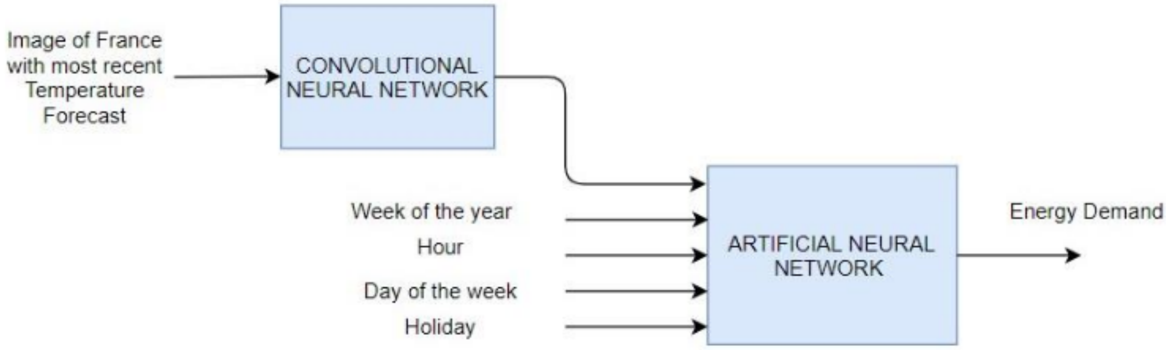

Figure 10. Concatenated CNN + ANN

In conclusion, a wide variety of deep learning models utilize concatenated architectures depending on the type of data inputted. Studying the papers above led us to conclude that models that use multiple architectures could be beneficial in helping us reach our aim.

3.2.3. Conceptualization:

Referring to the definition of our problem, we aim to build a model that takes into account the energy output of different renewable sources as well as other pertinent explanatory variables and study their real-time effect on the energy system's balancing market prices. Additionally, we will be investigating how independent input variables affect the system's direction. Different sensitivity analysis methods could be deployed. Moreover, an important procedure in Machine learning is the horizontal dimensionality reduction of input variables. Principal component analysis could be used to filter out inputs with the highest variance [53]; Thus, helping us determine the most pertinent variables. We also would like to note that upon deploying deep learning models, there will not be an indication from the model that could help us determine the importance of independent variables and their effect; This is due to the added non-linearity activation functions that constitute the bulk of deep learning layers. In order to counter the problem of non-linearity, we could first deploy neural nets with no hidden layers, fundamentally turning it into a generalized form of linear regression. Looking at the weights assigned to each variable could give us an intuitive sense of the importance of each variable.

Once the variables have been accounted for, the next step would be to choose a model that is capable of modeling time-series sequential data with multiple parameters. As mentioned in previous sections, RNNs and their more complex variants are most widely used. Depending on the literature review we have conducted, different concatenated models that utilize CNNs, LSTMs, and ANNs, could be experimented with. It is also worth mentioning that we also plan to experiment with statistical methods such as exponential smoothing and Autoregressive integrated moving average models and their variants.

Referring to the architectures mentioned in Section 3.7.3, using an LSTM layer to handle sequential data and concatenate its hidden output with the output of a CNN based architecture, and adding a fully connected layer at the end could help us achieve satisfactory results. BLSTM networks have also proven successful in predicting time-series data. We could also use BLSTMs instead of conventional LSTMs and compare our results. An illustration of a similar model will be illustrated in Fig 11. This figure is taken from Kim & Cho's (2018). paper on predicting residential energy consumption using CNN+LSTM architectures [54].

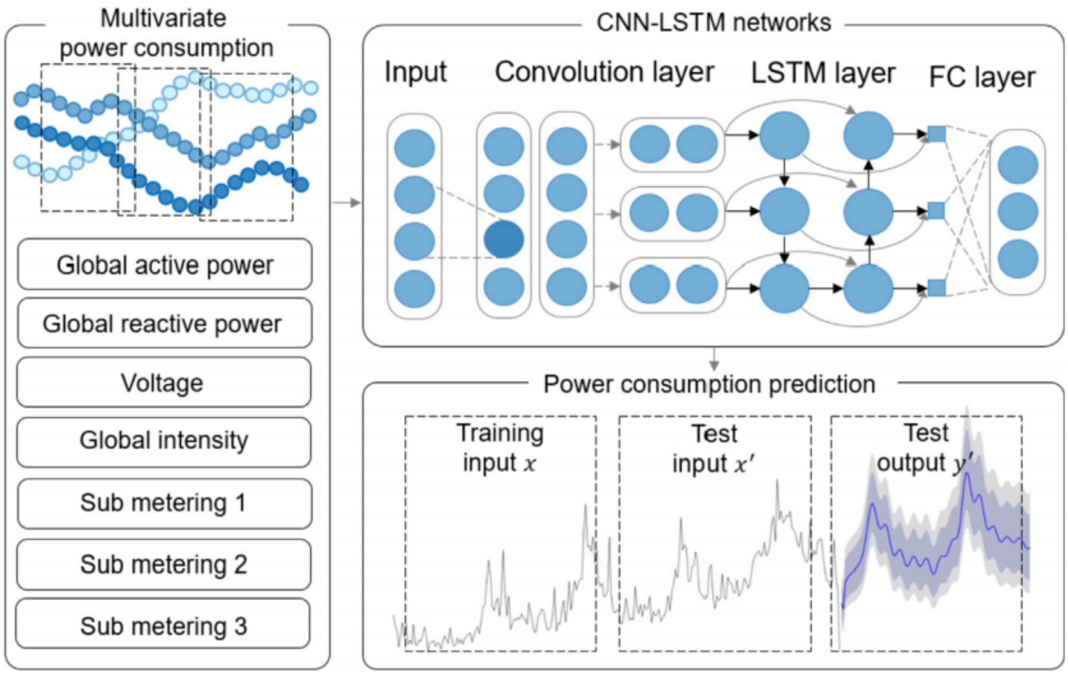

Figure 11. CNN-LSTM networks

3.2.4. Methodological architecture

The visualization of the steps that will be taken in the modelling and analysis part of the project is illustrated in Fig. 12.

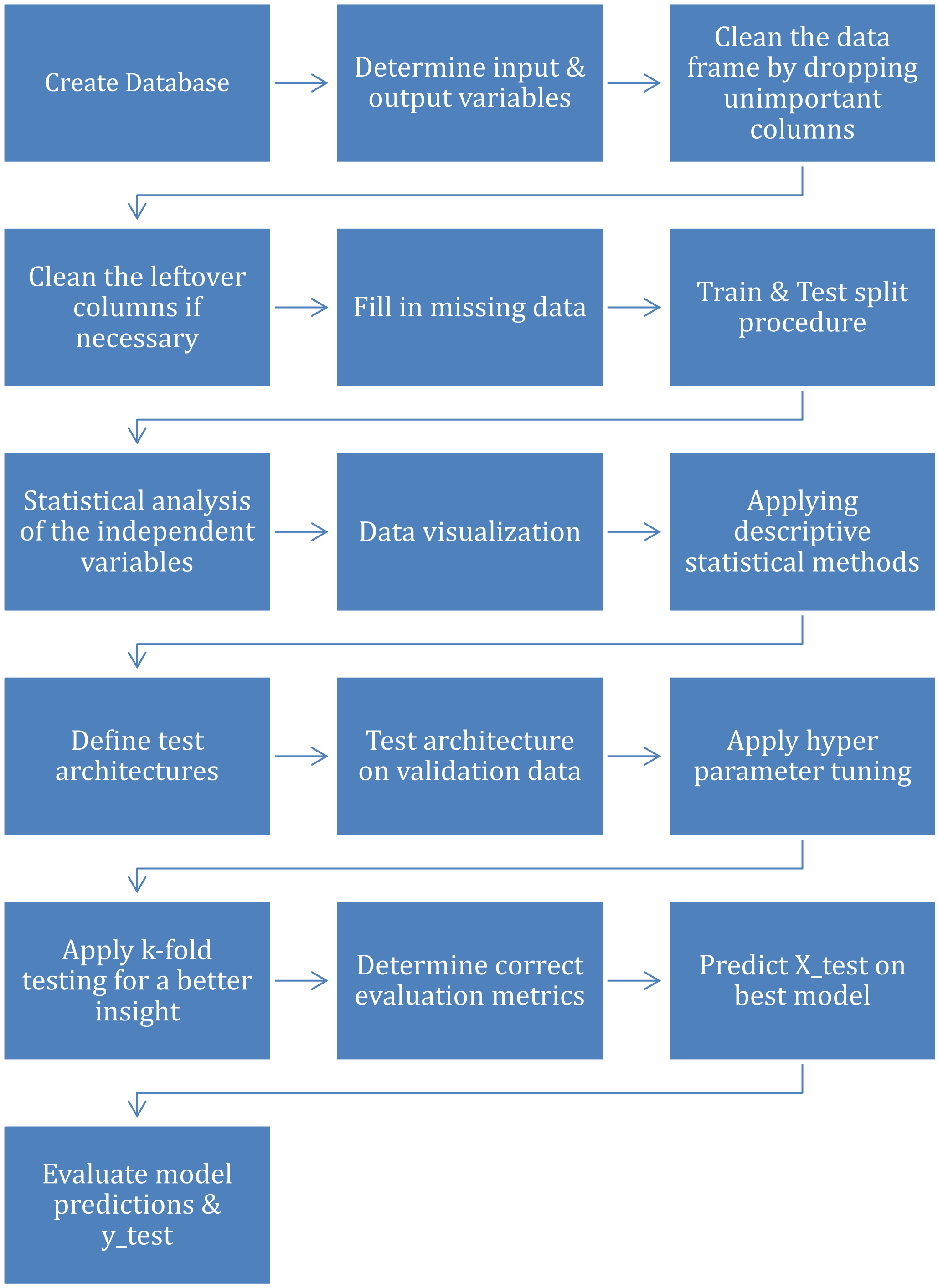

Figure 12. Methodological architecture

3.2.5. Review the availability of the data

Considering the data required for modelling, it can be seen that it is divided into long-term and short-term categories. The necessary short- and long-term parameters were mentioned earlier. However, in the integration and implementation process additional parameters may be required.

Parameter	Availability
Time Factors	The necessary time parameters include working time, leisure time, sleeping time. These parameters can be obtained from GATES Enerji A.Ş.
Economic Factors	Economic factors can be generalized as Gross domestic product (GDP) of the country, Per capita income (PCI), employment data, unemployment rate, etc. These datasets can be collected from International Monetary Fund, World Bank, or United Nations' database.
Weather Data	Weather data should be collected from the local data collectors to increase the reliability. Moreover, renewable energy generator firms can collect their own data with various sensors. Consequently, weather data can be obtained from the GATES Enerji A.Ş.
Market Prices	Market prices can be obtained from different sources such as: Enerji Piyasaları İşletme A.Ş. (EPİAŞ) and GATES Enerji A.Ş.
Additional Market Data	Generated and consumed energy amount and other important energy data can be easily achieved from EPİAŞ and GATES Enerji A.Ş.

Our initial conclusion is that we will not face any major drawbacks with regards to the collection, cleaning and cleansing of the data.

3.2.6. Risk assessment

Measuring risks before projects makes it easier for project members to decide on later processes. The project risk matrix was created earlier at the beginning of the *Section 3*.
As a closer look of risk matrix, inadequate data is crucial for the data analysis processes since this will directly affect the accuracy of the models. Moreover, low data quality and incorrect data editing may occupy group members more than necessary, so the project time may be consumed unnecessarily, and the data may be corrupted.
In modelling part, selecting the suitable forecasting method is another important process. Comparing different methods will decrease the possibility of choosing the unsuitable method. Furthermore, changing the dataset for each machine learning method may occur some problems; to reduce the risk, the project members should keep the different versions of the datasets for each ML model. In additional to the modelling part, overfitting and underfitting the training data cause many problems. Severity rating of overfitting the data is *Major* since it is hard to realize and can affect the overall performance for different datasets. On the other hand, severity rating of underfitting the training data is *Minor* because this problem can be easily noticed by the outputs of the model.

3.2.7. Evaluation Planning

An essential step in any data science project could be considered to be the use correct metrics in the evaluation process on the test set. The use of accuracy on an unbalanced set could lead the engineer to evaluate their model as incorrectly accurate and declare the model generalizable. Classification algorithms depend on evaluation metrics such as F1 scores and receiver operating characteristic curves. In the domain of regression tasks, simpler evaluation metrics exist, most notably, mean absolute error (MAE), mean squared error (MSE), root mean squared error (RMSE), mean absolute error percentage (MAPE). In our project, the evaluation metrics will be determined in the later stages by our supervisors but considering that the majority of academic papers written in this field evaluate their results using MAPE. We will take the time here to describe it.

MAPE:
The relative difference between the predicted values and their observed instances normalized over the length of our prediction. Mathematically it is formulated as in Eq.10.

$$\mathrm{M} = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{A_t - F_t}{A_t}\right| \tag{10}$$

It is worth mentioning that the evaluation should only take place on the test data set. Evaluating it on the training set would be considered a major mistake.

3.6.8. Discussion of limitations

Our project's limitations will take a clear form once the application phase of our project takes place. The constraints discussed in part 1 could affect the scope of our project. Thus, limiting our experiments to simpler deep learning models and the use of smaller data sets. Working with a company could help us alleviate most of these constraints. The use of local servers offered by the company could help us experiment with bigger models. Additionally, the limitation of our study will be constrained by the Turkish energy market and its regulations. The difference between international and local markets might render models successful in other markets unsuccessful for our case. These are all limitations that will be much clearer once the application phase of our project occurs. If we wanted to list the limitations to our project, they could be listed in the following manner:

1. Market data
2. Market regulations
3. Market rules that lead to memory leaks between models

4. CONCLUSION

As a result, thanks to the research and the meetings that we made in this project, we understood well that what our problem and aim are. In other words, we will be trying to understand the characteristics of the production changes in renewable energy and find the effect of this on the real-time system direction and prices in the system. For example, if we take a 24-hour time period, we want to model the response of the day ahead price according to certain acceptances to the changes that will occur within the framework of certain acceptances in the coming days in real-time. When we make a price forecast, there are certain parameters that can affect these price forecasts. At the same time, we tried to determine these parameters in our project, and in the third part of this thesis, we determined these parameters in detail in the factors affecting the price estimation section. In case of any risk caused by these parameters while making the price estimation, we determined the relevant solutions in the risk section of the 3rd section. On the other hand, we determined that we need data for some renewable energy sources in order to be used as input in the system, we will establish this for facilitating the estimation while making price forecast. We also conducted research on what these data could be. For example, the most important data we will use is the reference electricity price of renewable resources determined in the day-ahead market. Our aim to create a system where we can evaluate all these data and parameters that affect the price forecasting and when we use them, we can estimate the electricity prices and characteristics of the production changes in the balancing power market of renewable energy sources. Of course, while creating this system, we determined that mathematical modeling was also needed, and we also conducted a literature search on what has been done with mathematical/computational models until today. We have also specified the models that we have found in detail in the industrial section of our thesis. Our plan for the upcoming period is to decide exactly which data to use, which appropriate modeling we will choose, after creating the system that we want to create.

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