Czech Technical University in Prague

Faculty of Electrical Engineering

Topic of thesis "Wind Energy in Izmir - How to Face the Extra Demand Caused by the Population Increase?"

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Bachelor's Programme: Electrical Engineering and Computer Science

Department: Department of Economics, Management and Humanities

Branch: Power Engineering

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ZADÁNÍ BAKALÁŘSKÉ PRÁCE

I. OSOBNÍ A STUDIJNÍ ÚDAJE

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Zadávající katedra/ústav: **Katedra ekonomiky, manažerství a humanitních věd**

Studijní program: **Electrical Engineering and Computer Science**

II. ÚDAJE K BAKALÁŘSKÉ PRÁCI

Název bakalářské práce:

Wind Energy in Izmir - How to Face the Extra Demand Caused by the Population Increase?

Název bakalářské práce anglicky:

Wind Energy in Izmir - How to Face the Extra Demand Caused by the Population Increase?

Pokyny pro vypracování:

1. Electricity production and consumption in Izmir (Turkey)
2. Wind production in Izmir
3. Propose of the installations of new wind capacity
4. Technical and economical evaluation of the solution and results discussion

Seznam doporučené literatury:

BREALEY, R., MYERS, S., ALLEN, F. Principles of Corporate Finance, 12th ed. McGraw-Hill, 2016. ISBN:9781259253331

Jméno a pracoviště vedoucí(ho) bakalářské práce:

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Datum zadání bakalářské práce: **07.02.2022** Termín odevzdání bakalářské práce: **20.05.2022**

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III. PŘEVZETÍ ZADÁNÍ

Student bere na vědomí, že je povinen vypracovat bakalářskou práci samostatně, bez cizí pomoci, s výjimkou poskytnutých konzultací. Seznam použité literatury, jiných pramenů a jmen konzultantů je třeba uvést v bakalářské práci.

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Datum převzetí zadání	Podpis studenta

Declaration:

I hereby declare that this Bachelor’s Thesis is the product of my independent work and that I have clearly stated all information sources used in this thesis according to methodological instructions on maintaining ethical principles when working on a university final project in CTU Prague.

Prague, May 2022

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Atahan AYHAN

Acknowledgments

I would like to express my gratitude to the people who helped me in my effort in writing this thesis. With the help from their side, it was possible for me to understand the path I had to take while writing the chapters below. I am also extremely grateful for without them I wouldn't have been able to find a very important source which I used for the final and most important part of my thesis; it greatly reduced the stress of finding relative information online.

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I am thankful to all the people who were there when I was in need. Without their support I would've had harder time finishing my work.

Abstract:

This thesis was written to fulfill the extra demand for electricity which will be caused by the population rise in Izmir in the next 10 years with wind energy. The thesis includes assumptions on how much electricity do we need for two scenarios where one is the least amount of population rise and the second is the highest amount of population rise expected, information on wind energy production in Turkey and Izmir, and technical and economical evaluations which include the needed amount of turbines and the investment for both scenarios of population change.

Keywords: renewable energy, Izmir, Turkey, wind energy, wind, renewable.

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Chapter 1: Motivation

As a person who was born in Turkey and have interest in the mechanism of the country, I always wanted to contribute with something to my homeland. Throughout my life I have watched so many news, read so many articles and had too many discussion and debates to come to this point where I knew what exactly are the missing things and how it can be fixed by using the great potentials of the land I am living in. There were many more options to take but as an Electrical Engineering and Computer Science student, whose main field is Power Engineering, this topic would be the one that I would be the most capable of. I believe Turkey has been under the influence of foreign sources for so long because it is not able to fulfill its electricity demand with it’s domestic production. Turkey had to use so much non-renewable sources, which it had to buy from other countries, to produce electricity and it harmed the economy and the nature of the country considerably. For these reasons, which I see as important problems, I felt the need to write a thesis which I believe would be efficient in fighting against the constantly rising electricity demand and with that, the constant stress of finding an alternative which would also keep the environment clean.

One of the most important parts of this thesis is the source we are using for the electricity generation, which in this case is wind. As the thesis focuses on electricity generation in Izmir I wanted choose the best option in Izmir and in the further chapters I explained why the best option would be wind in the geography of Izmir. Not only it is the best option for power production but it is also the most green choice in Izmir compared to other options.

The reason I chose Izmir for this thesis isn’t only becacuse wind has a great potential for power production in the region but also because it is the city I was born in and know very well. As someone who was born there and spent his life there until university I know the people, the weather conditions, the land, and the potentials it has for businesses in power industry and relative industries. In the future chapters I explained more details about the population of Izmir, the geography of Izmir and the economical state of Izmir. People of Izmir would not only be happy to see such environmentally friendly actions by the government but they would also have the opportunity to work in the jobs that will be provided when the plan is being put into action, for a big part of the young population is unemployed and well educated. Another reason of me choosing Izmir as the location for this plan is because of my personal affinity to it, so I would like to see Izmir develop and become a better version of itself.

Hopefully this thesis of mine will be useful for fulfilling the electricity demand which will occur with the rising population in Izmir while being as environmentally friendly as possible and will benefit the region both economically and socially.

Chapter 2: How Much Electricity Do We Need

2.1 Electricity Consumption in Izmir

Izmir, as third largest city in Turkey, has high electricity consumption. This value of electricity consumption went up to 19,24TWh(19.241.946MWh) in 2016. This was caused by the population and the industry together. Izmir, has a port located in it's centre also, so the upkeep needs of the port also consumes a considerable amount of electricity. The population of Izmir in 2016 was 4.223.545 people, compared to other cities Izmir again occupies the location of the third between Ankara and Bursa, and this information stands in 2022 also. With electricity consumption of 4.556kWh per person in 2016, 1.659kWh more than the average of Turkey in 2016, Izmir, again, stays at the top at electricity consumption ranking. The electricity consumption per person for industry was 2.527kWh and per household was 978kWh at the time. Both are way higher values than the average values for Turkey.[1]

The consumption of electricity in total and per person in Turkey has increased drastically since the beginning of 2000s. So in Izmir, as one of the largest cities with an alive day and night life, with industries and trade non-stop working, this change is even greater. With more technology available to many people and heating getting more depended on electricity than coal or wood, it is very natural to see an increase in the demand of electricity. Turkey, especially, faced the greatest change since then. The total consumption of electricity in Turkey in 2000 was 104.52TWh, this increased to 273.55TWh in 2020. [2]

For comparison there is a chart below which shows the difference in total electricity consumption between 2002 and 2020 in Czech Republic and Turkey.

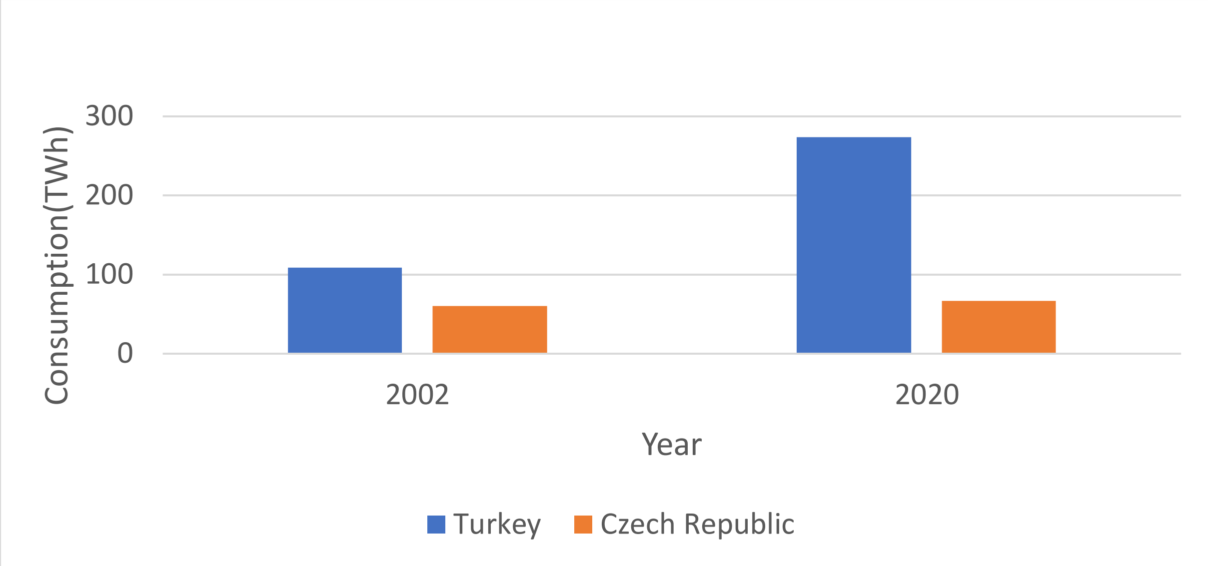

Figure.1 Difference in consumption change between 2002-2020 for Czech Republic and Turkey.[2][3]

Czech Republic's whole consumption was 60.1TWh in 2002 and this value went up to 66.99TWh in 2020. The consumption rised about %10 for Czech Republic where for Turkey the new consumption is more than two times of the previous value. This ratio is rare to find in the world in this interval of time.[3]

Turkey was able to deliver its people the electricity they demanded in this time thanks to the investments of the private sector into the field and with some government touch. The increase in private sector was huge at the ends of the 20th and the beginnings of the 21th century. In the graph below we can see the change in the percentage of state and private sector influence on the power generation.

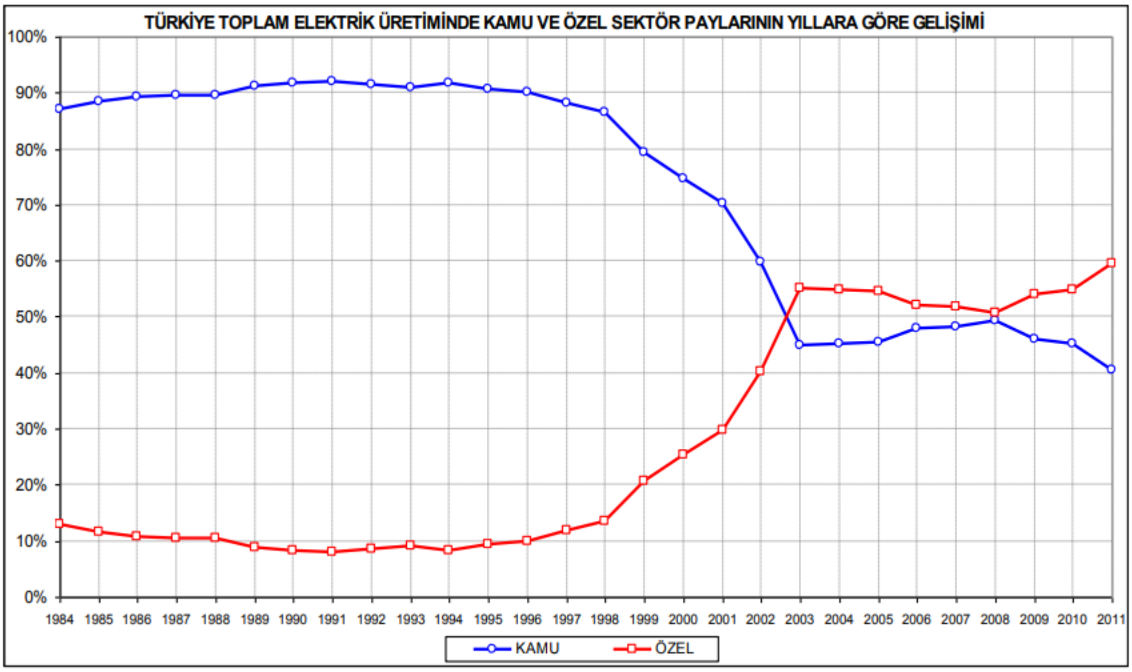

Figure.2 Change in the percentage of power generation in Turkey for the state and the private sector. (Red being the private sector and blue being the state.)[4]

Turkey in 2020, produced %56.4 of its electricity by domestic sources. Turkey has been keeping the ratio around %50 since 2002. Unfortunately, this percentage cost Turkey a lot of money since then, for it lost money to non-domestic sources and imported electricity from other countries such as Bulgaria and Georgia.[5]

Below there is a table which shows the percentage of domestic source for power generation per years, also with the information on how much power was generated and how much was imported and exported.

Year	Production	Import	Export	Domestic Part
2010	211,207.7	1,143.8	1,917.6	%45.6
2011	229,395.1	4,555.8	3,644.6	%44.3
2012	239,496.8	5,826.7	2,953.6	%43.5
2013	240,154.0	7,429.4	1,226.7	%43.2
2014	251,962.8	7,953.3	2,696.0	%37.4
2015	261,783.3	7,135.5	3,194.5	%46.0
2016	274,407.7	6,330.3	1,451.7	%49.4
2017	297,277.5	2,728.3	3,303.7	%45.2
2018	304,801.9	2,476.9	3,111.9	%48.9

2019	303,897.6	2,211.5	2,788.7	%61.2
2020	306,703.1	1,889.5	2,483.6	%56.4

Tabe.1 Table of values for power generation industry in Turkey. [5]

In between 2013 and 2017 Turkey lost about 213 billion dollars on energy because of high import. The production rate was increased after that but it didn't fix the situation much, for Turkey is still buying a large portion of electricity from outside sources. In the first months of 2022, this and other reasons, made Turkish people unable to pay the electricity bills. Other reasons than low production levels are mostly economic reasons. Because of the unstable state of the Turkish Lira, buying energy sources or buying electricity directly from neighbouring countries became difficult for Turkey and so it had to increase the electricity bills with natural gas prices also. [6][7]

For a lot of reasons, Turkey should be producing more of its electricity and Izmir is a good place to invest into. Not only Izmir is a good place to invest into but it also requires the investments for the population of Izmir is rising with a very high demand for electricity. To be able to face this new demand that will occur in time, 10 years in our case, Izmir's own potential should be used to face its own demand and also the rising demand of the rest of Turkey. In our case we will only focus on Izmir's possible demand.

2.2 Projection of Future Population

To be able to do this we should be able to assume the population in 2032. It is not possible to hit the bull's-eye when it comes to finding the population so there will be two assumptions. We will use the population growth we have now and assume the trend of the increase or decrease in the growth will be alike in this 10 year future, so we will have a decreasing or increasing slope or we will use the last population growth value we have for 2021, which is the time that the last official calculations were made, and we will have a graph which goes steady and increases or decreases linearly depending on the value we have. [8]

Population calculation can be done with an equation which consists the growth rate, base population(the population at the start of the calculation), time which we would like to calculate for and and exponential[9];

- $P_T = P_0 e^{k\Delta t}$
- P_T: The population after the timeline.
- k: Growth rate.
- Δt: Timeline we would like to calculate for.

With this equation I found these values for every each of the years I mentioned below;

Initial Population(Population of 2021): 4,425,789

Total Time: 11 years

Growth Rate: %0.71

For the linear change with %0.71 the values are;

Year	Population
2022	4,457,324
2023	4,489,083
2024	4,521,069
2025	4,553,283
2026	4,585,726
2027	4,618,400
2028	4,651,307
2029	4,684,450
2030	4,717,828
2031	4,751,444
2032	4,785,299

Table.2 Table of population projection per year for linear growth.

The non-linear change of the population growth can be found by finding the trend of the values from 2013 to 2021. From the calculation I made I found the population numbers as;

Year	Population
2022	4,454,650
2023	4,479,666
2024	4,500,320
2025	4,517,002

2026	4,529,668
2027	4,538,055
2028	4,542,141
2029	4,541,960
2030	4,537,873
2031	4,529,713
2032	4,517,047

Table.3 Table of population projection per year for exponential change.

The values in hand are easier to see on a graph which consist beginning as 2019 and end as 2032 with both scenarios.

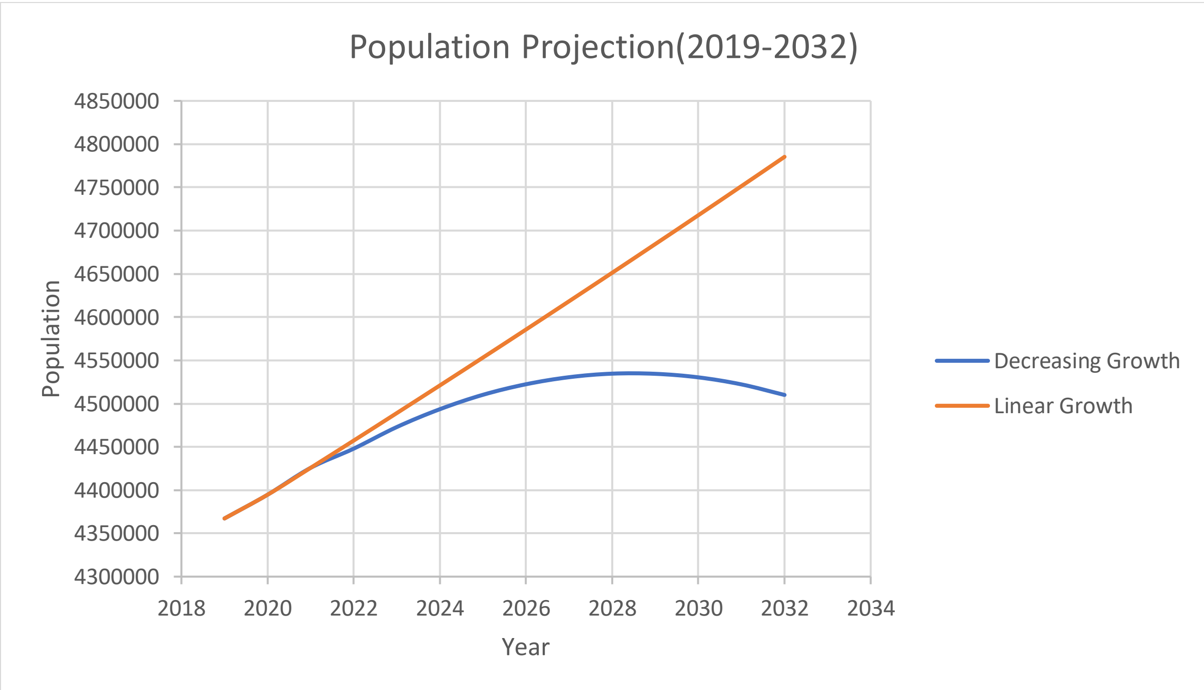

Figure.3 The graph of population projection with decreasing and linear growth.

The beginning was taken as 2019 to get a better view at the whole situation. The migration effects are taken into account in the growth rate.

2.3 Projection of Future Demand

From the projection graph we can see that there is a big gap between the lowest and highest points, which we will call the lowest and highest population expected after now. These values will help us to calculate the least and highest amount of extra electricity needed for our new population. For these calculations we will use a simple equation;

- [(Expected Population of 2032) – (Population of 2016)]×(Electricity Consumption per Person)

Which will be equal to the extra electricity needed at the end.

We will start with calculating the amount needed for the highest expected population, **4,785,299**;

- $(4{,}785{,}299 - 4{,}223{,}545) \times 4{,}556kWh = 2{,}559{,}351{,}224kWh$ - Yearly

To make it easier to use in the future, for we will use MW mostly, we will divide this number by 1000. So we get 2,559,351MWh for the highest expected population.

Now we will calculate the value for the lowest expected population;

- $(4{,}517{,}047 - 4{,}223{,}545) \times 4{,}556kWh = 1{,}337{,}195{,}112kWh$ - Yearly

We will divide this number by 1000 to turn it into MW. We get 1,337,195MWh for the lowest expected population.

- **Highest Amount of Extra Electricity Needed: 2,559,351MWh** – In the year 2032.
- **Least Amount of Extra Electricity Needed: 1,337,195MWh** – In the year 2032.

So in the we have two values which are probable for Izmir's new demand that will occur in 2032. It is important to understand if these values can be achieved or not and we will do a simple calculation for that also.

Ideally, the situation would be where the wind is always blowing, the machines are not broken or damaged in any way and the grid is in fine condition. This is realisticly not the case but thats the reason why wind or any renewable resources cant be used as the definers of base production levels where the minimum amount of electricity needed is defined. In our case we will use the theoretical capacity, average capacity factor and hours to calculate the maximum, ideal, production in Izmir.

- Theoretical Capacity: **12,000MW**
- Time: **365×24**
- Average Capacity Factor of Izmir: **%30.4**
- (Theoretical Capacity × Time × Average Capacity Factor of Izmir)
- = 12,000×365×24×$\frac{30{,}4}{100}$= **31,956,480MWh** [10][11]

31.956.480MWh, is the value which theoretically is the highest achievable value we can get. This is, as I wrote before, is not possible. But it doesn't need to be possible for we only need a very small fraction of it. There will be location where wind turbines cannot be put or there will be days where wind doesnt blow much or there will be days where there are natural causes which damage the turbines. It is okay, for it is way below what we need.

Highest amount of extra electricity we need is **2,559,351MWh**, which is **%8.0** of our theoretical production.

Least amount of extra electricity we need is **1,337,195MWh**, which is **%4.18** of our theoretical maximum production.

From the basic calculations above we are aware of the possibility of producing the needed amount of extra electricity in future. We are left with the way of producing such amounts, the costs of it, the time needed and people's views on the matter.

Chapter 3: Wind Energy Production in Izmir

3.1 Energy Mix in Turkey

Turkey is a country with so much when it comes to renewable resources but this potential cannot be seem with the non-renenwable resources unfortunatelly. This is one of the reasons why Turkey buys about %70 of its first energy resources, which is a value that changes every year but stays about the same when put into average. As I mentioned in the previous chapter, "Energy" in general costs Turkey an important amount of money every year. There is no set value for the expenses for electricity for it changes year by year. [12]

The lack of non-renewable resources can be seen from the trade of energy resources of Turkey. Below, there is a graph for the share of resources in Turkey's power production.

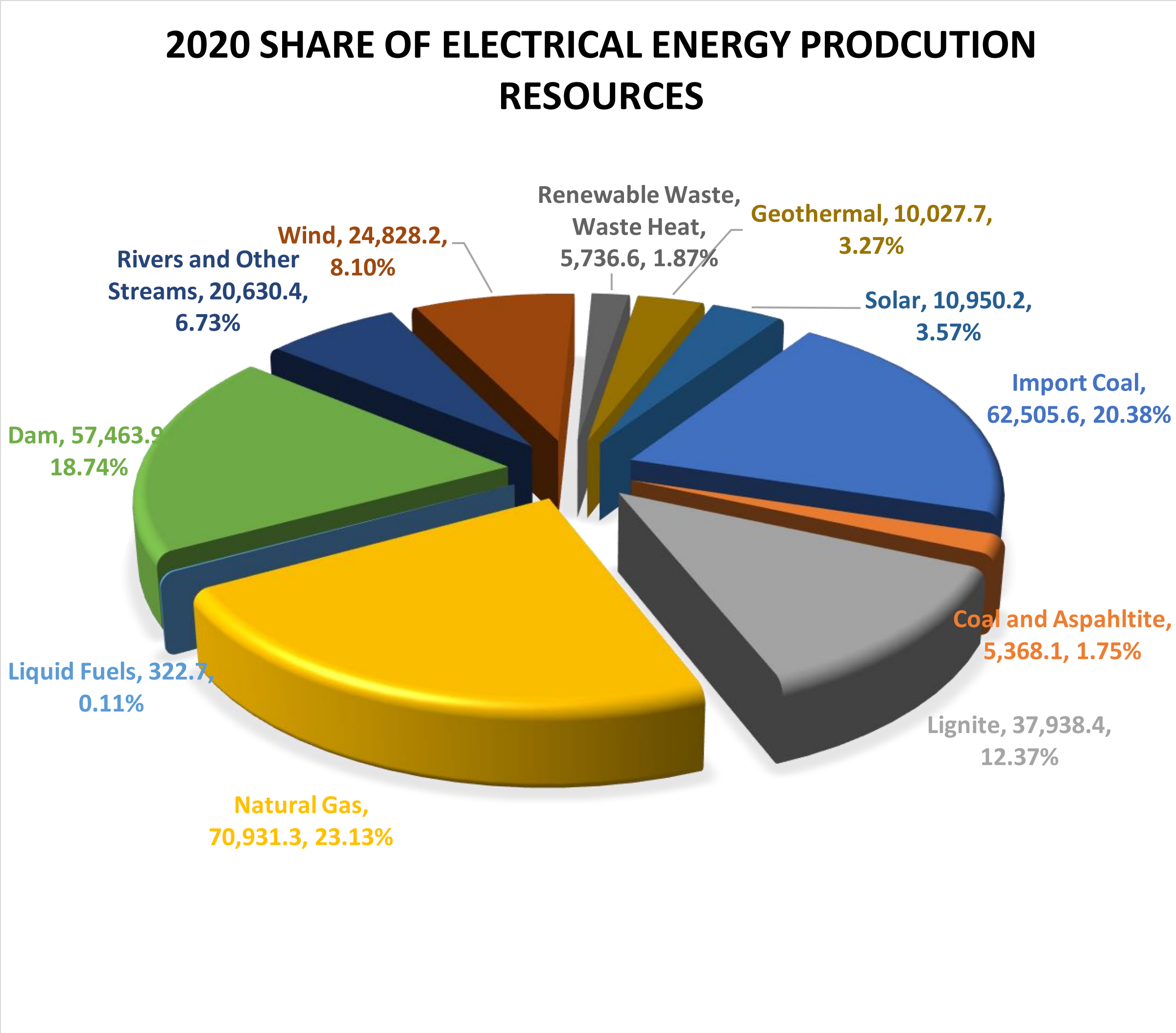

Figure.4 Turkey's share of electrical energy production resources.[13]

Source	Production (GWh)	Share (%)
Import Coal	62,505.6	20.38
Coal and Asphaltite	5,368.1	1.75
Lignite	37,938.4	12.37
Natural Gas	70,931.3	23.13
Liquid Fuels	322.7	0.11
Dam	57,463.9	18.74
Rivers and Other Streams	20,630.4	6.73
Wind	24,828.2	8.10
Renewable Waste and Heat Waste	5,736.6	1.87
Geothermal	10,027.7	3.27
Solar	10,950.2	3.57
TOTAL	**306,703.1**	**100.00**

Table.4 Turkey's share of electrical energy production resources.[13]

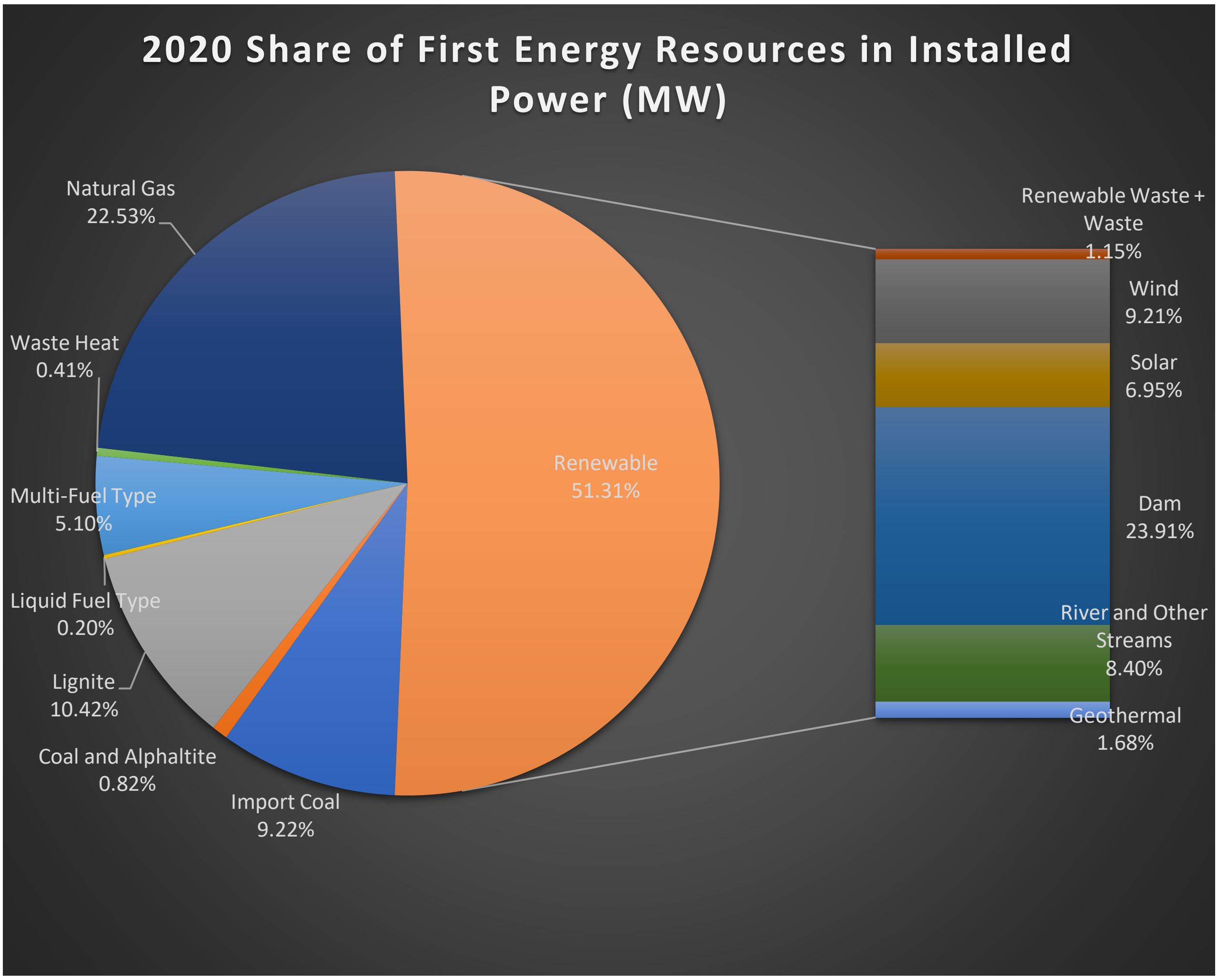

Figure.5 Shares of energy resources listed for 2020 installed power in Turkey.[14]

From the graphs above we can see that Turkey, when it comes to non-renewable resources, depends mostly on natural gas, lignite and import coal. There are many problems that come with this situation. First of all, coal and lignite are both insufficient sources of energy. Here is the proof:

We will try to produce power with a kilogram of Lignite/Brown Coal. Typically, in steam power plants, the efficiency of boilers is around 70-80%, which depends on the maintenance and how well they were built but we will go with an average. We will take **75%** as the efficiency value for our equation which we will solve below. Then for the second part we need the vapour cycle efficiency for it is an important part in steam power plants where the conversion of input heat energy into output power happens while using turbines in the process. This efficiency varies from 30-40%, we will take it as **35%**. Our overall efficiency in this case would be **26.24%**. We need the heat value now which we can take as **17.4Mj/kg** for Lignite/Brown Coal. [15][16]

We need to find the heat input needed to produce the electricity we want.

One kWh is 3,6Mj, so with 100% efficiency if we burn 1kg of coal:

- [$\frac{17.4Mj/kg}{3,6}$=4.83kWh]

But we know that our efficiency is about 26.24% so:

- [$0.2624 \times 4.83 \approx \mathbf{1.27kWh}$]

In the end, if we burn **1kg of Lignite/Brown Coal**, we know that we would get **1.27kWh**.

In comparison, from the source World Nuclear Association, heat value of Natural Gas varies between 42-55Mj/kg. Coal with highest efficiency, with about 23.9Mj/kg, is not even close to it. Small power output means greater values of the resource being used, and higher amounts of coal does nothing but worsening the situation of Earth, making global warming faster and giving the source of pollution a wider range of effect.[16]

Second problem that comes with this is that Turkey doesn't have natural gas resources, sufficient amount of them at least. Turkey, in 2020, put 441.27M Sm^3 of natural gas to sale in the market. This in number might seem a lot but compared to what is being used and to the amount there is in the neighbouring countries, it isn't much. The import on the other hand was 48,261.35M Sm^3 of natural gas. In the same year the supply was below demand for the sum of 'export' and consumption exceeded the import and production by 272.09M Sm^3. Below there is a table of values for an easier understanding.[17]

Production	Import	Domestic Sales (Consumption)	Export	Total Supply (Production + Import)	Total Demand (Domestic Sales + Export)
441.27	48,125.51	48,261.35	577.52	48,566.78	48,838.87

Table.5 Overview of the Natural Gas Market by the end of the December 2020 (Million Sm3).[17]

Below there are the countries where Turkey buys the natural gas from.

	Russia	Azerbaijan	Iran	Algeria	Nigeria	Other*	Total
2020	16,178	11,548	5,321	5,573	1,881	7,624	**48,126**

Table.6 Natural Gas Import Quantities by Source Countries (million Sm3).[17]

Clearly, Turkey is depending on other countries for its natural gas usage. This causes different problems and creates weaknesses for Turkey. Problems such as increasing bills, increasing budget for imported energy sources. With economic problems comes political problems also. As an example, it makes Turkey unable to take strong decisions against Russia and Iran.

If the weight of natural gas is lifted up from the shoulders of Turkey, by renewable resources and preferably wind, it would help Turkey with this situation it is in. Wind power can be a solution for some of the consumption sectors below.

Sectors	2019	2020
Conversion / Cycle Sector	11,258.00	13,645.29
Energy Sector	1,986.82	1,641.41
Transportation Sector	411.06	257.89
Industry Sector	12,424.04	12,697.67
Service Sector	4,606.06	4,288.43
Household	14,396.42	15,613.23
Other Sectors	203.10	117.43
Total	**45,285.50**	**48,261.35**

Table.7 Natural Gas Consumption by Sectors (million Sm3).[17]

As it can be seen from the table above most of the consumption is being done by households and industry. Renewable energy can help Turkey face some of it. Here is an example.

Let's take transportation sector as an example, to see what is possible and what is not.

Transportation Sector in 2020 used **257.89** $\boldsymbol{Sm^3}$ natural gas. We are able to convert this into megajoules, thanks to U.S. Energy Information Administration (EIA), we can do this automatically by using their website. [17][18]

- 257.89 Sm^3 = **9,970,227,879.859 MJ**

To turn MJ into MWh, we will use a simple calculation. We know that **1MJ=0.0002777778MWh** or 1MWh = 3600MJ.

- 9,970,227,879.859×0,0002777778MWh=**2,769,507.74MWh –** Year.

To understand if this is possible or not, we should take this value and put it into MW only. So, we will divide the number by 365×24 to see how many wind turbines or solar panels would it take to face this consumption.

- $\frac{2,769,507.74}{365\times 24}$=316MW

With the theoretical capacity we have only in Izmir, we can cover the natural gas usage of transportation sector of the nation.

3.2 Price of Electricity for Final Consumers

The lack of non-renewable, efficient resources like natural gas, also rises up the prices of electricity bills for many people. With every other day, with increasing population, the demand for electricity rises and Turkey, to provide electricity for this new population, buys more energy sources and while buying the energy sources it also buys electricity directly and so increases the taxes and bills for this reason.

Years	Production(GWh)	Import(GWh)	Export(GWh)	Demand(GWh)
2010	211,207.7	1,143.8	1,917.6	210,434.0
2011	229,395.1	4,555.8	3,644.6	230,306.3
2012	239,496.8	5,826.7	2,953.6	242,369.9
2013	240,154.0	7,429.4	1,226.7	246,356.6
2014	251,962.8	7,953.3	2,696.0	257,220.1
2015	261,783.3	7,135.5	3,194.5	265,724.4
2016	274,407.7	6,330.3	1,451.7	279,286.4
2017	297,277.5	2,728.3	3,303.7	296,702.1
2018	304,801.9	2,476.9	3,111.9	304,166.9
2019	303,897.6	2,211.5	2,788.7	303,320.4
2020	306,703.1	1,889.5	2,483.6	306,109.0

Table.8 Table of values for electricity production, import, export and demand through years.[19]

We can see that Turkey also rised up its power production but unfortunately, as it was mentioned in the previous part, a big portion of this production is with first energy sources that were bought from other countries. Which means that Turkey, by decreasing the import of electricity, still couldn't get out of the dependent state of its power industry. [19]

This problem also became worse because of the situation of the currency, Turkish Lira. With the value of Turkish Lira dropping, buying resources and electricity from outside became even more expensive. This situation might not occur all the time, Turkish Lira might increase in value in future, but in the last 20 years of Turkish Republic it has only been dropping, Turkey must be ready for this and become more independent in producing its own electricity. Using its own sources and choosing renewable over non-renewable for the lands of Turkey, Anatolia and Thrace, are lands with geography full of renewable energy potentials like solar, hydro, bio and most importantly, wind. [20]

Below there is a graph about the value of Turkish Lira in US Dollar through the years between 1997-2022 for a better understanding.

Figure.6 Value of Turkish Lira in US Dollar between 1997-2022.[20]

The graph alone tells enough about the problem that Turkey faces, now below, there are tables of values on the increase of active usage prices and distribution prices of electricity for industry, businesses and households.

Industry	1.Quarter	2.Quarter	3.Quarter	4.Quarter	1.Period	2.Period	Total
2011				200.12		200.12	200.12
2012	201.16	218.55	218.55	227.31	209.85	222.93	216.39
2013	227.31	227.31	227.31	227.31	227.31	227.31	227.31
2014	227.31	228.36	228.36	248.53	227.84	238.45	233.14
2015	248.53	248.53	248.53	248.53	248.53	248.53	248.53
2016	260.17	260.17	260.17	260.17	260.17	260.17	260.17
2017	260.17	260.17	260.17	260.17	260.17	260.17	260.17
2018	283.09	291.01	354.82	447.59	287.05	401.2	344.13
2019	447.79	447.95	515.02	591.72	447.87	553.37	500.62
2020	591.93	591.89	591.84	625.67	591.91	608.71	600.31
2021	665.02	665.02	764.62	764.62	665.02	764.62	714.82
2022	1729.01				1729.01		1729.01

Table.9 Table of electricity prices for Industry in Turkey in Turkish Lira in quarter base from 2011 to the first quarter of 2022.[21]

Businesses	1.Quarter	2.Quarter	3.Quarter	4.Quarter	1.Period	2.Period	Total
2011				249.32		249.32	249.32
2012	250.35	264.58	264.58	285.59	257.47	275.09	266.28
2013	285.59	285.59	285.59	285.59	285.59	285.59	285.59
2014	285.59	287.09	287.09	313.86	286.34	300.47	293.41
2015	313.86	313.86	313.86	313.86	313.86	313.86	313.86
2016	316.59	334.76	316.58	316.58	325.67	316.58	321.13
2017	316.58	316.58	316.58	316.58	316.58	316.58	316.58
2018	344.1	353.99	430.65	541.14	349.05	485.89	417.47
2019	542.47	543.56	624.26	717.1	543.01	670.68	606.85
2020	718.5	718.2	717.87	757.82	718.35	737.51	727.93
2021	806.29	806.35	926.12	926.12	806.32	926.12	866.22
2022	2113.26				2113.26		2113.26

Table.10 Table of electricity prices for Businesses in Turkey in Turkish Lira in quarter base from 2011 to the first quarter of 2022.[21]

Households	1.Quarter	2.Quarter	3.Quarter	4.Quarter	1.Period	2.Period	Total
2011	215.55	215.55	215.55	236.3	215.55	225.93	220.74
2012	237.34	258.86	258.86	283.86	248.1	271.36	259.73
2013	283.86	283.86	283.86	283.86	283.86	283.86	283.86
2014	283.86	284.86	284.86	310.48	284.36	297.67	291.02
2015	310.48	310.49	310.49	310.49	310.48	310.49	310.48
2016	331.84	331.83	331.83	331.83	331.83	331.83	331.83
2017	331.83	331.83	331.83	331.83	331.83	331.83	331.83
2018	361.37	371.25	422.37	478.5	366.31	450.44	408.37
2019	433.19	434.45	498.65	572.75	433.82	535.7	484.76
2020	574.39	574.03	573.65	605.08	574.21	588.98	581.59
2021	644.07	644.14	739.37	739.37	644.11	739.37	691.74
2022	1678.31				1678.31		1678.31

Table.11 Table of electricity prices for Households in Turkey in Turkish Lira in quarter base from 2011 to the first quarter of 2022.[21]

Below there is a graph for understanding the relation between the value of Turkish Lira in US Dollar and electricity prices per year.

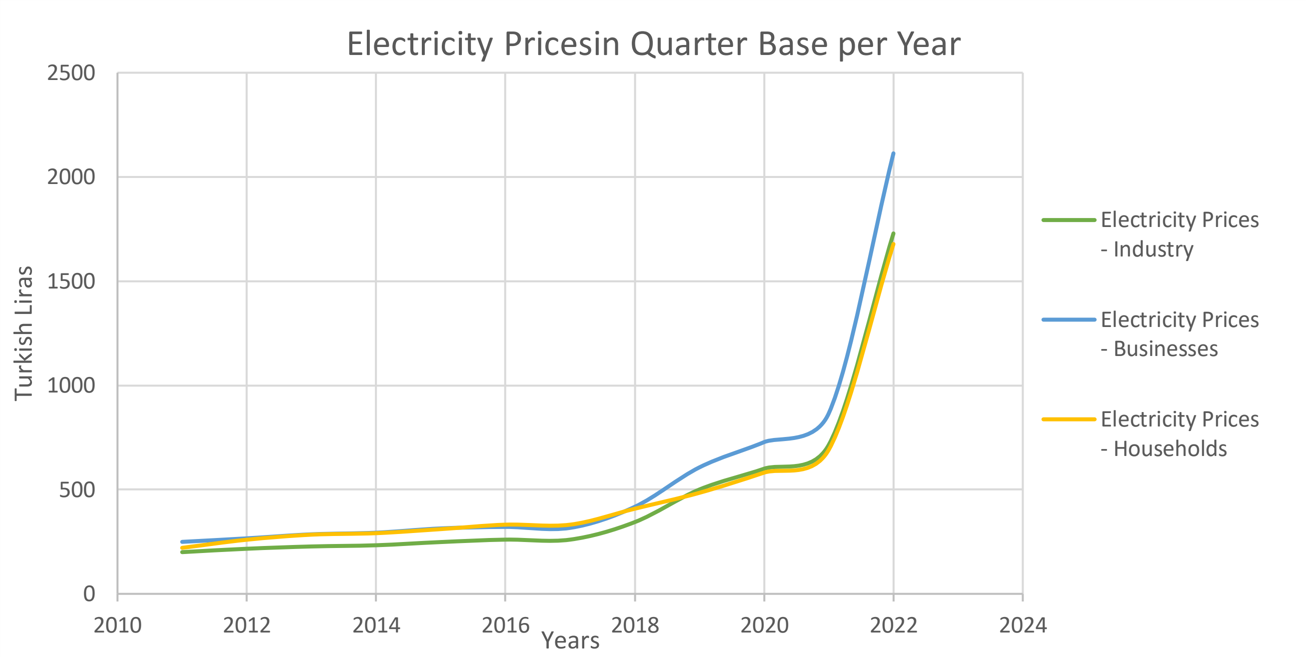

Figure.7 Combination of graphs of increase in electricity prices in Turkey.

The relation between the increase of electricity prices in the last two years and the value of the currency in the last two years can be seen clearly.

Despite the increase in the prices, for EU standards Turkey seems to cheaper than many countries in Europe. For the Euro Area, the average price for one kWh of electricity for a household was 0.2322 EUR. The highest price was in Germany with 0.3193 EUR per kWh. This value seems to be **0.0834 EUR** for Turkey but unfortunatelly Turkish people don't earn EUR, they earn TRY. Purchasing power of Turkish people didn't rise accordingly to the currency and inflation through years, so with every other increase in prices life becomes harder for many. Currenttly, in **08.03.2022 01:29PM GMT**, when we turn this eur price into try price we get **1.3219 TRY per kWh**. [22][23]

In Turkey, a big portion of the population works in minimum wage. The percentage of people who have to get through their lives with minimum wage or less than minimum wage in Turkey covers **33.8%** of the whole working population. Net minimum wage in Turkey, in 08.03.2022, is **4,250.40 TRY**. When it is converted into EUR with the value at **08.03.2022 01:29PM GMT,** we get the number **268.16 EUR**. Because we are comparing it to Germany, let us compare the minimum wage of Germany with Turkey's.[24][25]

- Net minimum wage in Germany is **1,621 EUR** per month.
- $\frac{1.621}{268,16} = \mathbf{6.04}$

The ratio between the net minimum wages of Germany and Turkey is 6.04 but the ratio between the prices of electricity per kWh is;

- $\frac{0,3193}{0,0834} = \mathbf{3.83}$

From the ratio above we can say that, for the people who live in Turkey, electricity is more expensive than it is for people who live in Germany.

If Turkey doesn't take action in becoming more independent in producing its own electricity soon, with increasing population, it will be harder and more expensive to deliver electricity to the people of the nation. This will hard especially for the large cities of Turkey where the usage of electricity is higher than usual. One of the examples is Izmir.

In Izmir the usage of electricity per person for a household was 978 kWh, while the average in Turkey was 642 kWh. The usage in total in 2016 was 19,241,946MWh, while the total in Turkey was 231,203,746MWh. This makes 8.32% of the whole country, with 81 cities and 84,680,273 people. The middle and upper class people in Izmir are also a big portion of the population of Izmir, the city is one of the most modern cities of Turkey if not the most modern one. People enjoy doing different activities at nights and throughout the day, and when it is Summer, between June and September, the temperatures of the months go between 34°C, in July and Agusut, to 17°C in September. In Summer, average highest temperature is about 35°C and the lowest is about 22°C. So the electricity usage increases with air conditioners and fans being opened.[1][26][27]

This situation is actually relevant for the whole country but the difference is greater in Izmir because of the geography. Below there is a table of electricity prices in try for households in 2021 for every month.

Month/ Year	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
2021	331.83	331.83	331.83	644.14	644.14	644.14	739.37	739.37	739.37	739.37	739.37	739.37

Table.12 Table of electricity prices in Turkish Lira for households.[21]

People's respond to this matter is not in the favour of the country. In the first quarter of 2022, Turkish opposition, with some public involvement, protested this situation by "Not paying the bills." Whether they did it or not doesn't matter, what matters is that people came to the point that they are willing to not pay or cannot pay in general. In the first months of 2022, there has been a good amount people who weren't able to pay and so their electricity was cut.[28][29]

Finally, with the information we have on the prices of electricity in Turkey, we can say that the prices are rising, not only because of the situation of the Turkish economy but also because of the dependency of electricity production on foreign sources.

3.3 Wind Potential in Izmir

In the previous parts we discussed the situation of electricity prices and their development thorugh time and also the share of resources in electricity production and the installed power. In conclusion from them, we decided that Turkey has to become more independent in power industry. This can be achieved with Turkey's natural resources, from these resources we should choose the renewable resources over non-renewable for, as we mentioned in the previous parts, Turkey's non-renewable resources are not enough and most importantly, non-renewable resources are a big threat to our future world. So in this case, we should talk about the potentials of wind on Turkish land then specificly, Izmir. But before talking about the potential of wind energy we should first explain what wind energy is.

Wind energy is the process where the wind creates mechanical energy or electricity through its movement. This energy can be produced by wind turbines where the rotating blades which are connected to a rotor spin the rotor with wind, the rotor then turns the shaft and the gearbox, if it is not connected directly to the generator, then the generator which is connected to the gearbox rotates and generates electricity. The size of this generated electricity can vary due to wind speed, the density of the air and the area that the blades cover which is called the swept area of the turbine. With increasing density, increasing wind speed, or increasing the radius of the rotor, the generated power can be enlarged. Below, is the equation to calculate the power output of a turbine.[30]

- $P = kC\rho\frac{A}{2}v^3, (A = \pi r^2)$

Where k is a constant to yield power in kilowatts, C is the coefficient of performance, ρ is the air density, v is the velocity of the wind, A is the swept area and r is the radius of the rotor.[31]

Wind energy is one of the most environmentally friendly options out there for generating electricity when it comes to renewable resources. A research that was made in 2017 by the Energy Institute of University of Texas at Austin states that grams of CO2 per kilowatt of electricity generated for wind goes up to 14 grams while this number goes up to 48 grams for solar energy, the solar energy also has its other problems like unavailability of sun throughout the night or a cloudy or a rainy day. With very limited battery technology we have right now it is really not efficient to use solar panels for huge electricity generation purposes, Solar panels may be used for singular buildings, households or offices, and in greater numbers sometimes for factories even, like the Gigafactory of Tesla in Nevada in US but this needs way larger investment and it is very expensive to maintain. For hydro energy this number goes down until 12 grams per kWh.

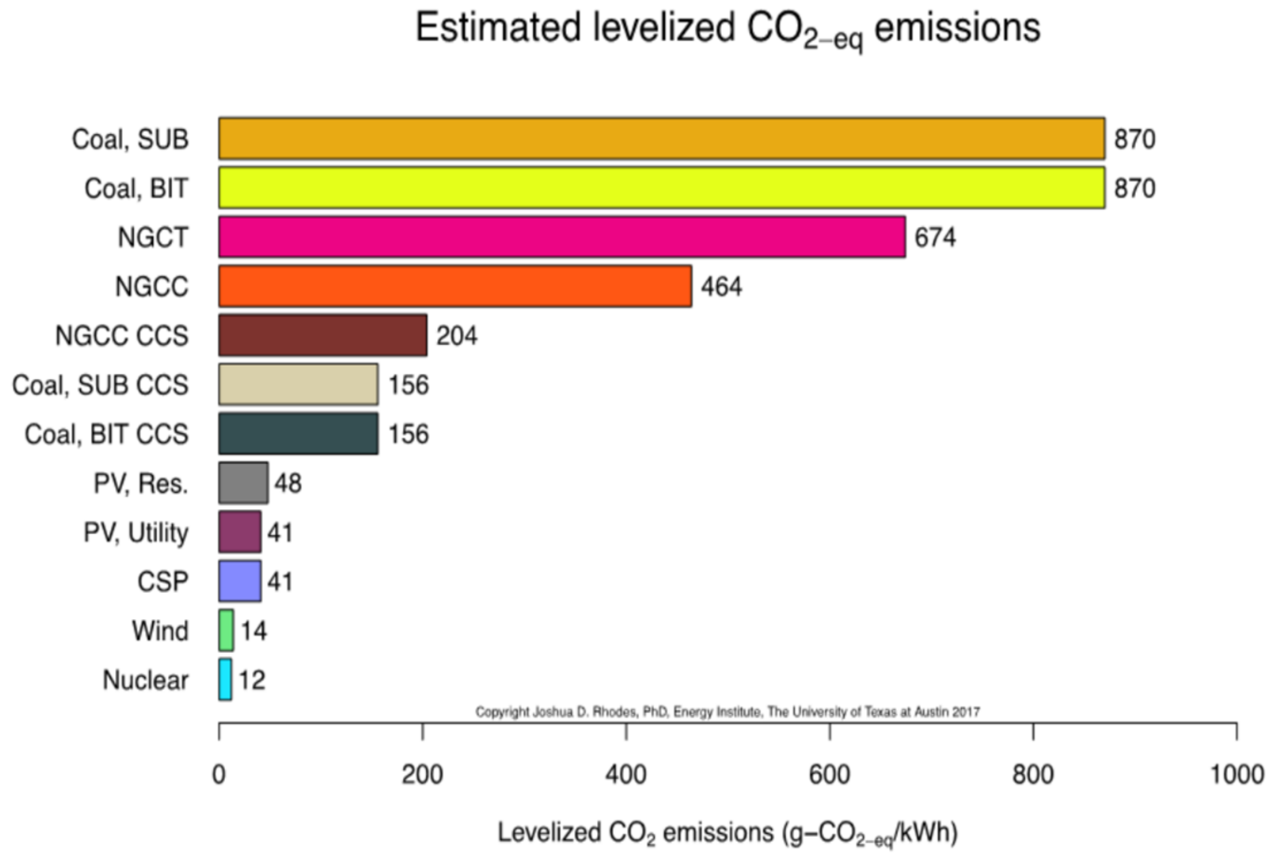

Figure.8 Graph for comparing the CO2 emissions per kWh for each of the resources given above.[32]

Unfortunately hydro plants in Izmir wouldn’t be the most efficient source of power for there isn’t much active water source in Izmir. There is the very important Gediz River but the river is not large in size and is very shallow. [33]

Figure.9 Picture of the Gediz River from an article from the news channel CNN Turk.[34][35]

Wind in this case is very available and is very green compared to its substitute, solar energy. In Izmir there is always wind, an effect of being a coastal city in the Aegean region, it is not too expensive compared to other options when the amount of electricity it generates and its reliability taken into account. Wind is seemingly the best option of renewable energy for Turkish Power Industry and Izmir.[36]

It is a must to pull more investors and put more attention into the renewable energy sector. This would save Turkey so much money and it would also help the development of industries related to power generation, production of power plant parts and power distribution which would also help the development of the region that the investments are being put into. Turkey has regions where this kind of an industry can be established. Marmara, Mediterranean and the South-eastern Anatolian regions have good potentials when it comes to this but none of them offer what Aegean can.[37][38]

Region	Average wind speed per year (m/s)	Average wind density per year (W/m^2)
Marmara Region	3.29	51.91
Aegean Region	2.65	23.47
Mediterranean Region	2.45	21.36
Inner Anatolian Region	2.46	20.14
Blacks Sea Region	2.38	21.31
Eastern Anatolian Region	2.12	13.19
South-eastern Anatolian Region	2.69	29.33

Table.13 Table of values for average wind speed and density per region. [38]

This region should specifically be the Aegean region with its perfect geographical conditions, its cities which are full of different possibilities of investment calling for investors and its core city, Izmir.

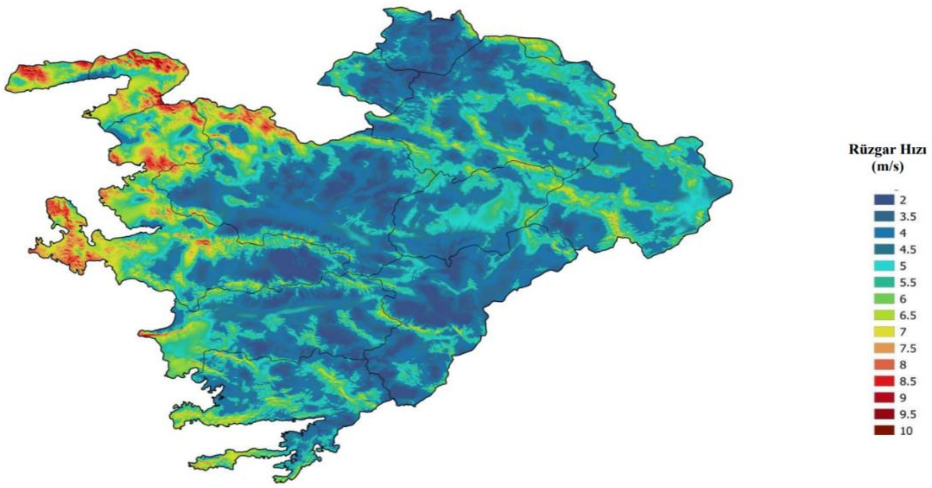

Figure.10 Map of wind speed in the Aegean region of Turkey. [38]

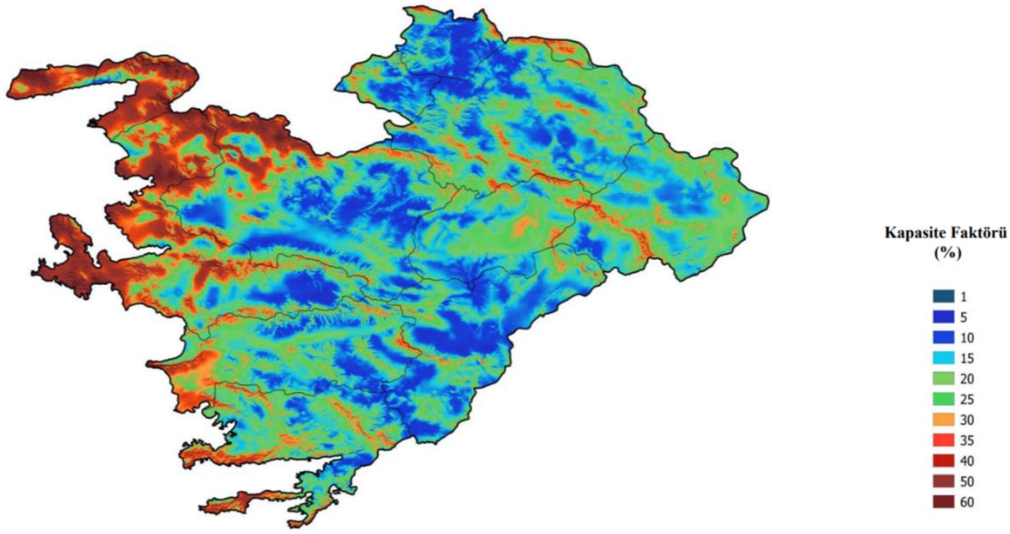

Figure.11 Map of capacity factor of the Aegean region which was made by taking a 3MW turbines technical information into account.[38]

Izmir, with 4,4 million, is the third biggest city in Turkey located in the west of Turkey in the Aegean region. It is a developed city with many industries settled in compared to many other cities in the country with a GDP equal to 263.04M₺ as measured in 2018. Izmir is a city that is pulling more investors for the last couple of years, for Istanbul had become an arena of investors and big companies, so small and new business are having hard times settling in and growing. Izmir has also been getting immigrants from other cities of Turkey, immigrants who are mostly educated and have decent economic conditions. With more investors, businesses and people in general coming into Izmir, the city will grow its size and economy, by doing so more industrial areas and offices will also be built and as the result of these the electricity demand will rise exponentially.[39][40]

Years	Immigration	Emigration	Net Immigration
2014	124.439	101447	22.992
2015	126.238	105.389	20.849
2016	122.668	98.902	23.776
2017	127.394	102.776	24.618
2018	130.032	117.113	12.979

Table.14 A table of values of immigration and emigration for Izmir.[40]

Izmir, unlike Ankara and Istanbul, which are the two biggest cities of Turkey, had positive immigration velocity in 2018, %3,0. Ankara and Istanbul had %-6,7 and %-13,8 respectively.[40]

Izmir can face this electricity demand with its huge renewable energy potential, especially with the wind power. In the Aegean region the already operating wind power plants take up to 3.511MW installed power, 1.798,15MW of this installed power is in Izmir. Taking the whole installed power of the country from 2020 into account, 9.305MW, Izmir gets the first place in the whole country. Even if the installed power of Izmir is the highest in the country, Izmir has much more potential than this, the theoretical capacity was measured as 12.000MW in 2020 which makes about one fourth of the whole theoretical capacity of wind power of the country. With more investment into the city, Izmir can easily produce enough electricity for itself and the region. This would also help the development process of the other cities in the region.[10][41]

According to the measures that are published in Invest in Izmir website until 2023, around $3 Billion wind energy power plant market and more than $18 Billion wind energy equipment market can be managed from Izmir, which is just an estimation with the current measures.[10]

Chapter 4: Technical and Economical Evaluations

4.1 Organizations

To talk about the economic evaluations and the process of investments and constructing a wind turbine we must first know the organizations of which are responsible in this field. Some of these organizations are govermental and some of them are private. Here are the names of the organizations[42]:

1- TEDAŞ: The organization that is responsible for distribution.
2- TEİAŞ: The organization that is responsible for transmission.
3- ENERJİ VE TABİİ KAYNAKLAR BAKANLIĞI: Ministry of Energy and Natural Resources of Turkish Republic. (MENR)
4- METEOROLOJİ GENEL MÜDÜRLÜĞÜ: General Directorate of Meteorology
5- GEDİZ EDAŞ: The organization that is responsible of distribution and sales in the region.
6- EPDK: Energy Market Regulatory Authority (EMRA)

TEDAŞ

Turkey Electricity Distribution Inc. (TEDAŞ), is a state economic enterprise that is responsible for distribution and retail sales of electricity. In 02.04.2004 it was put in the privatization program, the 21 distribution regions in Turkey was set afterwards, and in 13.08.2013 share transfer agreements between TEDAŞ and the companies were completed.[43]

TEİAŞ

The organization is responsible of developing the electricity transmission infastructure, building new transmission lines, making Turkish Electrical System reach the international standards in an economical and high quality way.[44]

Ministry of Energy and Natural Resources

The reason behind the existence of this Ministry is to help determine the targets and policies related to energy and natural resources in line with the defense, security and welfare of the country, the development and strengthening of the national economy, and to ensure that energy and natural resources are researched, developed, produced and consumed in accordance with these goals and policies. Legislative amendments related to renewable energy are carried out by the Ministry.[45]

General Directorate of Meteorology

Measurement station installation permits of wind power plants are given by the General Directorate of Meteorology.[46]

GEDİZ EDAŞ

Operating in the 11th distribution region, Gediz Elektrik Dağıtım A.Ş. (GEDİZ EDAŞ) provides electricity retail sales services to the cities of İzmir and Manisa.[47]

EMRA

Energy Market Regulatory Authority, makes the energy market a strong, transparent and competitive market and maintains these conditions; fulfills the duties of regulation and supervision regarding the energy market in order to present the electricity and energy resources to the consumers in the most appropriate way in terms of quality, quantity, price and environmental compatibility.[48]

4.2 Process of Getting a License

Now that the organizations are known we can see the process of taking the installation license.

1- Establishment of a company for the purpose of electricity generation in accordance with the Turkish Commercial Code.
2- Obtaining the right of use for the place where wind measurement stations will be installed, depending on the facility type, in the area where the project will be developed by the company.
3- Establishment of wind measurement stations.
4- Approval of the „Measurement Station Installation Report" prepared for the established measurement stations by the General Directorate of Meteorology or Accredited Institutions.
5- Sending the measurement data for at least 1 year to the General Directorate of Meteorology or Accredited Institutions.
6- Approval of the „Measurement Result Report" by the General Directorate of Meteorology or Accredited Institutions at the end of 1 year.
7- Preparation of application information and documents announced with the Electricity Market License Regulation and EMRA Board Decisions.
8- Preliminary license application on the dates announced by EMRA Board Decisions.
9- Preliminary examination of the pre-license application by EMRA

10- Technical evaluation of the applications, whose preliminary examination is found appropriate, by YEGM (General Directorate of Renewable Energy).
11- For those whose technical evaluation is deemed appropriate, the „Technical Evaluation Result Report" prepared by YEGM is sent to EMRA.
12- Completion of the „competition" process by TEIAS for applications that are technically evaluated and located in the same region.
13- Notification of the application, which undertakes to pay the maximum fee for the unit „MW" installed power, to EMRA by TEİAŞ.
14- Granting „Associate License" to the winning company by EMRA.
15- Obtaining all kinds of administrative permits for the establishment of the facility by the Company during the pre-license process and processing the facility into the zoning plans.
16- Granting a "license" to the company by EMRA.
17- Approval of the projects of the facility by the MENR or the institutions authorized by the MENR.
18- Completion of construction and installation processes.
19- Acceptance of the esis by MENR or institutions authorized by MENR.

[42]

What is left is to choose the wind turbine and maintain it. There are some companies that operate in Izmir for manufacturing, installation, operation, maintenance and consultancy. It can be found in the Invest in Izmir website, Wind Industry section.[49]

4.3 Expenses of Installation

There are different things to consider while installing a wind turbine. The type of the wind turbine, the location of the installation, the service cost, the road insurance and such. Below there is a table of costs every each of the things to consider while installing a turbine. The table was done with the information collected from "IŞIKLAR RES / 10 x Vestas V162 6 MW / FINANCIAL ANALYSIS ASSUMPTIONS". This investment is being done to build 10 Vestas V162 6MW type turbines in Erzurum. We will use the values written in the table below for our future calculations.[50]

Turbine Brand	Model	Unit Power (MW)	Number of Unit	Total Power
Vestas	10 x Vestas V162 6 MW	6	10	60
Unit Cost (Euro)	Total Cost (Euro)	Depreciation Period (Years)	Yearly Depreciation Cost (Euro)	
4,200,000.00 €	**42,000,000.00 €**	**10**	4,200,000.00 €	

Table.15 Table of values for turbine cost.[50]

Explanation	**O&M 1-2 years**	**3-5 years**	**6-10 years**	**11-15 years**	**16-20 years**

Vestas	50,000.00 €	50,000.00 €	50,000.00 €	50,000.00 €	55,000.00 €
Total (10 Turbine)	500,000.00 €	500,000.00 €	500,000.00 €	500,000.00 €	550,000.00 €

Table.16 Table of cost for operation and maintenance.[50]

The operation and maintenance cost increases in the last 5 years period of the turbine, because it is closer to finishing its expected lifetime, the expenses increases to maintain it.

CAPEX (Capital Expenditures)	**Euro**	**Ratio**
Civil Works (Road + foundation +crane Pads)	€ 2,700,000	4.98%
Turbine Supply, Installation, Commissioning	€ 42,000,000	77.40%
Electrical Works (Internal cabling, substation, energy transmission line)	€ 3,650,000	6.73%
Contingency (% 0,5)	€ 241,750	0.45%
Project Development	€ 5,670,000	10.45%
Total	**€ 54,261,750**	
ECA premium and other fees		
Total	**€ 54,261,750**	**100.00%**

Table.17 Table of capital expenditures of the investment for 10 Vestas V162 6MW type turbines.[50]

As it can be seen from the table above the highest expense is caused by the turbine and its installation. The expenses for electrical works would change depending on the location and also the foundation. But we can expect the ratio of the values to be similar and the price also.

Project Technical Summary	
Turbine Type	**Vestas V162 6 MW**
Number of Turbine	**10**
Total Mechanical Power (MWm)	**60.0**
Total Electrical Power (MWm)	**55.0**
Operation Lifetime (years)	**20**
Annual Energy Generation (MWh) – P50	**192,000.00**
Capacity Factor (MWm) – P50	**39.85%**

Table.18 Technical summary for the project of installation of 10 Vestas V162 6MW type turbines.[50]

P50 value is the centre/mean, and it represents the estimate that occurs with the highest probability. MWm is the maximum MW output.[51]

The capacity factor is calculated as:

- $\frac{Annual\ Energy\ Generation}{Total\ Electrical\ Power*24*365}\% = Capacity\ Factor$

- $\frac{192,000}{55*24*365} = \frac{192,000}{481,800} = 0,3985$ = **39.85%**

SUMMARY	10 x Vestas V162 6 MW
Total Investment Cost (Euro)	**€ 54,261,750**
ECA Credit Amount (Euro)	**€ 37,800,000**
Commercial Credit Amount (Euro)	
Total Equity Amount (Euro)	**€ 16,461,750**
Interest Cost (Euro)	**€ 9,112,500**
20 Years Average Operation Cost (Euro)	**€ 1,235,519**
20 Years Total Operation Cost (Euro)	**€ 24,710,385**
Expected Annual Energy Generation (MWh) – P75	**192,000**
20 Years Income from Electricity Selling (Euro)	**€ 200,169,290**
Operation Cost / Income Ratio (%) (for 20 years)	**12.34%**
1 MWh Generation Cost (Euro)	**€ 22.94**
20 Years Average Electricity Cost (MWh/Euro)	**€ 52.13**
Profit Range (%)	**127.25%**
20 Years Total Profit (million Euro) – Before Tax and Depreciation – EBITDA	**€ 112,084,655**
20 Years Total Profit (million Euro) – After Tax and Depreciation	**€ 85,992,874**
20 Years Total Tax (million Euro)	**€ 26,091,781**
Equity Internal Rate of Return (IRR) Before Tax and Depreciation for 20 Years	**28.54%**
Equity Internal Rate of Return (IRR) After Tax and Depreciation for 20 Years	**23.87%**
Equity Return Period Before Tax and Depreciation for 20 Years	**3.50**
Equity Return Period After Tax and Depreciation for 20 Years	**4.19**
Project Internal Rate of Return (IRR) Before Tax and Depreciation for 20 Years	**14.40%**
Project Internal Rate of Return (IRR) After Tax and Depreciation for 20 Years	**12.34%**
Project Return Period Before Tax and Depreciation for 20 Years	**6.95**
Project Return Peirod After Tax and Depreciation for 20 Years	**8.10**
Total Profit / Total Investment Cost Ratio (%)	**158.48%**
First 10 Years Total Profit	**€ 21,796,081**

Table.19 Summary of the project of installation of 10 Vestas V162 6MW type turbines.[50]

From the summary we can use some of the values to form a expected summary for the project of our own. In our case we need enough turbines to either produce at least **1,337,195MWh** or at most **2,559,351MWh** for the next 10 years. We have some values which differ from the tables above, like the capacity factor, electricity selling cost and while renting the land our price will be different for the turbines will be operating in Izmir and not in Erzurum.

We should first find the number of turbines needed for the project. As I mentioned above there are two scenarios, first scenario where the population rise is the least and the needed extra electricity caused by the increase in population is **1,337,195MWh**. This scenario will be considered first.

4.4 Least Amount of Extra Electricity Needed Scenario

The amount of turbines needed:

In this part I will consider the same type of turbine in the tables above and I will make the calculations depending on that. In our case the capacity factor will be different so I will be using the average capacity factor of Izmir, 30.4%.[51]

$\frac{1,337,195}{5,5*24*365*30.4\%} = \frac{1,337,195}{14,646} \approx 91$ this value is for 10 Vestas V162 6MW type turbines. So the number of turbines needed for the least amount of extra electricity needed would be **91**.

Turbine Brand	Turbine Cost	Amount	Total Cost
Vestas V162 6MW	4,200,000.00 €	91	**382,200,000.00 €**

Table.20 Table of total cost for 91 turbines.[50][57]

As it was said by, Abdullah Onur KISAR, the civil works and electrical works wouldn't differ more than 1%, it will be taken as the percentage of uncertainty in further calculations. Below is the cost of civil works and electrical works.

Cost of electrical works:

The cost of electrical works of the project above is;

Works	Cost (Euro)	Years
154 kV Switchyard and Energy Transmission Line project	50,000.00 €	10
MV Lines	600,000.00 €	10
154 kV Transmission Line and expropriation works	1,000,000.00 €	10
154 kV Switchyard Electrical Works	2,000,000.00 €	10

Total:	3,650,000.00 €	

Table.21 Cost of electrical works for 10 Vestas V162 6MW type turbines.[50]

In our case, this value will be;

- $3{,}650{,}000.00 \times 9.1 = 33{,}215{,}000.00$ €
- With 1% uncertainty this value will be between 32,882,850.00 € and 33,547,150.00 €.
- Cost of electrical works for the project for least amount of electricity needed is **($\mathbf{33{,}215{,}000.00 \pm 332{,}150.00}$ €)**

Cost of civil works:

The cost of civil works of the project above is;

Works	**Cost (Euro)**	**Depreciation Period (years)**	**Annual Depreciation**
Roads	**1,000,000.00 €**	**10**	
Crane Pads	**500,000.00 €**	**10**	
Turbine Foundation	**1,200,000.00 €**	**10**	
154 kV Switchyard Civil Works	**500,000.00 €**	**10**	
Total	**2,700,000.00 €**		**270,000.00 €**

Table.22 Cost of civil works for 10 Vestas V162 6MW type turbines.[50]

In our case this value will be;

- $2{,}700{,}000.00 \times 9.1 = 24{,}570{,}000.00$ €
- With 1% uncertainty this value will be between 24,815,700.00 and 24,324,300.00 €.
- Cost of civil works for the project for least amount of electricity needed is **($\mathbf{24{,}570{,}000.00 \pm 245{,}700.00}$€)**.

Cost of project development:

For the installation of the turbines we mentioned the process one has to go through. For this process the investor also has to make some budget. This budget consists of the expenses of consultancy, permits, design, mapping and geothecnical works, financial and legal consultancy, administrative and acocunting expenses, technical project team, social aids, rental and purchase prices and forest chopping and afforestation costs. Obviously, there will be differences in different location in the country. This project was in Erzurum so the landscape is mostly rocky, mountainous and dry. On the other hand, Izmir is humid, covered with hills and has a Mediterrenian flora. For comparison below there are images of random locations from Erzurum and Izmir.

Figure.12 A photograph of Erzurum, Palandöken Mountain.[53][54]

Figure.13 A photograph of Izmir, Urla Kuşçular Village.[55][56]

Scopes	Cost (Euro)	Explanations
Consultancy	€ 50,000.00	Energy analysis, EIA, TEA etc.
Permits	€ 200,000.00	The cost required to complete the permits
Design, geotechnical, mapping	€ 50,000.00	Cost is estimated for remaining design, geotechnical and mapping works.
Financial and Legal Consultancy	€ 25,000.00	
Administrative and Accounting expenses	€ 20,000.00	Expenses of administrative and accounting teams until the commissioning
Technical Project Team	€ 50,000.00	Technical personnel expenses until the commissioning
Social aids	€ 25,000.00	Social responsibility projects
Expropriation-lease-purchase	€ 200,000.00	Rental and purchase prices, especially for the external road
Project Purchase Price	€ 5,000,000.00	
Forest chopping and afforestation cost	€ 50,000.00	
Total	**€ 5,670,000.00**	

Table.23 Cost of project development for 10 Vestas V162 6MW type turbines.[50]

In our case this value will be;

- $5{,}670{,}000.00 \times 9.1 = 51{,}597{,}000.00$ €
- With 1% uncertainty this value will be between 52,112,970.00 and 51,081,030.00 €.
- Cost of project development for the project for least amount of electricity needed is **($\mathbf{51,597,000.00 \pm 515,970.00}$ €)**

After calculating these costs, we can sum them to calculate the total expenditures with their uncertainties.

- Expenses: $382{,}200{,}000.00 + 33{,}215{,}000.00 + 24{,}570{,}000.00 + 51{,}597{,}000.00 = \mathbf{491,582,000.00}$ €
- Uncertainty: $\mathbf{332,150.00 + 245,700.00 + 515,970.00 = 1,093,820.00}$ €
- Total Expenditures: $\mathbf{491,582,000.00 \pm 1,093,820.00}$ €

For the highest amount of electricity needed we need about $\mathbf{491,582,000.00 \pm 1,093,820.00}$ € to install the 91 turbines for the project.

Project Table for the Least Amount of Electricity Needed Scenario

Now that we know the investment needed for the least amount of turbines we should focus on the profit which the investor will get from it. Below there are the electricity selling prices from the project of 10 Vestas V162 6MW type turbines. We will use these values for the calculations.

Year	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**20230**	**2031**	**2032**	**2033**
Selling Price (EUR/MWh)	47.64	47.64	47.64	47.64	47.64	47.64	47.64	47.64	47.64	47.64

Table.24 Electricity selling prices between 2024 and 2033.[50]

Year	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**
Selling Price (EUR/MWh)	56.61	56.61	56.61	56.61	56.61	56.61	56.61	56.61	56.61	56.61

Table.25 Electricity selling prices between 2034 and 2043.[50]

The project for the least amount of electricity needed, which is being proposed from my side, requires 91 turbines, which I wouldn't expect one investor nor one company to fulfil. So I will be dividing this project into 17 projects of **5 turbines** and 1 project of **6 turbines**, so in total 18 projects.

Below there are the economical evaluations for the **5 turbines project**. The turbine that will be installed is the same turbine as the turbine which we used for the calculations of needed investment, Vestas V162 6MW.

The Investment Needed for Installing 5 Turbines

- $\frac{491{,}582{,}000.00 \pm 1{,}093{,}820.00}{91/5} = 27{,}010{,}000.00\ \pm 60{,}100.00€$

Income from Selling Electricity with 5 Turbine Project

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032
Selling Price (EUR/MWh)	47.64	47.64	47.64	47.64	47.64	47.64	47.64	47.64	47.64
Electricity Generation	73,230	73,230	73,230	73,230	73,230	73,230	73,230	73,230	73,230
Revenue (Mil EUR)	3.49	3.49	3.49	3.49	3.49	3.49	3.49	3.49	3.49

Table.26 Revenue from electricity generation between 2024 and 2032 for 5 turbines.[57]

The selling price of electricity, depending on the information that was given in the excel of the project for 10 Vestas Turbines, will be **47.64€** per MWh for the years between 2024 and 2033, so yearly with **73,230MWh** generation, the income would be **3.49 mil** euros**.** Total expected income from selling electricity with a 5 turbines project in the end of **9** years would be **31.41 million** euros. This part was until 2032 because of the period we are covering, but the lifetime of a turbine is about 20 years. So, for 20 years, if we use the values from the table[b], rest of the years would give out an income of **44.89 mil** euros**.** Which at the end sums up the total income of 20 years to **76.3 million** euros with 5 turbines.[57]

Now we will evaluate the same values for 6 turbines project.

The Investment Needed for Installing 6 Turbines

- $\frac{491{,}582{,}000.00 \pm 1{,}093{,}820.00}{91/6} = 32{,}426.253.30\ \pm 72{,}151.71\ €$

Below there is the table for a 6 turbines project.

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032
Selling Price (EUR/MWh)	47.64	47.64	47.64	47.64	47.64	47.64	47.64	47.64	47.64
Electricity Generation	87,880	87,880	87,880	87,880	87,880	87,880	87,880	87,880	87,880
Revenue (Mil EUR)	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19

Table.27 Revenue from electricity generation between 2024 and 2032 for 6 turbines. [57]

With 87,880MWh per year and with the selling price being 47.64€ per MWh, the expected income from a 6 turbines project in the next 9 years after the instalment of the turbines is **37.71 million** euros. For the total 20 years of lifetime of the turbines, the total income from the project would be **91.6 million** euros with 53.89 million added in between.[57]

4.5 Highest Amount of Extra Electricity Needed Scenario

The amount of turbines needed:

In this part I will consider the same type of turbine in the scenario above and I will make the calculations depending on that. In our case the capacity factor will be again 30.4% for our projects are located in Izmir.[51]

$\frac{2,559,351}{5.5*24*365*30,4\%} = \frac{2,559,351}{14,646} \approx 175$ this value is for 10 Vestas V162 6MW type turbines. So the number of turbines needed for the highest amount of extra electricity needed would be **175**.

Turbine Brand	Turbine Cost	Amount	Total Cost
Vestas V162 6MW	4.200.000,00 €	175	$\mathbf{735,000,000.00€}$

Table.28 Table of total cost for 175 turbines. [50][57]

Using the same information from the previous scenario, with direct proportion, we can find the new total investment needed for the highest amount of extra electricity needed.[57]

Cost of electrical works:

The cost of electrical works of the project above is;

Works	Cost (Euro)	Years
154 kV Switchyard and Energy Transmission Line project	50,000.00 €	10
MV Lines	600,000.00 €	10
154 kV Transmission Line and expropriation works	1,000,000.00 €	10
154 kV Switchyard Electrical Works	2,000,000.00 €	10
Total:	3,650,000.00 €	

Table.29 Cost of electrical works for 10 Vestas V162 6MW type turbines.[50]

In our case, this value will be;

- $3,650,000.00 \times 17.5 = 63,875,000.00$ €

- With 1% uncertainty this value will be between 63,236,250.00 € and 64,513,750.00 €.
- Cost of electrical works for the project for least amount of electricity needed is **($63,875,000.00 \pm 638,750.00$ €)**

Cost of civil works:

The cost of civil works of the project above is;

Works	Cost (Euro)	Depreciation Period (years)	Annual Depreciation
Roads	**1,000,000.00 €**	**10**	
Crane Pads	**500,000.00 €**	**10**	
Turbine Foundation	**1,200,000.00 €**	**10**	
154 kV Switchyard Civil Works	**500,000.00 €**	**10**	
Total	**2,700,000.00 €**		**270,000.00 €**

Table.30 Cost of civil works for 10 Vestas V162 6MW type turbines.[50]

In our case this value will be;

- $2{,}700{,}000.00 \times 17.5 = 47{,}250{,}000.00$ €
- With 1% uncertainty this value will be between 47,722,500.00 and 46,777,500.00 €.
- Cost of civil works for the project for least amount of electricity needed is **($47,250,000.00 \pm 472,500.00$€)**.

Scopes	Cost (Euro)	Explanations
Consultancy	€ 50,000.00	Energy analysis, EIA, TEA etc.
Permits	€ 200,000.00	The cost required to complete the permits
Design, geotechnical, mapping	€ 50,000.00	Cost is estimated for remaining design, geotechnical and mapping works.
Financial and Legal Consultancy	€ 25,000.00	
Administrative and Accounting expenses	€ 20,000.00	Expenses of administrative and accounting teams until the commissioning

Technical Project Team	€ 50,000.00	Technical personnel expenses until the commissioning
Social aids	€ 25,000.00	Social responsibility projects
Expropriation-lease-purchase	€ 200,000.00	Rental and purchase prices, especially for the external road
Project Purchase Price	€ 5,000,000.00	
Forest chopping and afforestation cost	€ 50,000.00	
Total	**€ 5,670,000.00**	

Table.31 Cost of project development for 10 Vestas V162 6MW type turbines.[50]

In our case this value will be;

- $5{,}670{,}000.00 \times 17.5 = 99{,}225{,}000.00$ €
- With 1% uncertainty this value will be between 100,217,250.00 and 98,232,750.00 €.
- Cost of project development for the project for least amount of electricity needed is **($\mathbf{99,225,000.00 \pm 992,250.00}$ €)**

Total expenditures for the project of highest amount of electricity needed is;

- Expenses: $735{,}000{,}000.00 + 63{,}875{,}000.00 + 47.250.000.00 + 99{,}225{,}000.00 = \mathbf{945,350,000.00}$€
- Uncertainty: $\mathbf{638,750.00 + 472,500.00 + 992,250.00 = 2,103,500.00}$ €
- Total Expenditures: $\mathbf{945,350,000.00 \pm 2,103,500.00}$ €

For the highest amount of electricity needed we need about $\mathbf{945,350,000.00 \pm 2,103,500.00}$ € to install the175 turbines for the plan.[57]

Because 175 is divisible by 5, the suggested project type for 175 turbine plan would be the 5 Turbines Project. For more information on the projects, there is an excel made by me by using the information from the “10 Vestas V162 6MW project”. In the excel one can find information on total operational costs and total revenues per year, total cash flow, income tax, project internal rate of return before and after tax and depreciation and equity internal rate of return before and after tax and depreciation and also the periods of project and equity internal returns.[50][57]

Chapter 5: Conclusion

5.1 Process

In the second chapter we explained the development of the cunsomption in the World and in Turkey, then specificly we focused on Izmir for it is th main interest of this thesis. We have showed the development of the effect of private sector and the state in the energy industry also to show the need of individual investments into this area. Then we have informed the reader about the situation of the energy industry when it comes to domestic and foreign influence to show the need of investment into the field of electricity production. Afterwards, we measured the electricity that should be generated to face the population rise that will happen in soon future, we have done that by assuming the population to rise at the same speed or to increase at first and decrease gradually in time. For both scenarios we have done assumptions and calculated the needed electricity generation. Then we made sure that it is achievable by calculating the highest possible generation with wind in Izmir.

In the third chapter, we informed the reader about the energy mix in Turkey, what are the percentages of resources in power production and the percentages when it comes to imported resources of energy. In this part we focused on the necessity of electricity generation with renewable resources in Turkish borders. In addition we informed the reader about the price of electricity for final consumers to validate the need of electricity generation with renewable resources. We made a comparison between Turkey and the most expensive in Europe, Germany. We proved that Turkey was more expensive for Turkish people then Germany is for German people which also confirmed the rightness of our suggestion. We then talked about the wind potential in Izmir in more detail by adding more information about wind power, how a turbine works, how clean is wind and what is the potential of Izmir and its region when it comes to wind. Afterwards we explained Izmir and its people and showed that a project like this, which would develop the region, would be accepted and liked by the people of the region.

In the fourt chapter, the technical and economical evaluations were discussed. The total investments for both scenarios of populations were calculated and for both of the plans 5 turbines and 6 turbines projects were suggested with details given with an excel sheet. The source used for this calculation was an already planned project for ISIKLAR RES, where 10 Vestas V162 6MW turbines will be built in 2023 and will operate in 2024. An uncertainty of 1% was taken while calculating the expenses as it was said by Abdullah Onur Kısar who gave the excel " Işıklar RES_10 türbin" as an example for my calculation.

5.2 Conclusion

The main idea of the thesis was to create a solution, a plan, for the future electricity demand that will occur with the population growth of Izmir. The idea was to cover this new extra electricity demand with wind power which would also help the development of the related industries in the region and most importantly keep the environment clean for years to come. We have proven that wind for power generation is the green and efficient choice for Izmir through the chapters.

We have also proven that it is economically achievable and profitable for both the investors and the state which is one of the most important points. Respectfully the net present values of both the 5 turbines project and the 6 turbines project are, **0.41** and **0.49**. The average annual income for 5 turbines project is **2.55 million** euros per year while for 6 turbines project this number goes up to **3.06 million** euros. The total investment needed for the installment of turbines is **491,582,000.00±1,093,820.00 €** for the least amount of expected extra demand and **945,350,000.00±2,103,500.00 €** for the highest expected extra demand. For these two plans to be fulfilled we have suggested 2 options for investors. First one is the 5 Turbines Project which needs a total investment of **27.01 million euros** and the second one is the 6 Turbines Project which needs a total investment of **32.43 million euros**, for both we gave information about in the 4th Chapter and gave detailed information in the Excel sheet “5 and 6 Turbines Project”.[57]

Focusing on renewable energy is the key for Turkey to achieve independence in the industry of power production. It is important to be self sufficient while generating electricity, for it creates great expenditures when energy sources or electricity is bought from other nations. Hopefully this thesis will be useful for finding a solution for the increasing electricity demand caused by the population rise of Izmir and the other cities of Turkey which are rich in potential wind energy.

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