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Wind Energy in Turkey: Potential and Economic Viability

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Wind Energy in Turkey: Potential and Economic Viability

by

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To my wife and family

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Abstract

Wind Energy in Turkey: Potential and Economic Viability

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Turkey wants to encourage renewable electricity generation to reduce dependence on imported natural gas and meet its highly growing power demand. The government's objective is to increase the share of renewable resources in electricity generation to at least 30 percent by 2023, and the specific target for the installed wind energy capacity is 20 GW by that date. Fortunately, Turkey has an enormous wind energy potential to exploit for electricity generation. When from "good" to "outstanding" wind clusters are taken into account, the overall technical wind power generation capacity in Turkey is calculated to be nearly 48 GW. In this context, this thesis investigates whether policy instruments in the Turkish regulatory frame contribute to economic viability for wind power projects or not. The financial results point out that an electricity price of 7.3 USD cent/kWh, which is the guaranteed price for wind power generation by current regulations, does not make a typical onshore wind power plant located in a "good" windy

resource economically viable. However, when locally produced wing blades and turbine towers are used in the project, the purchase price increases to 8.7 USD cent/kWh, and the project becomes economically viable. As a result, the local content element introduced in recent regulations promotes wind energy investments and helps government to reach its renewable target for 2023.

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Chapter 1: Introduction

The need for energy has increased tremendously in the 20th century due to the economic and technological developments. The fact that fossil fuel resources of the world are limited and the rising awareness about environmental degradation has forced energy sector to seek new resources to meet the energy demand. As a result, the renewable energy sources, and especially wind energy have been welcomed by the industry and society as clean, environmentally friendly, and economical options for electricity generation.

Wind power is the world’s fastest growing energy source. From 1996 to 2010, the wind power capacity grew annually at a rate of more than 20% (Global Wind Energy Council (GWEC), 2011). The improvements in wind turbine design and technology have also fostered the wind power installations by reducing the electricity production costs. Wind power in Turkey also has grown at a remarkable rate in the last few years, from 20 MW in 2005 to 1329 MW at the end of 2010.

Turkey is an energy importing country that has very limited domestic resources of crude oil, natural gas and coal. However, the country is considered as rich in terms of renewable resources. Regarding wind energy, Turkey has the highest technical potential among European OECD countries (Wijk and Coelingh, 1993). In this context, wind power possesses a very attractive option for electricity generation.

The Turkish government aims to increase the share of renewable resources in electricity generation to at least 30 percent by 2023. The specific target for the installed wind energy capacity is 20 GW. Several support mechanisms and incentives are put into force to accomplish this objective.

The aim of this study is to investigate the economic viability of wind power generation in Turkey based on the wind energy potential figures and current regulatory support mechanisms. The thesis is organized as follows:

In the second chapter, the supply and demand characteristics of Turkish electricity market with up-to-date figures, future projections and targets are presented. Chapter 3 provides detailed information about Turkey’s onshore and offshore wind energy potential. The most recent status of wind power in the world and Turkey is presented in the fourth chapter. The current support mechanisms and incentives for wind power generation are presented in the fifth chapter. Finally, the economic viability of a typical onshore wind power plant is discussed thoroughly in the sixth chapter.

Chapter 2: Electricity Market in Turkey

2.1 Demand Growth

With a growing young population and continued high economic growth in recent years, the electricity market of Turkey has been one of the fastest growing power markets in the world in the last decade.

Turkey's economy, 17^{th} largest in the world and 6^{th} largest in Europe, is a dynamic and emerging economy (The World Bank, 2010). The economy is progressively more powered by the industry and service sectors although the agriculture segment still employs nearly 25% of the work force. Thanks to its developed infrastructure and growing private sector and international competitive work forces, Turkey's economy has been performing well in recent years with sustainable growth and long term foreign investments.

Turkey has undergone major financial and fiscal reforms associated with an IMF program after a serious financial crisis struck the country in 2001. The structural reforms within the stable politics improved the fundamental indicators of the Turkish economy and the country moved into a fast growing period. Turkey has experienced an average Gross Domestic Product (GDP) growth rate exceeding 6% annually until 2009. The global economic turmoil and tight fiscal policy reduced the economy 4.7% in 2009. Because of Turkey's robust financial structure and well regulated banking regime, the economy recovered brightly with an estimated growth rate of 7.8% in 2010 (International Monetary Fund (IMF), 2011). Table 1 presents some important selected indicators of Turkey. Similar to other developing countries, the electricity demand in Turkey is increasing rapidly because of its economic development and population growth.

Further structural economical reforms and sector regulations, together with political stability and prospective European Union (EU) membership, will provide a more favorable international business environment for investors and eventually result in higher economic growth in Turkey.

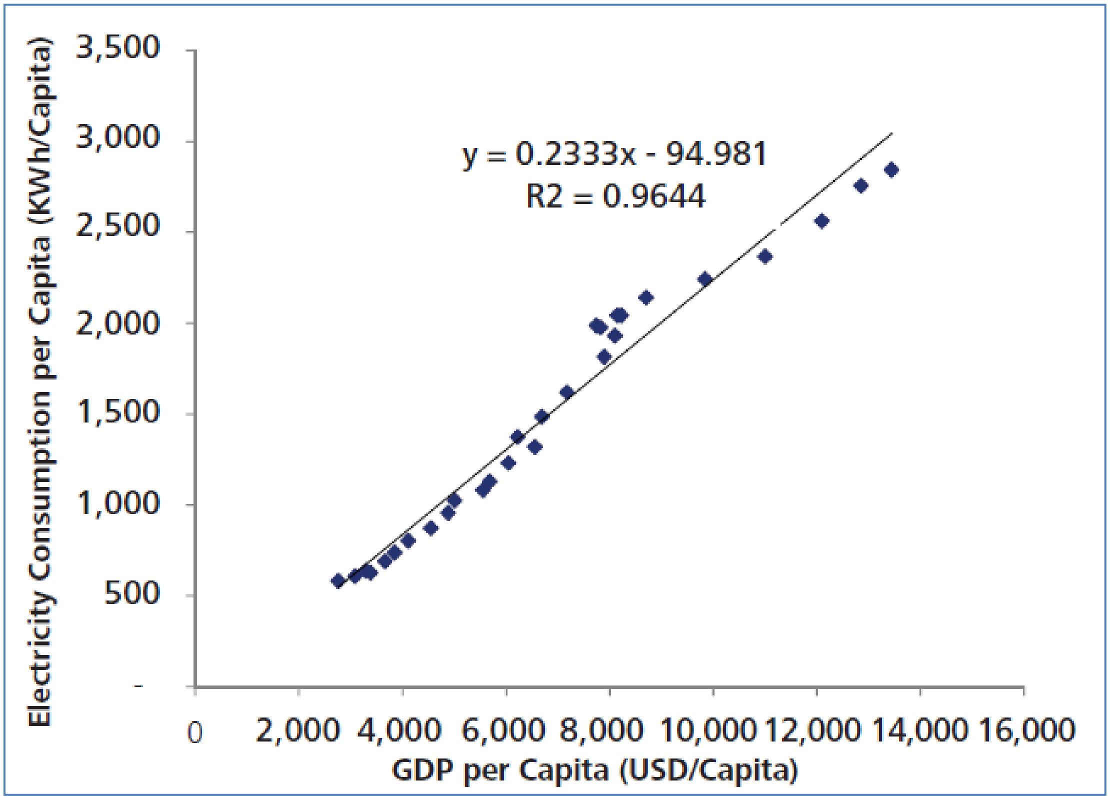
Table 1. Selected Indicators of Turkey

Indicator	**Value**
Population	78,785,548 (July 2011 est.)
Population growth rate	1.235% (2011 est.)
GDP (purchasing power parity)	$958.3 billion (2010 est.)
GDP (official exchange rate)	$729.1 billion (2010 est.)
GDP - real growth rate	7.8% (2010 est.)
GDP - per capita (PPP)	$12300 (2010 est.)

Source: CIA World Factbook, 2011 and IMF, 2011.

Economic growth is the most crucial driver of electricity demand. Electricity consumption increase has been proven to be correlated with GDP growth for many countries. GDP per capita and the electricity consumption per capita values beginning from 1980 exhibit almost a linear relationship for Turkey as shown in Figure 1. The electricity consumption per capita of 750 kWh and GDP of $2,100 per capita in 1980s both doubled in 1990s. GDP per capita achieved $6,350 on average and electricity consumption per capita achieved 2,300 kWh in 2000s (Deloitte 2010). With the decreasing impacts of the global economic turmoil, the GDP per capita began to accelerate. The rising pattern indicates that there still exists a significant potential for electricity consumption growth for the future.

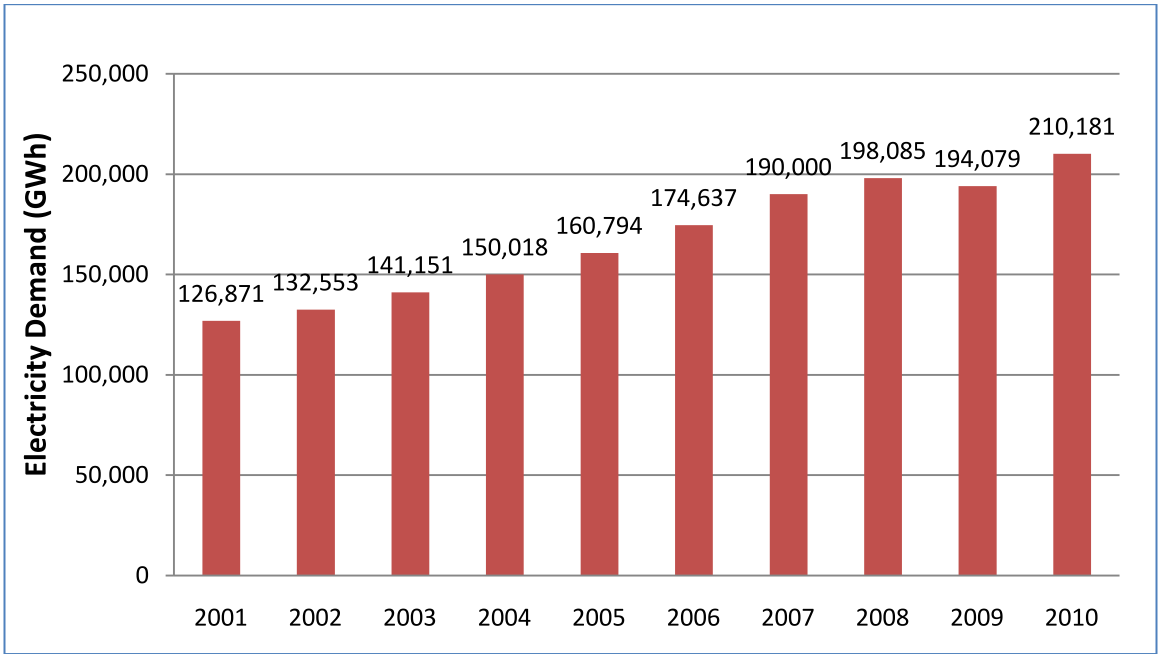
Figure 1. GDP per Capita versus Electricity Consumption per Capita



Source: Deloitte, 2010.

As a result of high economic growth and population increase in the last decade, the electricity consumption of Turkey increased from 128 TWh in 2001 to 210 TWh in 2010 as depicted in Figure 2. The cumulative average growth rate of electricity consumption in this period was 5.8%. The global financial crisis had a negative impact on the electricity demand in 2009, there was a 2.0% decrease in the demand compared to 2008. However, the electricity consumption of Turkey rebounded back with an impressive growth rate of 8.3% in 2010 reaching 210 TWh.

Figure 2. Electricity Demand Growth in Turkey (2001-2010)



Source: TEIAS, 2011.

The electricity demand will expectedly experience a similar increase of 6.3% to 7% in the near future. Total electricity consumption of Turkey in 2018 is projected to reach 336 TWh with annual growth rate of 6.3% in base scenario and 357 TWh with annual growth rate of 7% in high scenario (TEIAS, 2009).

2.2 Supply Development

Turkey has very limited indigenous resources of crude oil, natural gas and coal. The country is not even listed among the top 50 countries where oil and natural gas resources are present. The situation for domestic coal resources is not promising either. The country has only 0.46% of the coal reserves in the world (SETA, 2008). Taner Yildiz, Minister of Energy and Natural Resources, recently stated that Turkey imports

97% of its natural gas and 93% of its crude oil consumption, highlighting the energy imbalance of the country (BloombergHT, 2011).

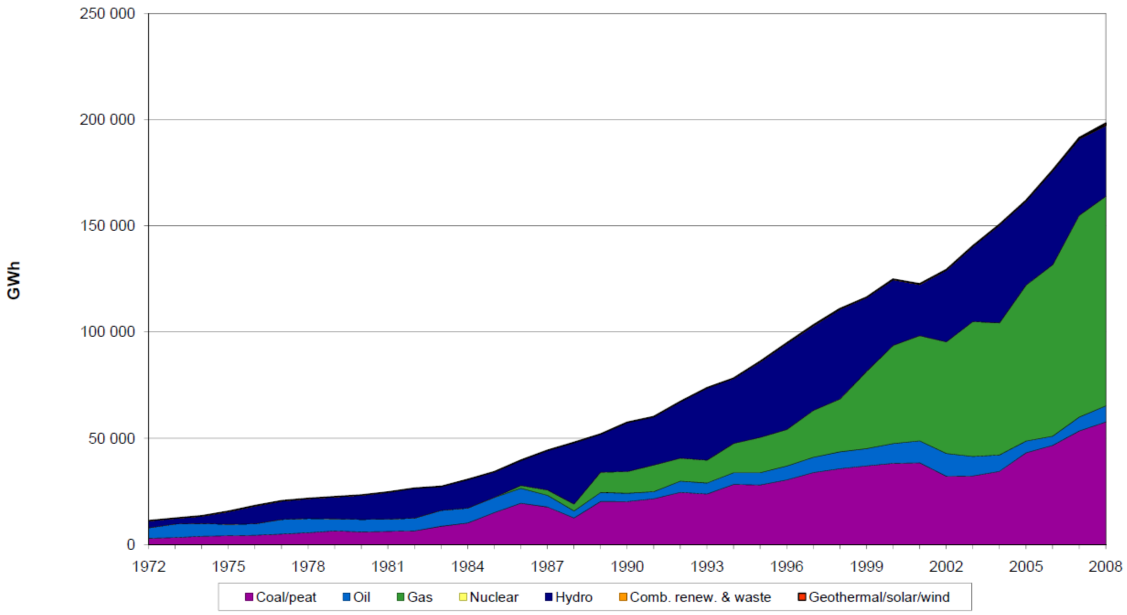
On the other hand, Turkey is currently being identified as an *energy corridor* due to its geographical location. Three fourths of the proven oil and natural gas reserves in the world are present in regions neighboring Turkey, namely the Middle Eastern and Caspian countries (Kaygusuz, 2002). Turkey plays a key role in transportation of the oil and natural gas resources with the increasing dependence of West and emerging Asian countries on these resources.

It's desirable to use the natural resources of a country as the main sources for electricity generation. The contribution of the renewable and domestic sources should be optimized without interrupting the stability of power system. Making the contribution of these sources as high as possible should be one of the main priorities of the energy policy of a country. However, the situation for electricity generation has been somewhat different for Turkey.

The electricity generation of Turkey by fuel types for the period of 1972-2008 is illustrated in Figure 3. Turkey's electricity generation heavily depends on imported fuels, such as, natural gas, oil and even coal. The increasing reliance on imported fuels in the electricity supply for the last decade, particularly natural gas, can be distinguished clearly.

Electricity generation by natural gas fueled plants increased by 48 TWh in Turkey in the period 2000-2009, representing 72% total incremental electricity supply. Coal-fired generation increased by 17 TWh, representing 25% of total incremental electricity generation in this period. Hydroelectric generation grew by 5 TWh. Oil fuelled generation is gradually decreasing after reaching its peak in 2002 (International Energy Agency (IEA), 2010). The share of energy sources used in electricity generation in 2009 is presented in Table 2. The percentage of natural gas fired generation was nearly half of the total generation, more than twice of the following hydroelectric generation.

Figure 3. Electricity Generation by Fuel Types in Turkey (1972-2008)



Source: IEA, 2010.

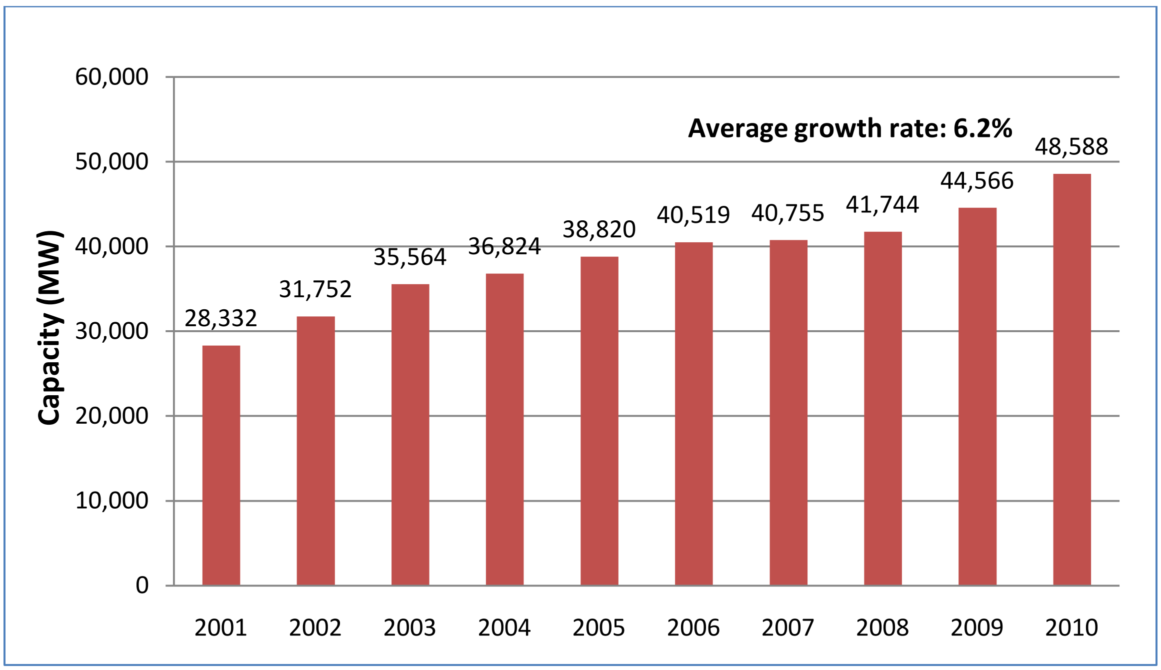
Table 2. Electricity Generation Breakdown in Turkey (2009)

Source	**Generation (TWh)**	**Percentage (%)**
Natural gas	94.4	48.6
Domestic coal	42.2	21.7
Imported coal	12.8	6.6
Hydropower	35.9	18.5
Liquid fuels (oil)	6.6	3.4
Wind, geothermal, biogas	2.2	1.1
TOTAL	194.1	100

Source: EIA, 2010.

In accordance with the high growth rate in electricity demand, the installed electricity generation capacity has risen regularly between 2001 and 2010 from 28,332 MW to 48,588 MW, as illustrated in Figure 4. The cumulative average growth rate of installed capacity in this period was 6.2%. As expected, detailed analysis of incremental capacity according to fuel type confirms that especially natural gas fired plants have been implemented in the last years.

Figure 4. Electricity Generation Capacity in Turkey (2001-2010)

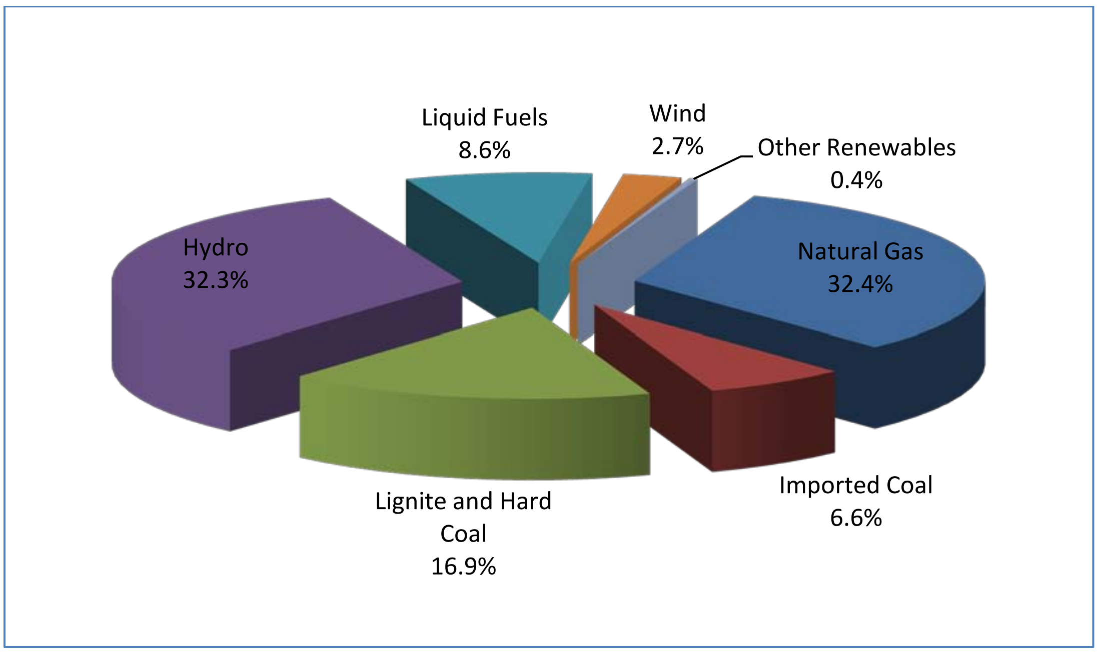


Source: TEIAS, 2011.

The heavy dependence on imported fuels in electricity generation in Turkey can also be noticed looking at the installed capacity breakdown of the country. The installed capacity breakdown of Turkey by the end of February 2011 is shown in Figure 5. Hydroelectric and natural gas plants make up the largest share in energy resources with

32% each, followed by lignite and hard coal plants forming 17% together. Although the hydroelectric capacity is nearly at the same level with natural gas capacity, annual hydroelectric generation may significantly fall behind gas-fired generation due to non-availability of hydropower generation depending on annual hydrological conditions, as happened in 2009 (See Table 4). The plants running with liquid fuels and imported coal constitute the major part of the remaining capacity with 8.6% and 6.6% respectively. Even though wind power has grown very fast in the last few years, it only makes up 2.7% of total installed capacity. The overall electricity generation capacity reached 50,004 MW by the end of February 2011 (TEIAS, 2011).

Figure 5. Capacity Breakdown by the End of February 2011 for Turkey



Source: TEIAS, 2011.

Diversification of the electricity generation portfolio using domestic energy resources can be a significant risk management approach to ensure security of supply. Each energy resource has its own technological, economical and market characteristics. The risk of overall generation portfolio declines when different energy resources with different features are utilized. In addition, all resources and technologies should be utilized in order to meet the strong projected growth in electricity consumption.

The Turkish government prepared the “Electricity Energy Market and Supply Security Strategy Paper” in 2009 to address the security of supply problem. In this paper, national targets for electricity generation have been established such as;

i. to reduce the share of gas fired generation to below 30% by 2020 in overall electricity generation, in order to mitigate the risks originating from dependency on natural gas imports

ii. to increase the share of renewable resources in generation portfolio up to at least 30% by 2023,

iii. to benefit from all proven lignite deposits and hard coal resources in electricity generation activities by 2023,

iv. to continue to use imported coal in power supply and,

v. to ensure that nuclear power plants account for at least 5% of electricity generation by 2020.

The strategy paper’s primary target is to ensure that renewable resources provide at least 30% of electricity generation by 2023. All technically and economically available hydroelectric potential, which is estimated to be 140 TWh, should be utilized according to government’s plan. The installed wind energy capacity should increase to 20,000 MW, which corresponds to 42% of the estimated 'good windy class'[1] technical capacity of 48 GW. The contribution of geothermal resources is estimated to be at least 600 MW. The use of solar energy for electricity generation should also be increased. Specific targets for renewable resources may be revised depending on the technological improvements and market conditions. The government also plans to implement a capacity mechanism to ensure that capacity investments are constructed timely to preserve security of supply (Higher Board of Planning, 2009).

After emphasizing the government's ambitious wind power capacity target of 20 GW by 2023, the wind energy potential of Turkey will be presented in the following chapter.

[1] The classification of wind clusters and technical wind energy potential of Turkey is discussed in detail in the following chapter.

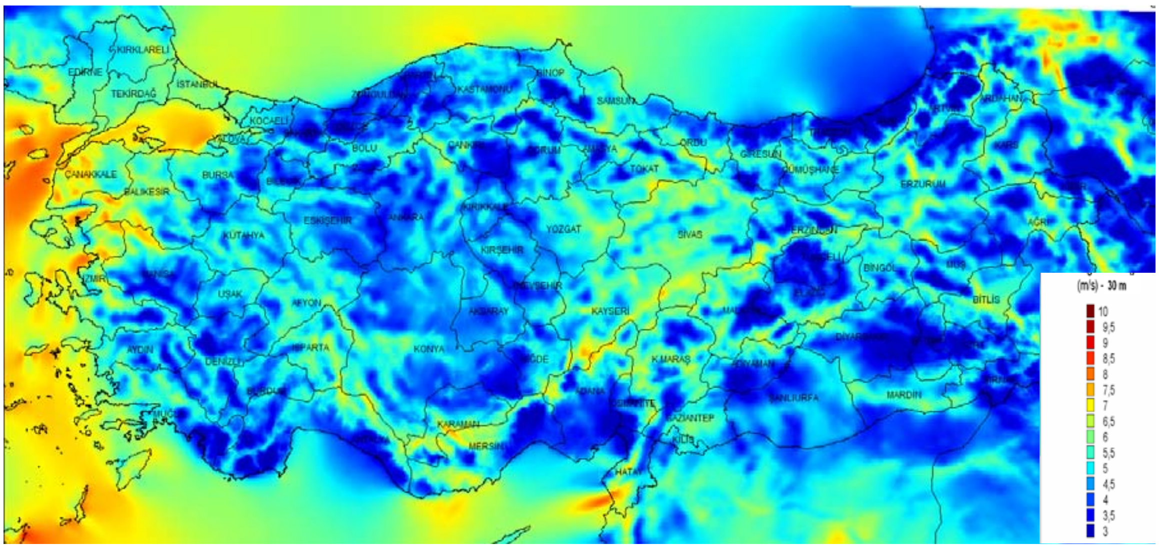
Chapter 3: Wind Energy Potential of Turkey

Topographic characteristics of a location play a key role on the occurrence of wind and the magnitude of wind speed. In general, land-sea intersection sites are supposed to be primary windy areas with stable conditions for wind speed and direction. Secondary areas for windy conditions are valleys, due to high variations between heating and cooling effects in a day period. Fortunately, both conditions can be observed in Turkey's geographical position (Sahin, 2008).

Turkey is located between Europe and Asia continents like a bridge. The country is surrounded by seas on three sides; the Black Sea in the north, the Marmara and the Aegean Sea on the west, and the Mediterranean Sea in the south. It has a land surface area of 781,000 km^2 and a long coast line of nearly 8500 km (Ogulata, 2003). Turkey’s location between the colder European and warmer Asian and African climate systems cause a wide variation in temperature and climatic conditions.

Turkey can be divided into three main climatic regions: First, the coastal regions including the Black Sea, Aegean Sea and Mediterranean Seas, second, the moderately mountainous regions alongside these coastal regions, and third, rather rocky plateaus in the central and eastern parts. Etesian winds blowing especially in the summer season from a N-NE direction in western Turkey provide a potential area for wind power generation. In central parts of Turkey, high wind velocities are observed due to the presence of deep valleys and high plateaus. During the wintertime, high pressure systems from Siberia and the Balkan Peninsula, as well as low- pressure systems from Iceland influence this region. Air clusters coming over the Black Sea also affect the wind characteristics of Turkey (Sahin 2008). The resulting wind speed distribution of the country is shown in Figure 6.

Figure 6. Wind Speed Map of Turkey at 30 m.



Source: Malkoc, 2008.

Many studies of wind energy potential in various regions of Turkey are present in the literature. The results of the studies indicate that most of the locations have an annual mean wind velocity greater than 4 m/s at a height of 10 m and the capacity factor may go up to 57.4% (Guler and Akdag, 2010).

A few of the researchers calculated a quantitative estimation of wind energy potential of Turkey as a whole. Wijk and Coelingh (1993) claimed that Turkey has the highest technical wind energy potential among European OECD countries with an 83,000 MW of wind power generation capacity (See Table 3). Ozakat (2001) estimated the technical wind energy potential of Turkey as 116,000 MW. Fortunately, at present, we do have more accurate wind potential data gathered from numerous wind speed stations across Turkey.

Table 3. Wind Energy Potential of European OECD Countries.

Country	Territory (thousand km²)	Specific wind potential (class >3) (thousand km²)	Side potential (km²)	Technical potential	
				MW	TWh/year
Turkey	781	418	9,960	83,000	166
UK	244	171	6,840	57,000	114
Spain	505	200	5,120	43,000	86
France	547	216	5,080	42,000	85
Norway	324	217	4,560	38,000	76
Italy	301	194	4,160	35,000	69
Greece	132	73	2,640	22,000	44
Ireland	70	67	2,680	22,000	44
Sweden	450	119	2,440	20,000	41
Iceland	103	103	2,080	17,000	34
Denmark	43	43	1,720	14,000	29
Germany	357	39	1,400	12,000	24
Portugal	92	31	880	7,000	15
Finland	337	17	440	4,000	7
The Netherlands	41	10	400	3,000	7
Austria	84	40	200	2,000	3
Belgium	31	7	280	2,000	5
Switzerland	41	21	80	1,000	1
Luxemburg	3	0	0	0	0

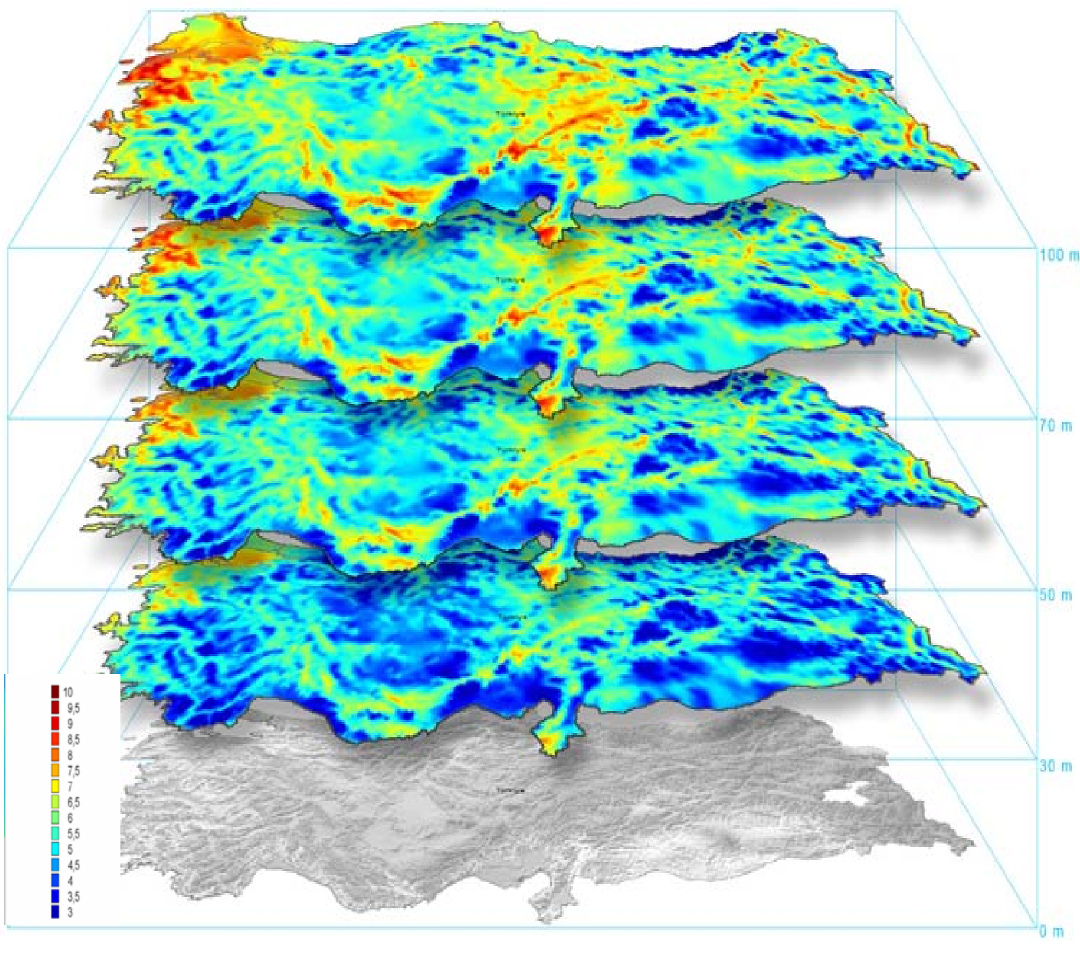
Source: Wijk and Coelingh, 1993.

In 2002, Wind Map of Turkey was prepared from the data collected by State Meteorological Service of Turkey. The findings of the wind map asserted a technical wind energy potential of 88,000 MW (Kenisarin et al., 2006).

In order to gather more accurate data about the characteristics and distribution of Turkey's wind energy resources, General Directorate of Electrical Power Resources and Development Administration has been conducted further research. As a result, the Wind Energy Potential Atlas (WEPA), a wind energy potential map of the country with 200 x 200 m. resolution, was prepared in 2006. The Weather Research and Forecasting (WRF) model and some other regional models are applied to compute the numerical potential of the country (Guler, 2010). WEPA provided a very useful set of wind engineering output data at a 200 x 200 m resolution for all of the country, as listed below:

i. Annual, seasonal, monthly, and daily average wind speed values at different heights, e.g., 30, 50, 70 and 100 m. Figure 7 demonstrates a 3-D view of WEPA showing annual average wind speeds at different heights. Wind resources are concentrated in the western and southern regions of Turkey.

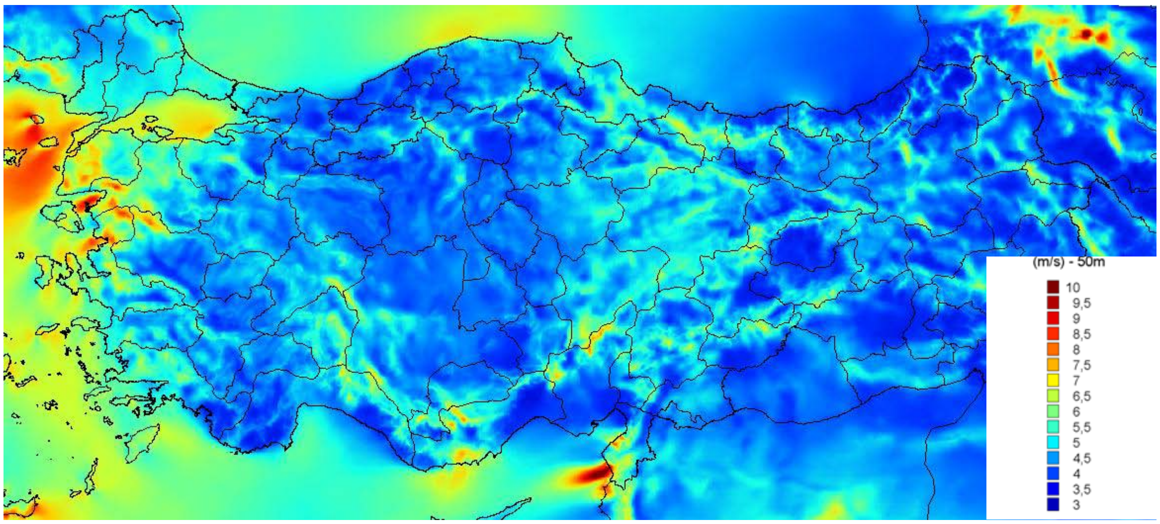
Figure 7. A 3-D View of WEPA Showing Annual Average Wind Speeds.



Source: Malkoc, 2008.

ii. Annual, seasonal, and monthly wind power densities at 50 and 100 m. Figure 8 shows the annual wind power density at a height of 50 m.

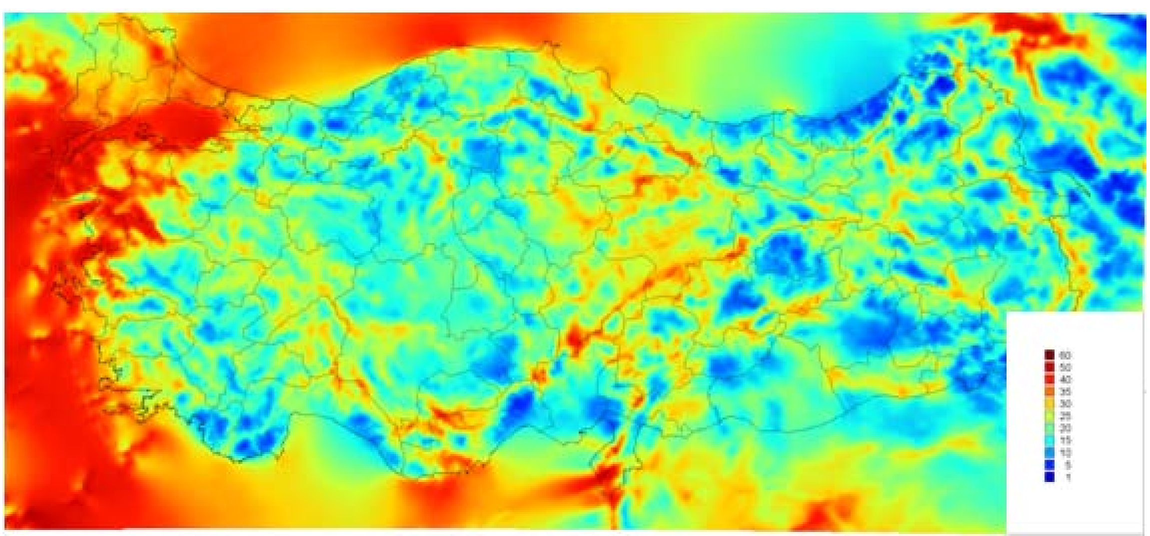
Figure 8. Wind Power Density Map at 50 m.



Source: Malkoc, 2008.

iii. Average capacity factors at 50 m (Figure 9).

Figure 9. Capacity Factor Map at 50 m.



Source: Malkoc, 2008.

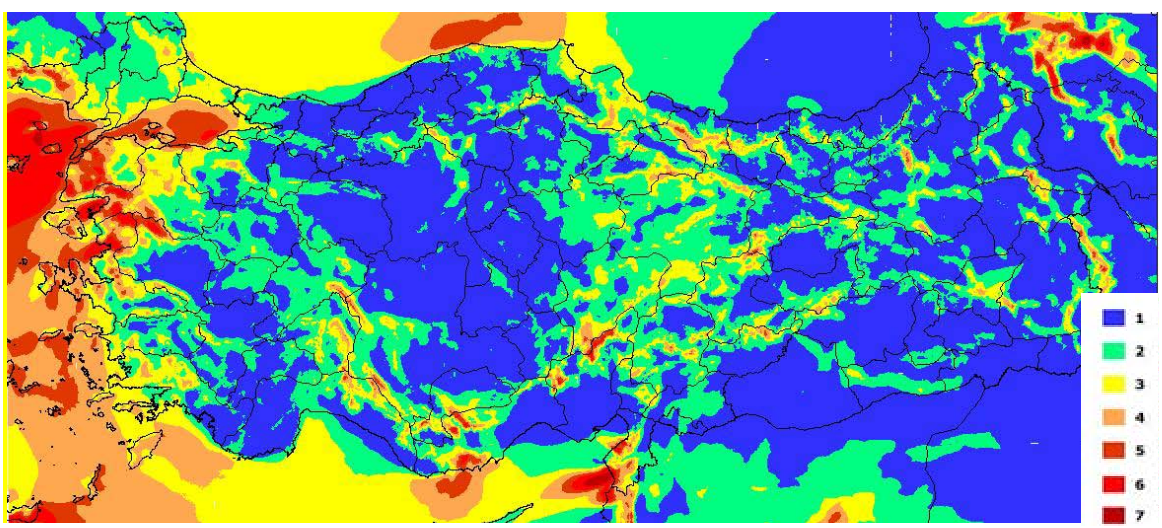
iv. Annual average wind clusters at 50 m (Figure 10). WEPA categorizes wind power clusters into seven classes, from weak to outstanding. The characteristics of wind clusters are listed in Table 4.

Table 4. Wind Clusters and Their Properties in WEPA.

Wind Source Grade	Wind Cluster	Wind Speed at 50 m (m/s)	Wind Power at 50 m (W/m^2)
Weak	1	<5.5	< 200
Low	2	5.5 - 6.5	200 – 300
Medium	3	6.5 – 7.0	300 – 400
Good	4	7.0 – 7.5	400 – 500
Very Good	5	7.5– 8.0	500 – 600
Excellent	6	8.0 – 9.0	600 – 800
Outstanding	7	> 9.0	> 800

Source: Sahin, 2008.

Figure 10. Wind Clusters Map at 50 m.



Source: Malkoc, 2008.

v. Average temperature in degrees at 2 and 50 m.

vi. Monthly average atmospheric pressures at sea level and 50 m.

With WEPA application, high density wind resources on the coasts and high altitude regions that could not be measured previously became visible to the public. The atlas also made possible wind resource parameters to be seen in a 3 dimensional way. The variation in wind resource characteristics with respect to time, location, and height can be analyzed.

Detailed wind resource information in WEPA provided an infrastructure for determination of the favorable regions for wind power generation. The overall wind power generation capacity of Turkey that can be achieved from the utilization of wind resources is also computed by General Directorate of Electrical Power Resources and Development Administration.

The overall wind power generation capacity is obtained by eliminating all parameters that may affect electricity generation on a 200 x 200 m resolution scale. More than 20 underlying maps are embedded in WEPA, namely terrain roughness, topography and altitude, sea depth, land slope, residential units and areas, lakes, rivers, wetlands, ports, power transmission lines and substations, power plants, earthquake fault zones, forests, environmental protection areas, bird migration routes, highways, railways and airports. On the other hand, underlying maps of some other obstacles (mines, oil and natural gas pipelines, military areas, private property, tourism regions and so on) for wind power generation were not incorporated in WEPA computations. For this reason, the areas that are not favorable to construct wind power plants are increased by certain amounts in specific locations to mitigate uncertainty (Malkoc, 2008).

Further assumptions are made to exclude the areas that are not favorable for wind power generation. The areas that are not included in capacity calculations are listed as follows:

- The areas with an annual average wind speed of less than 6.5 m/s,
- Lands with an altitude of more than 1500 m,
- Offshore areas more than 50 m deep,
- Lakes, rivers, wetlands, and dam reservoirs,
- National parks and other environmentally protected areas,
- The terrestrial lands with an inclination of greater than 20%,
- The areas remaining within the 100 m radius safety zone of highways and railways,
- Coastal areas within the 100 m radius zone of coastal protection,
- The areas remaining within 3 km radius to the airports,
- Urban areas and the areas remaining in 500 m radius of safety zones.

After extracting the unfavorable areas for the installation of wind power plants from the total surface area of Turkey, the overall wind power generation potential of the country at a height of 50 m. is computed under two scenarios:

I. Wind power density greater than 400 W/m^2 and wind speed greater than 7.0 m/s, that is, starting from “good” to “outstanding” wind cluster is taken into account.

II. Wind power density greater than 300 W/m^2 and wind speed greater than 6.5 m/s, that is, starting from “middle” to “outstanding” wind cluster is taken into account.

It is also assumed that 5 MW of capacity can be constructed in a 1 km^2 area for both scenarios. The capacity results are presented in Tables 5 and 6.

Table 5. Total Wind Power Potential under Scenario I

Wind Source Grade	**Wind Cluster**	**Wind Power at 50m (W/m^2)**	**Wind Speed at 50m (m/s)**	**Total Area (km^2)**	**Windy Area (%)**	**Total Capacity (MW)**
Good	4	400 – 500	7.0 – 7.5	5,851.87	0.79	29,259.36
Very Good	5	500 – 600	7.5– 8.0	2,598.86	0.35	12,994.32
Excellent	6	600 – 800	8.0 – 9.0	1,079.98	0.15	5,399.92
Outstanding	7	> 800	> 9.0	39.17	0.01	195.84
TOTAL				9,569.89	1.30	**47,849.44**

Source: Malkoc, 2008.

According to Scenario I, that is when the wind speed is greater than 7.0 m/s and wind power density is greater than 400 W/m^2, overall wind power generation capacity in Turkey calculated by WEPA is **47,849 MW**. The area occupied under this scenario is 9,569.89 km^2 which corresponds to 1.30 % of Turkey's total surface area.

Table 6. Total Wind Power Potential under Scenario II

Wind Source Grade	**Wind Cluster**	**Wind Power at 50m (W/m^2)**	**Wind Speed at 50m (m/s)**	**Total Area (km^2)**	**Windy Area (%)**	**Total Capacity (MW)**
Medium	3	300 – 400	6.5 – 7.0	16,781.4	2.27	83,906.96
Good	4	400 – 500	7.0 – 7.5	5,851.87	0.79	29,259.36
Very Good	5	500 – 600	7.5– 8.0	2,598.86	0.35	12,994.32
Excellent	6	600 – 800	8.0 – 9.0	1,079.98	0.15	5,399.92
Outstanding	7	> 800	> 9.0	39.17	0.01	195.84
TOTAL				26,351.3	3.57	**131,756.4**

Source: Malkoc, 2008.

In Scenario II, that is when the wind speed is greater than 6.5 m/s and wind power density is greater than 300 W/m^2, WEPA calculations show that possible overall wind power generation capacity in Turkey is around **131,756 MW**. The surface area occupied under this scenario is 26,351.3 km^2, corresponding to 3.57 % of Turkey's total area.

The wind power potential of the country can also be divided into ***onshore*** and ***offshore*** generation using WEPA. The results under both conditions are presented in Tables 7-10.

Table 7. Offshore Wind Power Potential under Scenario I

Wind Source Grade	**Wind Cluster**	**Wind Power at 50m (W/m^2)**	**Wind Speed at 50m (m/s)**	**Total Area (km^2)**	**Windy Area (%)**	**Total Capacity (MW)**
Good	4	400 – 500	7.0 – 7.5	1,026.64	6.86	5,133.20
Very Good	5	500 – 600	7.5– 8.0	688.96	4.60	3,444.80
Excellent	6	600 – 800	8.0 – 9.0	348.51	2.33	1,742.56
Outstanding	7	> 800	> 9.0	28.54	0.19	142.72
TOTAL				2,092.66	13.98	**10,463.28**

Source: Malkoc, 2008.

Table 8. Offshore Wind Power Potential under Scenario II

Wind Source Grade	**Wind Cluster**	**Wind Power at 50m (W/m^2)**	**Wind Speed at 50m (m/s)**	**Total Area (km^2)**	**Windy Area (%)**	**Total Capacity (MW)**
Medium	3	300 – 400	6.5 – 7.0	1,385.98	9.26	6,929.92
Good	4	400 – 500	7.0 – 7.5	1,026.64	6.86	5,133.20
Very Good	5	500 – 600	7.5– 8.0	688.96	4.60	3,444.80
Excellent	6	600 – 800	8.0 – 9.0	348.51	2.33	1,742.56
Outstanding	7	> 800	> 9.0	28.54	0.19	142.72
TOTAL				3,478.64	23.25	**17,393.20**

Source: Malkoc, 2008.

Table 9. Onshore Wind Power Potential under Scenario I

Wind Source Grade	Wind Cluster	Wind Power at 50m (W/m^2)	Wind Speed at 50m (m/s)	Total Area (km^2)	Windy Area (%)	Total Capacity (MW)
Good	4	400 – 500	7.0 – 7.5	4,825.23	0.66	24,126.16
Very Good	5	500 – 600	7.5– 8.0	1,909.90	0.26	9,549.52
Excellent	6	600 – 800	8.0 – 9.0	731.47	0.10	3,657.36
Outstanding	7	> 800	> 9.0	10.63	0.00	53.12
TOTAL				7,477.23	1.03	**37,386.16**

Source: Malkoc, 2008.

Table 10. Onshore Wind Power Potential under Scenario II

Wind Source Grade	Wind Cluster	Wind Power at 50m (W/m^2)	Wind Speed at 50m (m/s)	Total Area (km^2)	Windy Area (%)	Total Capacity (MW)
Medium	3	300 – 400	6.5 – 7.0	15,395.4	2.13	76,977.04
Good	4	400 – 500	7.0 – 7.5	4,825.23	0.67	24,126.16
Very Good	5	500 – 600	7.5– 8.0	1,909.90	0.26	9,549.52
Excellent	6	600 – 800	8.0 – 9.0	731.47	0.10	3,657.36
Outstanding	7	> 800	> 9.0	10.63	0.00	53.12
TOTAL				22,872.7	3.16	**114,363.2**

Source: Malkoc, 2008.

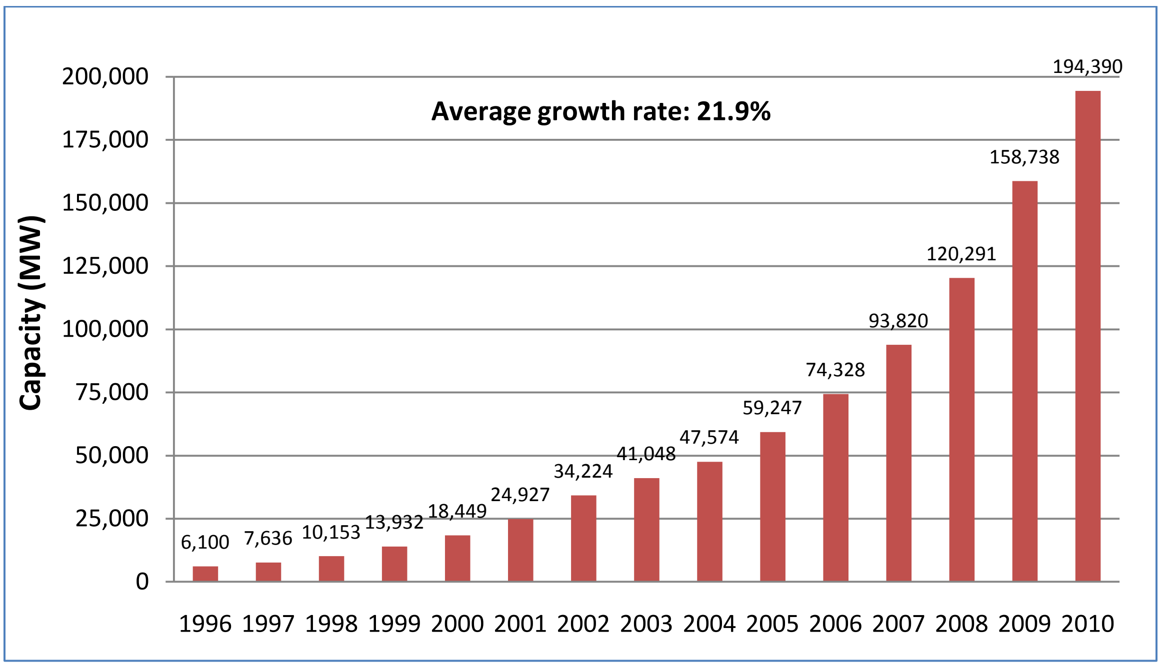
As a result, Turkey has an enormous wind energy potential to exploit for electricity generation. Even in the case of a conservative scenario, the calculated total wind power potential is around 48 GW.

Chapter 4: Current Status of Wind Energy

4.1 Status In The World

Wind power is the fastest growing renewable energy source globally. Since 1996, global wind power capacity has continued to grow at an average annual rate of 21.9%. The main factors for this impressive growth rate in wind power capacity are the promotion of models of renewable energy sources, the security of energy supply, fuel diversification efforts, environmental awareness, and economical advantages. Figure 11 shows the cumulative installed wind power capacity increase in the world between 1996 and 2010.

Figure 21. Global Cumulative Installed Wind Power Capacity (1996-2010)



Source: GWEC, 2011.

By the end of 2010, global wind power installations reached 194,390 MW. As shown in Table 11, almost 36,000 MW of new wind power capacity was installed around the world in 2010, and for the first time ever, the majority of that new capacity was in developing countries and emerging economies rather than in the traditional markets of Europe and North America (GWEC, 2011).

Table 11. Regional Distribution of Global Wind Power Capacity (MW)

	End 2009	**Installed 2010**	**End 2010**
Egypt	430	120	550
Morocco	253	33	286
Total Middle East and Africa	**866**	**213**	**1,079**
China	25,805	16,500	42,287
India	10,926	2,139	13,065
Japan	2,085	221	2,304
Total Asia	**39,639**	**19,022**	**58,641**
Germany	25,777	1,493	27,214
Spain	19,160	1,516	20,676
Italy	4,849	948	5,797
France	4,574	1,086	5,660
UK	4,245	962	5,204
Denmark	3,465	327	3,752
Portugal	3,357	345	3,702
Netherlands	2,223	15	2,237
Sweden	1,560	603	2,163
Ireland	1,310	118	1,428
Turkey	*801*	*528*	*1,329*
Total Europe	**76,300**	**9,883**	**86,075**
Brazil	606	326	931
Mexico	202	316	517
Total Latin America and Caribbean	**1,306**	**703**	**2,008**
U.S.	35,086	5,115	40,180
Canada	3,319	690	4,009

Total North America	**38,405**	**5,805**	**44,189**
Australia	1,712	167	1,880
New Zealand	497	9	506
Total Pacific Region	**2,221**	**176**	**2,397**
World TOTAL	**158,738**	**35,802**	**194,390**

Source: GWEC, 2011.

The growth of wind power capacity outside of the traditional markets was mainly driven by the exceptional growth in China. A record high wind power capacity of 16.5 GW was installed in China in 2010, taking the total wind power capacity of the country up to 42.3 GW. With these new installations, China has outstripped the U.S. and become the world's leading wind power country as indicated in Table 12 below.

Table 12. Total Installed Wind Capacity in Top 10 Wind Power Markets

	Installed Capacity (MW)	**Percentage (%)**
China	42,287	21.8
US	40,180	20.7
Germany	27,214	14
Spain	20,676	10.6
India	13,065	6.7
Italy	5,797	3
France	5,660	2.9
UK	5,204	2.7
Canada	4,009	2.1
Denmark	3,752	1.9
Rest	26,546	13.7
World TOTAL	194,390	100

Source: GWEC, 2011.

The financial crisis and the economic slowdown resulted in lower new wind power installations in OECD countries, particularly in the United States. The wind market in U.S. installed 5.1 GW last year, only about half of the 2009 installations. Texas is the leading state with 10,085 MW of total wind power capacity and wind electricity now meets 7.8% of the state's electricity consumption, more than in Germany (American Wind Energy Association (AWEA), 2011).

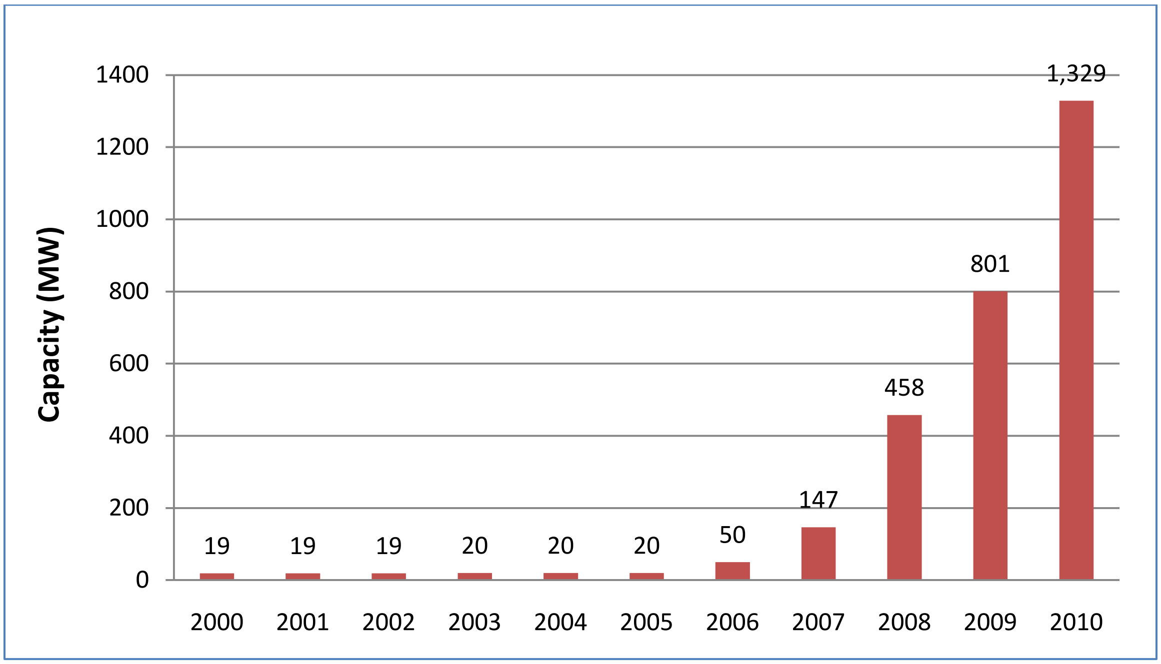
Europe hosts the biggest wind power capacity in the world by the end of 2010; however, the lead will be overtaken by Asia after 2013, according to European Wind Energy Association (EWEA). The total installed wind capacity in Europe now generates 180 TWh of electricity and meets 5.3% of overall European electricity demand (EWEA, 2011).

4.2 STATUS IN TURKEY

The wind power development in Turkey was started with a 1.5 MW capacity wind plant in 1998. The plant consisting of three 500 kW wind turbines was erected in Cesme-Germiyan (Özer, 2004).

Recent years have seen the beginning of a wind power rise in Turkey as illustrated in Figure 12. The total wind power capacity was 20 MW at the end of 2005, and then the wind power market witnessed an impressive growth. 528 MW of new wind power installations, referring to an annual growth rate of 66%, was implemented in 2010. The total installed wind power capacity reached 1,329 MW and this represents more than 2% of the overall electricity generation capacity of Turkey. The introduction of wind generation support mechanisms in 2005 and the subsequent amendment in 2007 helped the Turkish wind energy market to experience such a remarkable progress. Current wind power projects in operation in Turkey are listed in Appendix, together with their location, installed capacity, commission date and turbine manufacturer data.

Figure 12. Cumulative Installed Wind Power Capacity in Turkey (2000-2010)



Source: EWEA, 2011.

Wind power capacity will probably exhibit further increase in the near future with the addition of planned and expected projects. The projected wind power installations for 2011 are nearly 420 MW according to Turkish Electricity Transmission Company (TEIAS)[2]. Installed wind power capacity is projected to expand at between 500 MW-1,000 MW annually reaching more than 5 GW by 2015 (TEIAS, 2010).

[2] TEIAS is the state-owned transmission company and system operator of Turkey.

Turkey has a goal of reaching 20 GW of installed wind power capacity by 2023, assisting the country's aim to obtain 30% of its power generation from renewable energy sources by that date (Higher Board of Planning, 2009). In order to achieve this goal, the transmission infrastructure of the country might require considerable improvements to allocate such large capacity increments.

The current support mechanisms for wind power generation in Turkey will be discussed in detail in the following chapter.

Chapter 5: Wind Power Support Mechanisms in Turkey

Current Turkish laws and regulations regarding the use of renewable energy sources in electricity generation also apply to the wind power generation as wind energy is included in the definition of renewable energy resources. There is no specific legislation existing for wind energy alone.

One of the main responsibilities of the Energy Market Regulatory Authority (EMRA) is to take necessary measures to promote the use of renewable energy resources in electricity generation. In 2003, EMRA amended its Electricity Market Licencing Regulation (EMLR) to include the definition of renewable energy resources, which referred as the first legislative step for renewable electricity generation (IEA, 2004). Some support mechanisms and incentives are also brought into existence with this amendment, which are listed below:

i. The legal entities applying for licenses for construction of generation facilities based on renewable energy resources will only pay 1% of the total licensing fee (Article 12),

ii. The generation facilities based on renewable energy resources will not pay annual license fees for the first 8 years following the facility completion date inserted in their respective licenses (Article 12),

iii. The legal entities engaged in generation activity at facilities based on renewable energy resources may purchase electricity from wholesale companies in order to flatten their supply curves (Article 17),

iv. If the price of electricity generated at facilities based on renewable energy resources is lower than or equal to wholesale electricity price and if there is no cheaper alternative in the market, retail/distribution license holders will be obliged to purchase electricity based on renewables for their electricity needs (Article 30),

v. TEIAS and/or distribution system operators will assign priority for system connection of electiricy generation facilities based on renewable energy resources (Article 38),

vi. Article 6 of Communiqué on the Principles and Procedures of Financial Settlement in the Electricity Market which mentions the legal entities subject to settlement, will not apply to wind generation facilities and canal-type hydroelectric generation facilities (Provisional Article 4),

vii. Generation facilities based on renewable energy resources will be exempt from power transaction duties and fees in the Balancing and Settlement activities.

As the renewable energy market players did not find the incentives provided in EMLR adequate, the desired renewable capacity investments have not been achieved. Hence, Turkey enacted its first Renewable Energy Law[3] in order to promote renewable electricity generation in 2005.

The Renewable Energy Law defined renewable energy resources as wind, solar, geothermal, biomass, biogas, wave, current, and tidal energy resources, together with canal or run-of-river type hydroelectric plants and those with reservoir areas less than 15 km^2. Although being accepted as a renewable energy resource, larger hydroelectric power plants are not incorporated in the support mechanism in the law.

A feed-in tariff scheme implemented based on a fixed wholesale price for all types of renewable energy resources in the Renewable Energy Law. Feed-in tariff support

[3] The Law on Utilization of Renewable Energy Resources for the Purpose of Generating Electrical Energy, (Law No: 5346, enactment date: 5/10/2005).

is the most preferred and effective tool to promote the renewable electricity generation in the EU (Mendona, 2007).

In May 2007 and December 2010, Turkish parliament carried out two amendments to the Renewable Energy Law to improve the feed-in tariffs scheme and other incentives. The up to date legal framework in Turkey to promote renewable electricity generation include the following major incentives:

Feed-in Tariffs

In the initial version of the Renewable Energy Law enacted in 2005, it is stated that average wholesale electricity price of the previous year, which is determined by EMRA, will be paid for renewable electricity generation. With the amendment in 2007, the average wholesale price was lower bounded to 5 Euro cent/kWh and upper limited to 5.5 Euro cent/kWh.

One major criticism to this tariff scheme was the payment of an identical electricity price for all types of renewable energy generation, as power generation costs significantly differ for each renewable energy resource. For example, solar power generation can not to be achieved with a relatively low price of 5.5 Euro cents, considering the high costs of solar technology.

The amendment in December 2010 has replaced this flat electricity price of between 5 Euro cents/kWh and 5.5 Euro cents/kWh with a range of guaranteed prices to promote various types of renewable energy, as shown in Table 13. An unexpected change was that the currency quoted in tariff scheme has changed from Euro cents to USD cents. The amendment marked guaranteed prices of 7.3 USD cent/kWh for wind power and hydroelectric generation, 13.3 USD cent/kWh for solar and biomass and 10.5 USD cent/kWh for geothermal.

Table 13. Guaranteed Prices for Renewable Electricity Generation

Type of Generation Plant	**Prices to apply (USD cent/kWh)**
Hydroelectric	7.3
Wind	7.3
Geothermal energy	10.5
Biomass	13.3
Solar	13.3

Source: Renewable Energy Law Amendment, 2010.

A local content element was also embedded into the tariff scheme with the amendment in December 2010. A long list of supplementary tariff increments was made available to investors who prefer to use locally made Turkish equipment in their power generation plants, as listed in Table 14.

In addition to a guaranteed price of 7.3 USD cent/kWh, a maximum of 3.7 USD cent/kWh was envisaged for wind power generation depending on how much locally produced equipment was used (See Table 14). At present, domestic production of wind plant parts is only limited to wing blades and turbine towers, which adds up a total electricity price of 8.7 USD cent/kWh at most for wind power generation. Although there seems a good opportunity that international turbine manufacturing companies will invest in domestic production, it might probably take at least two years before any locally produced turbines are available.

Table 14. Additional Price Incentives for Locally Made Equipment

Type of the Plant	Domestic Production	Additional Price (USD cent/kWh)
A- Hydroelectric	1- Turbine	1.3
	2- Generator and power electronics	1.0
B- Wind	1- Blades	0.8
	2- Generator and power electronics	1.0
	3- Turbine tower	0.6
	4- Entire mechanical components in rotor and nacelle groups (excluding payments for the wing group and generator and power electronics.)	1.3
C- Solar PV	1- Production of PV panel integration and solar structural mechanics	0.8
	2- PV modules	1.3
	3- Cells constituting the PV module	3.5
	4- Inverter	0.6
	5- Material on the PV module that focuses solar ray	0.5
D- Concentrating Solar	1- Radiation collection tube	2.4
	2- Reflector surface sheet	0.6
	3- Solar tracking system	0.6
	4- Mechanical parts of the heat storage system	1.3
	5- Mechanical parts of the tower steamer collecting solar rays	2.4
	6- Stirling engine	1.3
	7- Panel integration and structural mechanics of the solar panel	0.6
E- Biomass	1- Fluid-bed steam boiler	0.8
	2- Fluid or gas-run steam boiler	0.4
	3- Gasification and gas cleaning group	0.6
	4- Steam or gas turbine	2.0
	5- Internal combustion or stirling engine	0.9
	6- Generator and power electronics	0.5
	7- Cogeneration system	0.4
F- Geothermal	1- Steam or gas turbine	1.3
	2- Generator and power electronics	0.7
	3- Steam injector or vacuum compressor	0.7

Source: Renewable Energy Law Amendment, 2010.

Purchase Obligation

It was stated in the Renewable Energy Law that the electricity retailers are obliged to purchase the power generated from renewable energy resources. The share of renewable generation within the retailers' portfolio cannot be less than their share of the domestic market in the previous year.

The tariff mechanism will be applied for 10 years to renewable energy plants completed in 2005 to 2015. Although the electricity generation from wind energy is obliged to be purchased for 10 years at a minimum price of 7.3 USD cent/kWh, wind power generators may prefer sell their output on the national power spot market or to eligible customers in bilateral agreements. In practice, average spot market prices have been generally higher than the maximum feed in tariff since 2007, and spot market has become more profitable for renewable energy investors (Aslan Y., 2010). However, higher prices in the spot market are not guaranteed to last forever and the investors will want to rely on the purchase obligation.

Reduced fees for project preparation and land acquisition

During the first 10 years of operation of renewable energy plants, an 85% discount is applied on several land use fees. This includes the fees related to permission, rent, right of access, and usage when the property is under the possession the General Directorate of Forestry or the Under Secretariat of Treasury. The 85% discount is also applied to fees related on investments in the transportation infrastructure and power lines until the connection point to the grid.

As a result, Turkey has made considerable progress on the legislative side to promote electricity generation from renewable energy resources. The Renewable Law was the cornerstone of renewable energy legislation. With the introduction of support mechanisms in the Law in 2005 and the subsequent amendment in 2007, Turkish wind energy market has experienced a remarkable progress, from a wind power capacity of 20 MW in 2005 to 1329 MW in 2010. The latest amendment in December 2010 will further encourage wind energy investments and help government to reach its 20 GW target in 2023.

Chapter 6: Economic Assessment of a Wind Power Project

In this chapter, the economic viability of a typical onshore wind power plant residing in a "good" windy resource location will be investigated. As discussed in Chapter 3, a wind resource is classified as a "good" grade when wind power density is between 400 and 500 W/m^2 and wind speed is between 7.0 and 7.5 m/s at a height of 50 m. The analysis is conducted using RETScreen Clean Energy Project Analysis Software, which is a free of charge decision support tool developed by Canadian government.

After a brief introduction on RETScreen software, the electricity output, cost components, and financial viability of the wind power project is presented in the following sections.

6.1 RETSCREEN SOFTWARE

RETScreen is developed under the leadership and support of the CanmetENERGY research centre of Natural Resources Canada, a department of the Government of Canada. The software is developed in collaboration with a number of other government and multilateral organizations, and with the efforts of several experts from government, industry, and universities.

RETScreen Clean Energy Project Analysis Software is a free of charge decision support tool. The software provides the user with a broad variety of options for assessing the energy production and savings, costs, emission reductions, financial viability, and risk for several types of renewable energy technologies. RETScreen also includes trivial databases including product, project, hydrology and climate databases. A global climate database obtained from 4,700 ground-based stations and NASA's satellite data is incorporated in the software (RETScreen, 2011).

The Wind Energy Project Model, which is the embedded in the RETScreen software, can help users to evaluate the energy output, life cycle costs and greenhouse gas (GHG) emissions of wind power projects, ranging in size from large wind farms to a single wind turbine. Five worksheets, namely, *Energy Model, Cost Analysis, Emission Analysis*, *Financial Analysis* and *Risk Analysis* are provided in the model workbook. *Emission Analysis* and *Risk Analysis* worksheets are optional and are not included in our project analysis.

The user follows a top down approach while working on the worksheets. Definitions of the input parameters, chosen values, and obtained results for each of the worksheet will be presented next.

6.2 ENERGY MODEL

The *Energy Model* worksheet is designed to help the user determine the annual energy production of a wind power project. The energy model mainly consists of initial selection of the wind speed, wind turbine, and electricity export rate as inputs. The capacity factor and annual electricity generation amount are the computed outputs. The inputs and the outputs of the worksheet are discussed below.

Wind Speed and Height

The annual average wind speed at the hub height of the wind turbine is used to calculate the annual energy output of the wind power plant. Annual average wind speed is taken to be 7 m/s at 50 m. in order to assess the energy potential of a windy location that belongs to a “good” grade wind resource as indicated before.

Annual Average Temperature

Annual average temperature is needed in the calculation of the power generated available from the wind. The annual average temperature in Turkey ranged from 6 to 22°C in 2010 with a mean of 15.2 °C (Turkish State Meteorological Office, 2011). Thus, a value of 15.2 °C is used for this parameter in this analysis.

Annual Average Atmospheric Pressure

Another input requested from the user is the annual average atmospheric pressure on the site. The value of this parameter typically varies from 60 to 103 kPa. A value of 60 kPa corresponds to a site at an elevation of approximately 4,000 m whereas 103 kPa corresponds to sea level (Elliot et al, 1986).

The atmospheric pressure declines as altitude increases. The average atmospheric pressure, P (kPa), at an altitude of x meters above sea level can be computed by the formula below:

$$P = P_{sealevel} * \boldsymbol{e}^{(-x/8200)}$$

where $P_{sealevel}$ is the atmospheric pressure at sea level (i.e., 101.3 kPa).

The average elevation of Turkey is 1132 m (Dombayci, 2009). Using the formula, annual average atmospheric pressure is found to be 88.6 kPa for Turkey.

Wind Turbine Selection

A single Vestas V47 - 50M wind turbine with a capacity of 660 kW is used in the project. A Vestas turbine is preferred as Vestas leads the Turkish wind market in terms of cumulative installed wind capacity (30%), followed by Enercon (28%) (GWEC 2010). On the other hand, V47 model has the highest energy yield at the height of 50 m in comparison with other Vestas turbines. As the wind energy potential of Turkey is present only for the height of 50 m, this wind turbine is preferred in the project.

The power curve and energy curve data of this turbine is presented in Table 15. The data are prepared by the manufacturing company of the wind turbine and readily present in the wind turbine product database of RETScreen.

Table 2. Power and Energy Curve Data for Vestas V47-50M Turbine

Wind speed m/s	**Power curve data kW**	**Energy curve data MWh**
0	0.0	
1	0.0	
2	0.0	
3	0.0	125.7
4	2.9	415.0
5	43.8	851.4
6	96.7	1,364.7
7	166.0	1,887.0
8	252.0	2,375.0
9	350.0	2,808.6
10	450.0	3,181.7
11	538.0	3,493.5
12	600.0	3,744.7
13	635.0	3,936.5
14	651.0	4,071.7
15	657.0	4,154.6
16	659.0	
17	660.0	
18	660.0	
19	660.0	
20	660.0	
21	660.0	
22	660.0	

Source: RETScreen, 2011.

The Energy Losses and Availability

The user also enters loss percentage figures for the output electricity generation, namely, array losses, airfoil soiling losses, and other miscellaneous losses.

The array losses are a result of the interaction of the wind turbines with each other. Turbines in the "shadow" of others do not get as much wind as the front ones and overall energy production is decreased. As a single turbine is used in this analysis, the value of array losses is assumed to be 0%.

Airfoil soiling losses are a result of soiling of the blades caused by environmental factors, such as ice. The aerodynamic performance of the blades falls and the total energy production may drop. Typical values vary from 1 to 10% of gross energy output (WECTEC, 1996). Airfoil soiling losses due to climatic conditions is assumed to be 3% in this study.

Miscellaneous losses represent the losses due to starts and stops, off-yaw operation, high wind and cut-outs from wind gusts. Parasitic power requirements and transmission line losses are also included in this parameter. Miscellaneous losses are typically in the range of 2 to 4% of gross energy output (Conover, 1994) and assumed to be 3% in this analysis.

Electricity Export Rate

Electricity export rate is the electricity price paid by the electric utility or another customer. This value is not necessary for the calculation of total electricity production but entered in the *Energy Model* worksheet and is copied automatically to the *Financial Analysis* worksheet. 7.3 USD cent/kWh, which is the guaranteed purchase price for wind power generation endorsed in the Renewable Energy Law, will be assumed at this stage.

Further improvements can be made on the purchase price of wind power generation, as we will discuss later.

Results of the Energy Model

The *Energy Model* worksheet computes the wind plant capacity factor and annual electricity generation amount. The capacity factor represents the ratio of the energy delivered to the electrical system over the wind plant's capacity multiplied by the total hours in a year.

Using the values for input parameters discussed in the previous parts, the capacity factor is calculated as 26.8% and the annual net electrical energy produced by the plant is 1552 MWh.

6.3 COST ANALYSIS

The *Cost Analysis* worksheet enables a detailed cost allocation related with a wind energy project. The costs are separated into two main categories; the initial (investment) costs and the annual costs.

6.3.1 Initial Costs

The initial (investment) costs include items, such as the preparation of a feasibility study, performing the project development, completion of the necessary engineering, installation of the energy equipment, and construction of the balance of wind turbine.

6.3.1.1 Feasibility Study

A feasibility study for a wind power plant comprise cost items, such as, a site investigation, a wind resource assessment, an environmental assessment, a preliminary project design, a detailed cost estimate, and a final report preparation. Travel and accommodation costs and project management costs are also among the other costs incurred. Table 16 shows the level of effort (person-days) and cost items associated with the feasibility study for the wind power project.

Table 3. Costs Associated with Feasibility Study

Feasibility Study	**Unit**	**Quantity**	**Unit Cost ($)**	**Amount ($)**
Site Investigation	p-d	2	500	1,000
Resource Assessment	project	1	17,500	17,500
Environmental Assessment	p-d	2	500	1,000
Preliminary Design	p-d	2	500	1,000
Detailed Cost Estimate	p-d	10	500	5,000
Report Preparation	p-d	2	500	1,000
Project Management	p-d	2	500	1,000
Travel and Accommodation	p-trip	20	200	4,000
TOTAL				31,500

Site Investigation

A site investigation is necessary after a general area has been determined for the installation of the wind turbine. A project team including at least a wind plant project expert and a meteorologist visits the site in order to explore and gather necessary data required for the turbine construction. The costs of a site investigation with at least two experts typically vary from $300 to $1,000 per person (RETScreen, 2004). In this project analysis, the site investigation costs are assumed to be $500 per person (Ozcan, 2009).

Wind Resource Assessment

A reliable and realistic assessment of the wind energy resource is of great importance for the success of the power project. Wind resource assessment involves the establishment of one or more measurement stations, which will be used for collection of resource data for at least one year in the field.

The installation cost of a measurement station typically varies from $10,000 to $25,000, depending on the diversity of the requested data and the height of the station (RETScreen, 2004). For a single wind turbine, one or two measurement stations are sufficient for the assessment of wind resource. The cost for wind resource assessment is assumed to be $17,500 in this project analysis.

Environmental Assessment

Environmental assessment is an important step in the feasibility study of renewable energy projects. This stage aims to investigate the environmental impacts of the project, such as, noise, visual impacts, and the impacts on vegetation and animals. The daily fee of an environmental expert will range from $200 to $800 per day (RETScreen, 2004). The total cost of this step is assumed to be $1,000.

Preliminary design

This stage is required in order to determine a detailed estimation of the optimum system capacity, the size and layout of the equipment, and construction costs. The cost of preliminary design depends largely on the size of the plant. For a single turbine, the cost of this stage is assumed to be $500 for 2 days, resulting $1,000 in total.

Detailed Cost Estimate

The detailed cost estimate is based on the previous stages of feasibility study. This phase is carried out by companies providing engineering services, specializing in wind energy projects. The cost typically ranges from $200 to $800 per person-day (RETScreen, 2004). The size of the wind power project affects the time and cost of the study. A 10 day study with a daily fee of $500 is assumed in this analysis.

Report Preparation

A final report describing the findings and recommendations of feasibility study is prepared in order to enable project investors to assess the project. The preparation of the final report includes between 2 and 15 person-days costing from $200 to $800 per person-day (RETScreen, 2004). A 2 day work with a daily fee of $500 is assumed in this analysis.

Project Management

Management of all the stages of the feasibility study, such as meetings with the shareholders, may take time and incur costs. This stage may take up between 2 and 8 person days at a daily fee of between $200 and $800 per person-day (RETScreen, 2004). A 2 person-day work with a daily fee of $500 is assumed in this analysis.

Travel and Accommodation

This item covers the estimated travel and accommodation costs of all experts in charge of the feasibility study. 20 trips each costing $200 is assumed in this analysis (Ozcan, 2009).

6.3.1.2 Development Costs

After the feasibility study has been completed, project development activities follow. The project development costs include contract negotiations, permits and approvals, site survey and land rights, project financing, legal and accounting, project management, and travel and accommodation costs. Table 17 shows the level of effort (person-days) and cost items associated with project development.

Table 4. Costs Associated with Project Development

Project Development	**Unit**	**Quantity**	**Unit Cost ($)**	**Amount ($)**
Contract Negotiations	p-d	2	300	600
Permits and Approvals	project	10	500	5,000
Site Survey and Land Rights	p-d	4	300	1,200
Project Financing	p-d	10	500	5,000
Legal and Accounting	p-d	20	500	10,000
Project Management	p-d	20	300	6,000
Travel and Accommodation	p-trip	10	200	2,000
TOTAL				29,800

Contract Negotiations

One of the main steps after the feasibility study is to make an electricity purchase agreement with the potential contractors. This step may involve between 0 and 30 person-days with a rate between $300 and $1,500 in general (RETScreen, 2004). As electricity retailers are obliged to purchase the wind generation in Turkey, only a 2 person-day work with a daily fee of $300 is assumed in this analysis.

Permits and Approvals

Several permits and approvals from government institutions and local authorities are necessary in Turkey for a wind energy project to be implemented. An estimated $5000 budget is allocated for these expenses (Ozcan, 2009).

Site Survey and Land Rights

The costs associated with the site survey and investigation of land rights are closely related to status of the land ownership and legal issues. A site survey of 4 days at a daily rate of $300 per day is assumed in this study (Ozcan, 2009).

Project Financing

The time and effort necessary to find project funding can be important for energy projects. Financial experts provide services such as identification of funds, finding the appropriate financing model (debt and equity commitments), and making required arrangements. The cost of these services may vary at a rate of between $500 and $1,000 per person-day (RETScreen, 2004). A 10 person-day work with a daily fee of $500 is assumed in this analysis.

Legal and Accounting

The support of legal and accounting experts will be necessary in many parts of the project development. A 20 person-day work with a daily fee of $500 is assumed in this analysis (Ozcan, 2009).

Project Management

Management of all the stages of the project development, such as public relations, may take considerable time and incur costs. A 20 person-day work with a rate of $300 will be sufficient for this case.

Travel and Accommodation

This cost item covers the estimated travel and accommodation costs of all experts in charge of project development. The travel and accommodation stage may involve 10 trips each costing $200 in this analysis.

6.3.1.3 Engineering Costs

The engineering costs of the wind power project include micro-siting, mechanical, electrical and civil design, tenders and contracting, and construction supervision. Table 18 shows the level of effort (person-days) and cost items associated with project development.

Table 5. Costs Associated with Engineering

Engineering	**Unit**	**Quantity**	**Unit Cost ($)**	**Amount ($)**
Site and Building Design	p-d	3	300	900
Mechanical Design	p-d	5	500	2,500
Electrical Design	p-d	5	500	2,500
Civil Design	p-d	10	500	5,000
Tenders and Contracting	p-d	5	500	2,500
Construction Supervision	p-d	30	300	9,000
TOTAL				22,400

Site and Building Design

This cost item covers the cost of engineering services associated with the individual wind turbine micro-siting that might be necessary because of site specific variations in winds due to topography, terrain and obstructions. The site and building costs may involve costs for additional topographical data and wind resource modeling. For a single wind turbine, a 3 person-day work with a daily fee of $300 will be sufficient for site and building costs (Ozcan, 2009).

Mechanical Design

Mechanical engineering tasks such as facility design and erection of wind turbine are included in this step. The mechanical design costs vary between 3 and 10 person-days at a rate of between $300 and $1,000 per person-day (RETScreen, 2004). A 5 person-day work with a daily fee of $500 is assumed in this analysis.

Electrical Design

The design of the connection of the wind power plant to the power transmission system and the construction of electrical system inside the plant facility are the main electrical design tasks in the project development. Electrical design costs vary between 3 and 10 person-days at a daily rate between $300 and $1,000 per person-day (RETScreen, 2004). A 5 person-day work with a daily fee of $500 is assumed in this analysis.

Civil Design

The design of the establishment of the plant base and access roads are the principal civil design tasks in the project development. Civil design costs involve between 3 and 20 person-days at a rate of $300 and $1,000 per person-day (RETScreen, 2004). A 10 person-day work with a daily fee of $500 is assumed in this analysis.

Tenders & Contracting

After a number of engineering design tasks have been completed, the next step is the preparation of the tender documents by the professionals. The selection of the contractors is followed after the announcement of the tender documents. The costs involve between 4 and 300 person-days at a rate of between $200 and $800 (RETScreen, 2004). For a single wind turbine, a 5 person-day work with a daily fee of $500 seems reasonable.

Construction Supervision

The construction supervision step involves the overseeing of the power plant by a consultant or a project manager. Regular inspections of the project are done on field trips. A 30 person-day work with a daily fee of $300 is assumed in this project (Ozcan, 2009).

6.3.1.4 Power System Costs

The power system is the main cost component of a wind power project as it includes the costs of the wind turbine, road construction, and transmission line. Table 19 summarizes the cost items associated with power system.

Table 6. Costs Associated with Power System

Power System	**Unit**	**Quantity**	**Unit Cost ($)**	**Amount ($)**
Wind Turbine	kW	660	-	750,000
Road Construction	km	10	5,000	50,000
Transmission Line	km	5	20,000	100,000
TOTAL				900,000

Wind Turbine

A Vestas V47 - 50M wind turbine with a capacity of 660 kW is preferred in this model, as discussed in the previous parts. The cost of this turbine is approximately $750,000, according to a study by Renewable Energy Research Laboratory in 2004.

Road Construction

The construction of an access road might be necessary in some cases depending on the terrain of the wind power project. The presence of access roads is considered as an important criterion during site selection phase. Cost for road construction adds up to $50,000, assuming a $5,000 per km cost for construction per single wind turbine (Ozcan, 2009).

Transmission Line

Transmission line costs vary depending on the voltage level, the installed capacity and distance to the power substations. In case of installation of a larger wind farm, the transmission line costs per wind kW declines. Assuming a $20,000 cost per km (Zond, 1994) and 5 km long transmission line is required for this project, the total transmission costs are allocated as $100,000 for the single wind turbine.

6.3.1.5 Balance of System and Miscellaneous Costs

The costs associated with the wind turbine foundation and erection, spare parts, transportation, training and commissioning, contingencies and interest during construction are included in this cost item. Table 20 below lists balance of system and miscellaneous costs.

Table 7. Balance of System and Miscellaneous Costs.

Balance of System and Miscellaneous Costs	**Unit**	**Quantity**	**Unit Cost ($)**	**Amount ($)**
Wind Turbine Foundation	turbine	1	12,000	12,000
Wind Turbine Erection	turbine	1	20,000	20,000
Spare Parts	%	3	750,000	22,500
Transportation	project	-	-	20,000
Training and Commissioning	p-d	4	300	1,200
Contingencies	%	3	1,106,900	33,207
Interest during Construction	%5	12 months	1,140,107	28,503
TOTAL				123,903

Wind Turbine Foundation

The costs associated with the turbine foundation involve the labor and equipment costs. Transportation of equipment could also be a significant part of the cost. For medium wind turbines, foundation costs typically vary between $7,000 and $25,000 per turbine (RETScreen, 2004). Foundation cost for the 660 kW Vestas V47-50M is assumed as $12,000 in this analysis.

Wind Turbine Erection

Labor costs and rental costs of special erection equipment are involved in this cost item. The equipment needed for wind turbine erection might vary from cranes and heavy vehicles to special winches. Zond (1994) claims that the wind turbine erection costs typically represent 4% of the total wind energy equipment and balance of plant costs. A total of $20,000 is assumed in this analysis for turbine erection costs.

Spare Parts

The costs of the spare parts that are required to support the wind turbine are included in this cost item. The percentage of the total wind turbine cost is typically used as a cost estimate. Lynette (1992) asserts that 1.5% of the total turbine costs can be used to estimate the cost of spare parts for large wind projects, however; the ratio can increase for small wind projects and single turbines. The cost of spare parts for this project is assumed as 3% of the total wind turbine cost.

Transportation

Transportation costs vary depending on the plant location and the form of transport available. Transportation costs are also best described as a user-selected percentage of the total turbine cost and assumed as 5% of the cost of the turbine for this project (Ozcan, 2009). A total of $20,000 is assumed in this analysis for turbine erection costs.

Training and Commissioning

In order to perform periodic operation and maintenance tasks, a maintenance team should be trained and employed. The training costs will depend on the size and complexity of the project. For single turbines, one technician can be sufficient to manage operation and maintenance tasks. 2 day training at a rate of $300 is assumed for training in this analysis. Commissioning involves the initial operation of all the systems to detect and fix any faults, and make sure that the plant operates as guaranteed. The commissioning costs are also estimated as 2 person-day work at a rate of $300 for this project.

Contingencies

Costs for contingencies are estimated based on a user-selected percentage of the total project costs except the interest cost during construction. The tolerated percentage for contingencies is assumed to be 3% in this analysis, which nearly equals to $33,000.

Interest Cost during Construction

The short term financing during construction depends on the opportunity cost of money and the length of the construction. The user enters the interest during construction as a percentage and the length of construction in months. RETScreen assumes the average debt over the project duration as 50% of the project costs in the calculations. In this analysis, the overall project costs are assumed to be financed over 12 months at an annual rate of 5%.

6.3.1.6 Breakdown of Initial Costs

Main cost items and their percentages in the initial costs are summarized in Table 21 below:

Table 8. Breakdown of Initial Costs

Initial Costs	**Cost ($)**	**Percentage (%)**
Feasibility Study	$ 31,500	2.7
Development	$ 29,800	2.6
Engineering	$ 22,400	1.9
Power System	$900,000	77.0
Balance of System and Misc. Costs	$ 194,666	15.8
Total Initial Costs	$1,353,366	100.0

Power system costs have the largest share (79.4%) in initial costs and among the cost items listed in power system costs, the wind turbine costs have the largest portion (See Table 19).

6.3.2 Annual Costs

The annual costs are associated with the operational and maintenance costs of the wind power plant in times of operation. Land lease and resource rental, insurance premium, parts and labor, general and administrative costs, and contingencies are included in annual cost analysis. Table 22 shows the breakdown of annual operation and maintenance costs.

Table 9. Components of Annual Costs

Annual Costs	**Unit**	**Quantity**	**Unit Cost ($)**	**Amount ($)**
Land Lease	project	1	-	-
Insurance Premium	project	1	$ 4,000	$ 4,000
Parts and Labor	project	1	$ 10,000	$10,000
General and Administrative	%	10	$ 14,000	$ 1,400
Contingencies	%	10.0	$ 15,400	$ 1,540
TOTAL				$16,940

Land Lease

As the usage of properties of public domain is allowed for usage of renewable energy generation purposes and 85% reduction and/or exemptions are applicable for several land use fees in Turkey, land lease or rental costs are neglected in this analysis (Ozcan, 2009).

Insurance Premium

Insurance is at least required for public liability, property damage, and operation failure. As a rule of thumb, the annual insurance premium for a wind power project can typically vary from 2 to 4% of energy revenues (Conover, 1994) Hence, the costs associated with insurance are estimated as $4,000.

Parts and Labor

The cost item for parts and labor involves the cost of spare parts[4] and labor necessary for periodic and urgent maintenance and operation of the wind power plant. The parts and labor costs are typically stated as dollars per kWh produced by the wind plant. A cost of 0.7 cents/kWh for parts and labor seems to be a reasonable estimation (Gipe, 1995). As the annual electricity output is computed as 1552 MWh in energy model part, the parts and labor costs are assumed to be $10,000.

General and Administrative Costs

The costs associated with general and administrative duties are best expressed as a percentage of total annual operation and maintenance costs. For a single turbine, 10% of total annual costs can be considered as a reasonable approximation (RETScreen, 2004).

Contingencies

Analogous with contingencies examined in the balance of system part, the cost is estimated based on a percentage of total annual costs. The tolerated percentage typically varies between 10 and 20% of these costs (RETScreen, 2004). The costs associated with contingencies are assumed to be 10% in this analysis.

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[4] The cost of the spare parts in this section are different from the one in the Balance of System and Miscellaneous Costs. The previously mentioned costs were for inventorial purposes and generally an element of the purchase price of the wind turbine from the manufacturer.

6.4 Financial Analysis

One of the main features of RETScreen software is that it helps the decision-makers better evaluate the economic viability of the wind power project. *Financial Analysis* worksheet computes important financial outputs, such as, simple payback, net present value (NPV), and internal rate of return (IRR), using the user defined financial parameters such as inflation rate, discount rate, and debt ratio and the previously recorded energy production and cost data.

The financial inputs necessary to conduct the financial analysis are introduced first, and the results of the financial analysis for different scenarios are then presented in the following parts.

Inflation Rate

The projected annual average rate of inflation over the life of the project is required for the financial computations. Inflation rate is assumed to be 3% in this analysis (Blanco, 2009).

Discount Rate

Discount rate is the rate used to bring future cash flows to a value in order to obtain their present worth. A company's weighted average cost of capital is commonly considered as the most appropriate rate. The discount rate is assumed to be 10% in this analysis. This ratio is reasonable for wind power projects, and has been used in several studies (RETScreen, 2004).

Income Tax

The RETScreen software calculates after tax cash flows and after tax financial indicators if an income tax rate is provided by the user. In Turkey, corporate income tax is applied at 20% rate on the corporate earnings (Revenue Administration, 2011).

Project Life

The wind power plants are assumed to have a 25 year project life as this is the period that most manufacturers guarantee the wind turbine can operate (ENTRIX, 2009 and Recalde, 2010).

Debt Conditions

The debt ratio as well as the term and interest of the debt have a significant effect on the financial viability of a wind power project. As the energy projects in general are capital intensive investments, the ratio of debt in financing of the projects typically range from anywhere from 50 to 90%. The debt ratio is assumed to be 80% in this analysis in parallel with many studies from literature (Blanco, 2009 and Ozcan, 2009).

Debt term is the number of years over which the debt is reimbursed. In general, the financial viability of an energy project improves as the debt has a longer term. The term of the debt is assumed to be 15 years (Ozcan, 2009).

The debt interest rate is used to compute the debt payments at the end of each year of the debt term. At a minimum, the debt interest rate will correspond to the yield of government bonds with the same term as the debt term. For the wind power projects in Turkey, the debt interest rates typically vary between 6 month LIBOR + 2.5-4 percent (Ozcan, 2009). Six month LIBOR is for a six month deposit in U.S. dollars on the last business day of the previous month. The 6 month LIBOR rate for March 2011 is reported as 0.464 percent (Moneycafe, 2011). As a result, a debt interest rate of 3.5% is assumed in this analysis.

6.5 RESULTS

The Renewable Energy Law offers a guaranteed electricity price of 7.3 USD cent/kWh for wind power generation, with an additional maximum of 3.7 USD cent/kWh depending on how much locally produced equipment was used in the project (See Table 13). However, local production of wind plant equipment is only limited to wing blades and turbine towers as of now, adding up to a total price of 8.7 USD cent/kWh at most for wind power generation.

The economic analysis is conducted under two scenarios based on the electricity prices stated above. In the first scenario, an electricity price of 7.3 USD cent/kWh is used assuming no local equipment is employed in the wind power plant, and in the second scenario, 8.7 USD cent/kWh is used assuming locally produced wing blades and turbine towers are employed in the plant.

Financial results including the annual electricity export income, payback period, annual cash flows, NPV, and IRR will be presented for both scenarios in the following parts.

6.5.1 First Scenario

The annual net electrical energy produced by the plant is 1552 MWh. For an electricity sale price of 7.3 USD cent/kWh, the annual electricity sale income is $113,284.

Payback Period

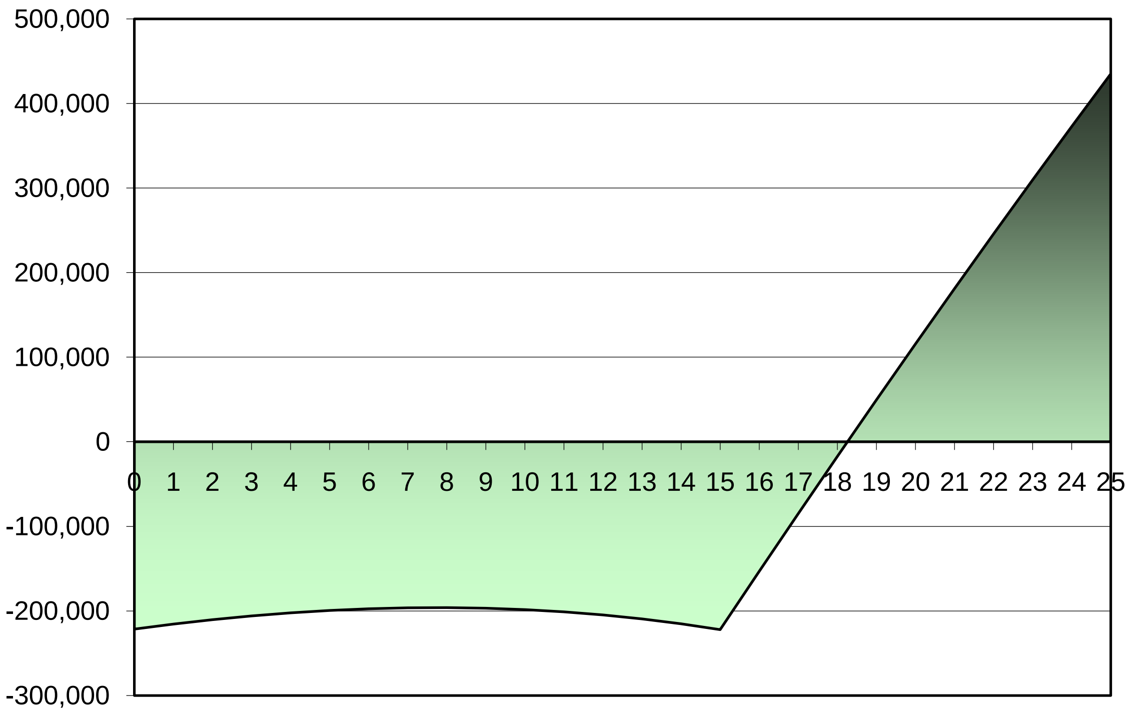
RETScreen software calculates the simple payback period, which is a common and easy parameter to assess the economic viability of an investment. The payback period is the number of years that it takes for an investment project to recoup its own initial costs. In order to compute the simple payback period, total initial costs are divided by the difference between annual energy income and annual operating costs. The yearly cash flows of the project is shown in Table 23 and depicted in Figure 13.

Table 10. Yearly Cash Flows for the First Scenario

Year #	**Pre-tax** $	**After-tax** $	**Cumulative** $
0	-221,521	-221,521	-221,521
1	18,902	5,937	-215,583
2	18,379	5,197	-210,386
3	17,839	4,433	-205,953
4	17,284	3,645	-202,308
5	16,712	2,831	-199,478
6	16,123	1,990	-197,487
7	15,516	1,123	-196,364
8	14,891	228	-196,136
9	14,247	-696	-196,832
10	13,584	-1,650	-198,482
11	12,901	-2,634	-201,116
12	12,198	-3,650	-204,767
13	11,473	-4,699	-209,466
14	10,727	-5,782	-215,248
15	9,958	-6,900	-222,148
16	86,101	68,881	-153,268
17	85,285	68,228	-85,040
18	84,445	67,556	-17,483
19	83,580	66,864	49,381
20	82,689	66,151	115,532
21	81,771	65,417	180,948
22	80,826	64,660	245,609
23	79,852	63,881	309,490
24	78,849	63,079	372,569
25	77,816	62,253	434,822

The simple payback method should not be utilized as the main indicator to assess an investment as it does not take into account the time value of money, nor the inflation impact on the costs. The simple payback is 11.5 years and equity payback is 18.3 years for the first scenario, which may be considered as high payback periods.

Figure 3. Cumulative Cash Flows for the First Scenario.



NPV

The NPV method is the principal indicator of the economic viability of investments. NPV is calculated by discounting future positive and negative cash flows to present values using an appropriate discount rate. The difference between the present values of these cash flows, i.e. NPV, signals if the project is generally an economically viable investment or not.

As a rule of thumb, a positive NPV shows a profitable investment and an NPV lower than zero indicates the opposite. The projects with negative NPV values should not be invested. RETScreen model computes the NPV using the cumulative after tax cash flows. The discount rate is assumed to be 10% and NPV is found -$112,525, indicating that the first scenario is not economically viable.

IRR

IRR can be considered as a “breakeven” discount rate which makes the NPV of the project equal to zero. The main advantage of the IRR is that it is an evaluation of investment efficiency. A good IRR should be higher than the opportunity cost for some other project.

Computed after tax IRR on equity for the first scenario is 5.7%, which is lower than the discount rate, indicating that the first scenario is not economically viable.

6.5.2 Second Scenario

An electricity price of 8.7 USD cent/kWh, which is the total purchase price when locally produced wing blades and turbine towers are used in the wind power plant, makes the annual electricity income $135,010.

Payback Period

The simple payback is 9.4 years and equity payback is 11.7 years for this scenario. The computed payback periods are lower than the first scenario, as expected.

Yearly cash flows of the project for second scenario is shown in Table 24 and depicted in Figure 14.

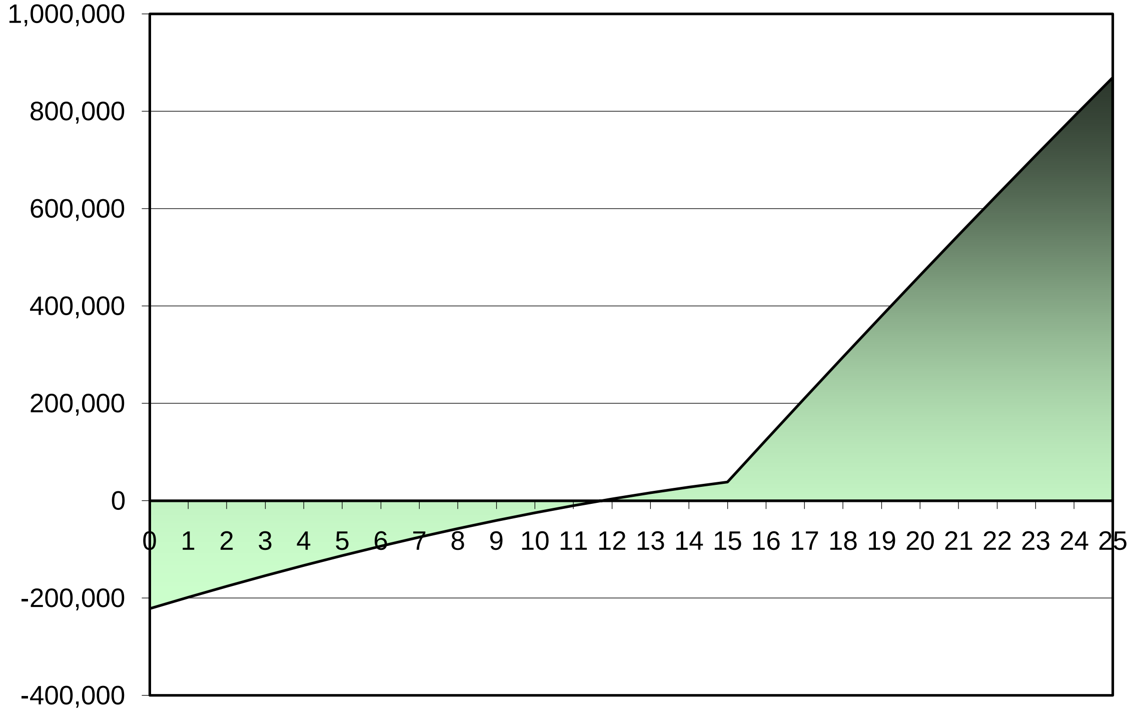
Table 11. Yearly Cash Flows for the Second Scenario

Year **#**	**Pre-tax** **$**	**After-tax** **$**	**Cumulative** **$**
0	-221,521	-221,521	-221,521
1	40,628	23,318	-198,203
2	40,104	22,578	-175,625
3	39,565	21,814	-153,811
4	39,010	21,025	-132,786
5	38,438	20,211	-112,575
6	37,849	19,371	-93,204
7	37,242	18,504	-74,700
8	36,617	17,609	-57,091
9	35,973	16,685	-40,407
10	35,310	15,731	-24,676
11	34,627	14,746	-9,929
12	33,924	13,730	3,801
13	33,199	12,681	16,482
14	32,453	11,598	28,080
15	31,684	10,481	38,561
16	107,826	86,261	124,822
17	107,011	85,609	210,431
18	106,171	84,937	295,368
19	105,306	84,245	379,612
20	104,415	83,532	463,144
21	103,497	82,797	545,941
22	102,551	82,041	627,982
23	101,578	81,262	709,245
24	100,575	80,460	789,704
25	99,542	79,633	869,337

NPV

NPV for the second scenario is $45,240. A positive NPV indicates that an electricity purchase price of 8.7 USD cent/kWh makes the wind power project a profitable investment.

Figure 4. Cumulative Cash Flows for the First Scenario.



IRR

Computed after tax IRR on equity for this scenario is 11.8%. IRR is slightly higher than the discount rate, but still makes the wind power project economically viable.

Chapter 7: Conclusions

The Renewable Energy Law was the milestone for the promotion of wind energy use in electricity generation in Turkey. With the introduction of incentives in the Law in 2005 and the subsequent amendment in 2007, Turkish wind energy market has experienced a remarkable progress, from a wind power capacity of 20 MW in 2005 to 1329 MW in 2010. The latest amendment in December 2010 offered a guaranteed electricity price of 7.3 USD cent/kWh for wind power generation, with an additional maximum of 3.7 USD cent/kWh depending on how much locally produced equipment was used in the project. For now, domestic production of wind plant parts is only limited to wing blades and turbine towers, which adds up to a total electricity price of 8.7 USD cent/kWh at most for wind power generation.

The results of the economic analysis indicate that an electricity price of 7.3 USD cent/kWh, which is the guaranteed price for wind power generation in the Renewable Energy Law, does not make a typical onshore wind power plant residing in a “good” windy resource not economically viable. However, when locally produced wing blades and turbine towers are used in the plant, the electricity purchase price increases to 8.7 USD cent/kWh, and the project becomes economically viable in this case.

When from “good” to “outstanding” wind clusters are taken into account, the overall technical onshore wind power generation capacity in Turkey calculated by WEPA is nearly 37 GW, as discussed in Chapter 3. As a consequence, the local content element introduced with the latest amendment in the Renewable Energy Law further encourage wind energy investments and help government to reach its 20 GW target in 2023. In the long run, the law may also kindle investments of the wind turbine manufacturers to produce all wind power equipment in Turkey.

Appendix

Wind Power Projects in Operation in Turkey as of 5/10/2010.

Location	Company	Capacity (MW)	Date	Turbine Man.	Turbine Capacity (MW)	Number of Turbines
Izmir-Cesme	Alize Enerji Elektrik Üretim A.S.	1.5	1998	Enercon	0.5	3
Izmir-Cesme	Ares Alaçati Rüzgar Enerjisi Sant. San. ve Tic. A.S.	7.2	1998	Vestas	0.6	12
Istanbul-Hadimköy	Sunjüt Sun'i Jüt San. ve Tic. A.S	1.2	2003	Enercon	0.6	2
Balikesir-Bandirma	Yapisan Elektrik Üretim A.S.	30	2006	GE	1.5	20
Izmir-Çesme	Mare Manastir Rüzgar Enerjisi Santrali San. ve Tic. A.S.	39.2	2006	Enercon	0.8	49
Istanbul-Silivri	Teperes Elektrik Üretim A.S.	0.85	2007	Vestas	0.85	1
Çanakkale-Intepe	Anemon Enerji Elektrik Üretim A.S.	30.4	2007	Enercon	0.8	38
Manisa-Akhisar	Deniz Elektrik Üretim Ltd. Sti.	10.8	2007	Vestas	1.8	6
Çanakkale-Gelibolu	Doðal Enerji Elektrik Üretim A.S.	14.9	2007	Enercon	0.8 and 0.9	13-800 kW 5- 900 kW
Manisa-Sayalar	Doðal Enerji Elektrik Üretim A.S.	34.2	2008	Enercon	0.9	38
Istanbul-Çatalca	Ertürk Elektrik Üretim A.S.	60	2008	Vestas	3	20
Izmir-Aliaða	Innores Elektrik Üretim A.S.	57.5	2008	Nordex	2.5	23
Istanbul-Gaziosmanpasa	Lodos Elektrik Üretim A.S.	24	2008	Enercon	2	12
Mugla-Datça	Dares Datça Rüzgar Enerji Santrali Sanayi ve Ticaret A.S.	29.6	2008	Enercon	0.9	37
Hatay-Samandag	Deniz Elektrik Üretim Ltd. Sti.	30	2008	Vestas	2	15
Aydin-Didim	Ayen Enerji A.S.	31.5	2009	Suzlon	2.1	15
Balikesir-Samli	Baki Elektrik Üretim Ltd. Sti.	90	2009	Vestas	3	30
Hatay-Belen	Belen Elektrik Üretim A.S.	30	2009	Vestas	3	10
Tekirdag-Sarköy	Alize Enerji Elektrik Üretim A.S.	28.8	2009	Enercon	2 and 0.9	14- 2 MW 1-800 kW
Izmir-Urla	Kores Kocadag Rüzgar Enerji Santrali Üretim A.S.	15	2009	Nordex	2.5	6
Çanakkale-Ezine	Alize Enerji Elektrik Üretim A.S.	20.8	2009	Enercon	2 and 0.8	10-2 MW 1-800 kW

Balikesir-Susurluk	Alize Enerji Elektrik Üretim A.S.	20.7	2009	Enercon	0.9	23
Izmir-Bergama	Ütopya Elektrik Üretim Sanayi ve Ticaret A.S.	15	2009	GE	2.5	6
Izmir -Çesme	Mazi-3 Rüzgar Enerjisi Santrali Elektrik Üretim A.S.	30	2009	Nordex	2.5	12
Balikesir-Bandirma	Akenerji Elektrik Üretim A.S.	15	2009	Vestas	3	5
Balikesir-Bandirma	Borasco Enerji ve Kimya Sanayi ve Ticaret A.S.	45	2009	Vestas	3	15
Osmaniye-Bahçe	Rotor Elektrik Üretim A.S.	95	2010	GE	2.5	54
Manisa-Soma	Soma Enerji Elektrik Üretim A.S.	49.5	2010	Enercon	0.9	55
Balikesir-Bandirma	As Makinsan Temiz Enerji Elektrik Üretim San. ve Tic. A.S.	24	2010	Nordex	3	10
Mersin-Mut	Akdeniz Elektrik Üretim A.S.	33	2010	Vestas	3	11
Çanakkale-Bozcaada	Bores Bozcaada Rüzgar Enj. Sant. San. ve Tic. A.S.	10.2	2000	Enercon	0.6	17
Izmir-Aliaga	Bergama RES Enerji Üretim A.S.	90	2010	Nordex	2.5	36
Edirne-Enez	Boreas Enerji Üretim A.S.	15	2010	Nordex	2.5	6

Source: Turkish Wind Energy Association (TWEA), 2010.

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