Chapter 26
Wind Potential and Wind Economics in Türkiye

Gökhan Dündar and Özcan Atlam

Abstract Wind power has been widely used by humans throughout history for varied purposes. With the beginning of the industrial age, energy demand increased greatly and fossil fuels increased in usage. In the twenty-first century, due to environmental concerns, all the countries started to increase their renewable energy portfolio. Türkiye, sitting the world's major energy transfer routes, is highly dependent on imported fossil fuel resources. However, Türkiye has various and abundant renewable energy resources; hydropower in the mountainous eastern region, solar power in the southern, western and Marmara coastal regions and wind power mostly in the Aegean and Marmara region. This paper focuses on the wind potential in Türkiye, the biggest technical potential in Europe, green jobs created by wind, steps to be taken to adapt wind energy and contingencies associated with the policies.

Keywords Turkish wind potential · Wind energy · Wind power · Green jobs

1 Introduction

Energy plays a key role in development of the countries; there is a high correlation between economic growth and energy consumption [1]. Worldwide energy consumption is increasing; according to [2], 2009 was the only year evidencing a decrease in consumption (by an amount of 1.1%) in the last 30 years, a result of the 2008 global crisis. Since the effects of the COVID-19 pandemic have not been reported in detail at the time this article is being prepared, it is not possible to discuss the outcomes of the global crisis. However, a drop on energy consumption is expected due to the diminished supply and demand. In order to sustain economic growth and satisfy demand, different energy resources are being used, the primary being coal, oil, natural gas (NG), hydroelectric, nuclear and a small portion of renewables. At the beginning of the industrial age in eighteenth century, coal consumption increased greatly; with the invention of internal combustion engines oil took the crown from coal. Oil prices

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jumped from $5/barrel to $45/barrel in the oil crisis in the 1970s and have recently been fluctuating at the $90-$110/barrel level [3]. Türkiye, importing almost all of its fossil fuel resources including oil, has been highly affected by fluctuations in the energy market and volatile oil prices.

Türkiye has a wealth of renewable resources which can help increase its energy independence and drive economic growth. Biomass, in its primitive form, has been the major heating source in the Asia Minor for ages. Hydropower has been and is still being extracted from the rivers throughout the country. Two major rivers, the Firat and Dicle, feed the $36 billion Southeastern Anatolia Project, a set of dams and irrigation facilities which nourishes the dry Southeast Anatolian fields and plays a major role in supplying water to SE Anatolia, as well as Syria and Iraq. Even though solar power is mostly used in solar thermal form for water heating purposes in the Mediterranean region, investments in photovoltaics gained momentum in the past 10 years surpassing the solar thermal installations. In addition to aforementioned energy, sources electricity generation and ground heating in some parts of the geothermal rich west Aegean region are conducted via the warm geothermal generosity of mother earth.

Many articles have been investigated to best picture the current status of the wind market in Türkiye however most of them either lacked up to date information or do not have detailed data. Most of the data used in this article have been extracted from Turkish State Meteorological Service and European Wind Energy Association. Furthermore, current legislation has been investigated through Turkish Republic Ministry of Energy and Natural Resources website. During the literature survey, we realized that most of the scientific research has been conducted by Turkish State Meteorological Service and very little has been performed by the universities. Most of the studies published by academia use the analysis results of the state research.

This paper will focus on the current role of wind power, potential for increasing its employment and energy independence implications in Türkiye. Both wind turbine economics and the green jobs created from wind will be discussed in the economics section of the paper, with consideration given to the political aspects of wind energy installations.

2 General View of the Energy Market in Türkiye

Türkiye, having the 18th highest economic growth rate in the world and the 1st in Europe, 8.2% in 2010 [4], currently has the 20th biggest economy due to the economic impacts of pandemic [5]. This rate correlates linearly with energy consumption. Türkiye imported 41.2B$ worth energy in 2019. This amounts about 5% of GDP. When compared to previous terms, approximately 1% decrease in external dependency has been observed. Energy balance of Türkiye in 2018 is presented in Table 1 [6]. When we evaluate the data, it can be seen that despite a 3% drop in oil imports, there is a 40% increase in coal imports. Decrease in budget deficit is targeted by allowing more renewable penetration in the market. If sustainable economic growth

Table 1 Energy resources of Türkiye

Energy source	Production [×1015 btu]	Import [×1015 btu]	Consumption [×1015 btu]	Import rate (%)
Coal	0.739	1.018	1.757	56
Natural gas	0.016	1.775	1.791	99
Petroleum and products	0.12	1.822	1.942	94
Renewable resources	0.887	–	0.887	0

while ensuring energy security and decreasing carbon footprint is aimed, then Türkiye should seek to increase domestic energy resource utilization, mainly renewables.

Historical energy consumption for Türkiye is shown in Fig. 1. It can be seen that energy consumption in 2008 is almost four times bigger than it was in 1980s and is still increasing. The minor decreases in consumption relates to the global and domestic economic crises. However, the trend is almost linearly increasing. Since the last 2 years, data are not clearly reported they are not included in the graph but a drop is expected for 2020 due to the pandemic.

Despite the fact that Türkiye sits on the major energy transfer lines in the world, which connect the petrol rich Middle East and the NG-rich Russian/Caucasian region to Europe and the rest of the world, it has very limited economically feasible extractable fossil fuel resources [7]. Volatility of the oil prices and anthropogenic emissions associated with fossil fuels force Türkiye, like the rest of the world, to increase renewable energy share in its energy portfolio.

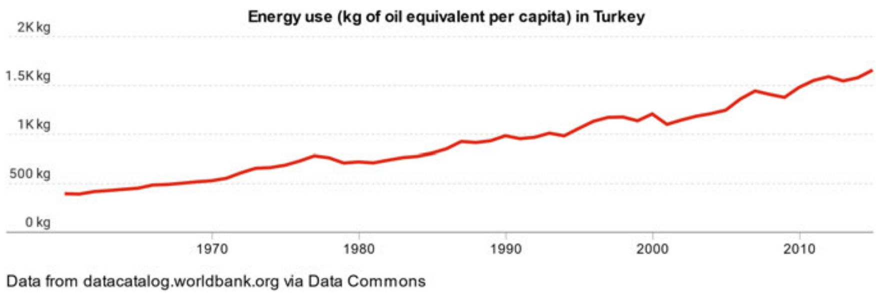

Fig. 1 Energy consumption of Türkiye

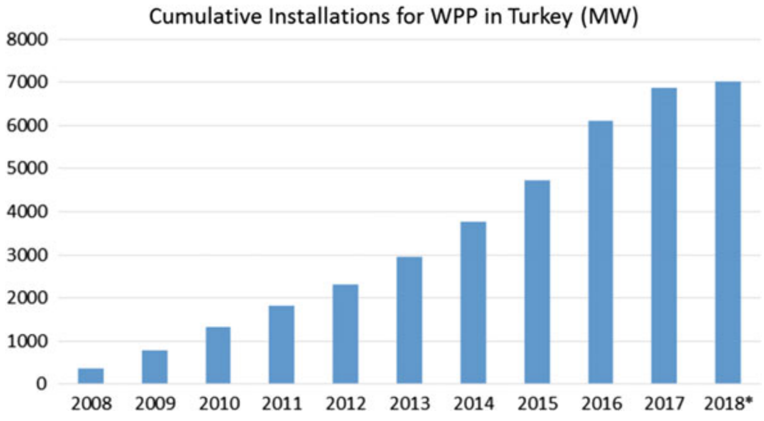

Fig. 2 Cumulative wind power installations in Türkiye

3 Wind Power in Türkiye

3.1 History and Evolution of Wind Power

Use of wind power in Anatolia goes back to ancient Troy. There are historical maps and pictures showing wind mills being used in the fourteenth century in Asia Minor. In the nineteenth century, according to a survey executed by Turkish Ministry of Agriculture, there were 749 wind mills, 718 of which were used for pumping water and 41 were used to generate electricity [8]. The first relatively large-scale implementation of wind power for electricity production was in 1986, in İzmir [9], with a 55 kW name plate capacity wind turbine. It was built for supplying energy to Altınyunus touristic facilities. Yet research into wind power did not turn to industrial/commercial applications until after 1996. The first commercial wind power plant, which has a 1.5 MW nominal capacity, was established in 1998 in Çeşme/İzmir [7]. Since then, there has been an increase in the wind power installations, both in terms of capacity and in terms of number of projects. An exponential increase in the cumulative wind capacity installation is shown in Fig. 2.

3.2 Current Wind Market

Wind power started to regain its value in late 1990s and the new wind market started to attract the attention of investors after the first commercial electricity producing wind plant was erected. Realizing there is a big potential to mitigate energy dependence, the Turkish Parliament enacted the “Electricity Market Law-4628” on February 2, 2001 to encourage more investment [10]. According to this legislation, the Turkish electrical grid changed to become a free electricity market, with grid operation passed

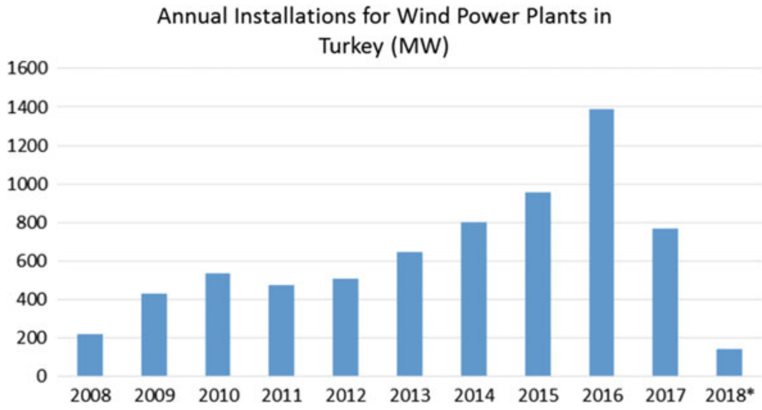

Fig. 3 Annual installation of wind power plants in Turkey

on to private companies, which made the sector attractive for private investments. With the aid of incentives, wind plant investments increased rapidly until 2017. Subsequently, a decrease in new installation is observed due to economic stress. Annual installations for wind plants are shown in Fig. 3.

The installed and proposed capacity numbers demonstrate the competitiveness of this new sector. However, the Turkish government is now faced with the challenge of separating proper proposals from those that are lacking in practicality. Only 1.5 MW of nameplate capacity out of a proposed 85 MW capacity was accepted by the government. By the end of 2018, total installed capacity in Türkiye reached up to 7369 MW. This increase amounts to 390 MW annual installation since 2008 and 730 MW since 2010. A comparison of installed capacity per country is given in Table 2.

4 Turkish Wind Potential Evaluation

A Turkish wind atlas was created using the Wind Atlas Analysis and Application Program (WASP), which is the main software to create the European Wind Atlas. All the calculations and the studies were executed by the Turkish State Meteorological Service. Based on the data derived from the field, measurements and calculations, the Turkish wind potential was estimated at 88,000 MW [13]. This places Türkiye's overall technical wind potential ahead of that of all European countries. Technical potential refers to the amount of wind power that can be extracted out of the gross potential. Gross potential estimates all the wind power over a region regardless of land use, land characteristics and economics while technical potential accounts for land use and applicability of the wind installation. According to wind energy prediction system (RETS–Rüzgar Enerjisi Tahmin Sistemi Tur.), the Turkish regional average wind speed and wind power density are shown in Figs. 4 and 5, respectively.

Table 2 Worldwide installed capacity

#	Country	2018 (MW) [11]	2019 (MW) [12]
1	China	211,392	236,402
2	European Union	178,826	192,020
3	USA	96,665	105,466
4	Germany	59,311	61,357
5	India	35,129	37,506
6	Spain	23,494	25,808
7	England	20,970	23,515
8	France	15,309	16,643
9	Brazil	14,707	15,452
10	Canada	12,816	13,413
11	Italy	9958	10,512
12	Sweden	7407	8804
13	Türkiye	7369	8056

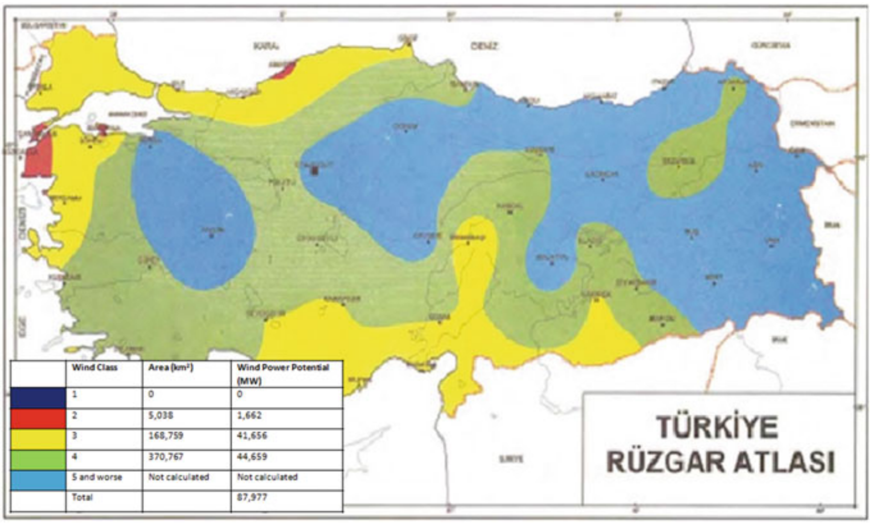

Fig. 4 Turkish Wind Atlas (wind class lower than 5 is not economically feasible so not calculated)

Wind power is stronger in the coastal regions, particularly in the western and northwestern coastal Marmara region. Average wind speed and wind potential in the mountainous inner regions are less than that are in the western regions, hence, most of the current installation proposals target the high wind west coast.

2020 energy consumption of Türkiye was 6.4 quadrillion BTU, an equivalent of 161MMtoe. If all the onshore wind energy in Türkiye were utilized with a capacity factor of 30%, 13% of total energy consumption would be satisfied. Given that oil

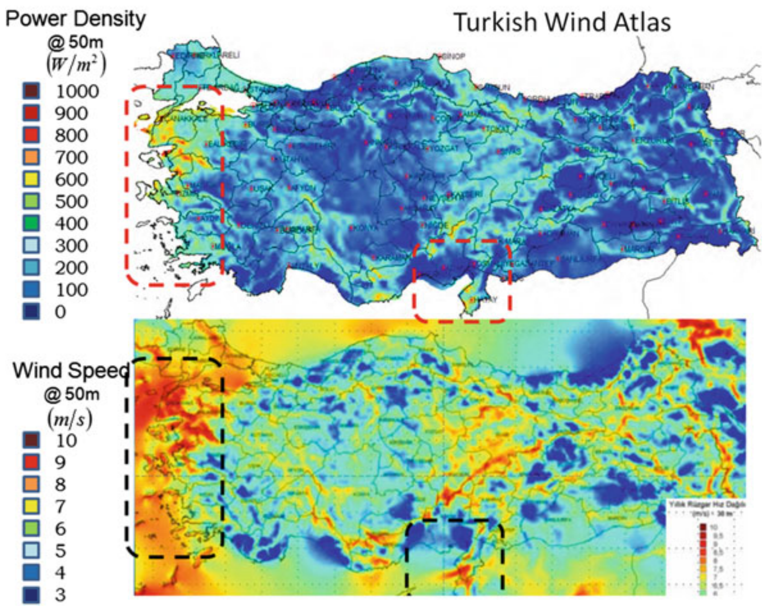

Fig. 5 Turkish Wind Atlas, power density and average wind speed

price is $100.5/barrel the economic value of the energy itself is $11.05 billion [14]. In addition to its sole economic value, new jobs created would significantly increase the prosperity of the local community.

5 Wind Power Economics

5.1 Wind Plant Economics

Wind energy worldwide, the fastest growing energy technology in terms of installed capacity since 2002, reached up to 651GW in 2019 yet still supplies only 1% of total global electricity [15]. The main reason for this is the highly matured conventional power plants, namely coal, nuclear and NG plants. Economics for diverse energy technologies differ in parameters that affect the cost, but converge in the same governing parameters, high installation costs and fuel costs. In fossil fuel power plants, the driving force for the levelized cost of energy (LCE) is fuel cost. For nuclear reactors, fixed and variable operation and maintenance (O&M) cost governs the LCE. It can be seen from Table 3 that variable O&M cost for renewable energy (excluding geothermal and biomass) is insignificant compared to other costs. The capital cost for wind is competitive with advanced coal plants and nuclear plants. The capital costs of photovoltaic and solar thermal are much bigger than those of other technologies. This makes wind power favorable among its alternatives. One challenge with wind power, however, is the almost perfect negative correlation between high-demand periods and high wind generation capability periods, namely the strongest winds usually blow at night, when the demand is the lowest while during the day wind usually stops or blows weakly. Therefore, the real value of wind, with a competitive LCE compared to conventional systems, is actually less than its cost. If wind power was to be delivered during the high demand, it would be more valuable pragmatically; there remains a solid need for conventional power plants (nuclear, coal, gas turbines) and/or backup systems. In order to provide grid-level energy storage to utilize more wind power, there are some mature technologies such as pumped hydrostorage or compressed air energy storage and some innovative technologies such as ocean renewable energy storage and energy storage in balloons [16].

Development in the wind turbine technologies has decreased the cost of electricity generation from 4 to 6 ¢/kWh to 2 ¢/kWh in the past 20 years [17]. However, even with technological advancement, wind still depends highly on financial incentives and/or subsidies. Since, onshore wind is a mature industry, the borders of which are well defined by the Betz Limit and current turbine aerodynamics, the cost associated with the technology itself is not expected to drop significantly. Therefore, it is not hard to conclude that the future of wind power is political in nature. In Türkiye, as in most countries, government subsidy policies are decided either annually or for a given period. This leads to long-term uncertainty since Türkiye still lacks a long-term energy strategy. Although, recent political and bureaucratic enhancements and modernizations in Turkish legislature are projected to make the wind market more stable.

In addition, despite not signing the Kyoto Protocol, there is popular public support toward securing a greener future, which eventually will result in more strict CO2 regulations. Measures to be taken to reduce CO2 emissions will make wind even more attractive than it is now.

In most part of the world, utilities buy wind power produced by individuals or private companies, this is called feed-in tariff (FIT). FIT for Türkiye and some EU countries is given in Table 4.

European officials claim that FIT prices in Türkiye are low thus not competitive compared to other EU countries. However, energy legislature is being adapted to EU legislature so that the entire infrastructure is becoming better organized and mature.

5.2 Role of Wind Nature on Wind Economics

The natural characteristics of the wind engender certain problems: Unlike other technologies, wind power is not concentrated at one point; instead, it is distributed over a region. Additionally, regions where there is high wind potential are not necessarily located close to the population centers and large population centers make the installation of wind turbines difficult for aesthetic and logistic reasons. Furthermore, large population areas usually have higher buildings which has a negative effect on onsite

Table 3 US levelized cost of electricity of various technologies

Plant type	Capacity factor (%)	US average levelized costs (2009 $/mega watt hour) for plants entering service in 2016				
		Levelized capital cost	Fixed O&M	Variable O&M (including fuel)	Transmission investment	Total system levelized cost
Conventional coal	85	65.3	3.9	24.3	1.2	94.8
Advanced coal	85	74.6	7.9	25.7	1.2	109.4
Advanced coal with CCS	85	92.7	9.2	33.1	1.2	136.2
Natural gas-fired						
Conventional combined cycle	87	17.5	1.9	45.6	1.2	66.1
Advanced combined cycle	87	17.9	1.9	42	1.2	63.1
Advanced CC with CCS	87	34.6	3.9	49.6	1.2	89.3
Conventional combustion turbine	30	45.8	3.7	71.5	3.5	124.5
Advanced combustion turbine	30	31.6	5.5	62.9	3.5	103.5
Advanced nuclear	90	90.1	11.1	11.7	1	113.9
Wind	34	83.9	9.6	0	3.5	97
Wind–Offshore	34	209.3	28.1	0	5.9	243.2
Solar PV[1]	25	194.6	12.1	0	4	210.7
Solar thermal	18	259.4	46.6	0	5.8	311.8
Geothermal	92	79.3	11.9	9.5	1	101.7
Biomass	83	55.3	13.7	42.3	1.3	112.5
Hydro	52	74.5	3.8	6.3	1.9	86.4

[1]Costs are expressed in terms of net AC power available to the grid for the installed capacity

Table 4 Feed-in tariff prices for EU countries [18]

Country	Feed-in tariff price c/kWh (USD)
Türkiye	7.3
Germany	9.6
France	11.3
UK	42.7
Denmark	4.82
Spain	9.65

wind profile. This characteristic of wind yields to long transmission lines which means both higher cost and bigger transmission losses.

The intermittent nature of the wind makes it impossible to act as a baseload or intermediate plant without the addition of a storage capability, which adds significantly enough to the capital cost to make it uncompetitive. There is no proven commercial large-scale energy storage device, other than pumped hydro storage and compressed air energy storage, which are both dependent on geological location.

Another problem associated with wind is dispatchability. You cannot turn on and off your wind plants to satisfy the demand. Both the intermittency and the non-dispatchable characteristics of wind make it hard to allow a smooth grid penetration. When wind stops unexpectedly, in a very short time compared to coal plants, low ramping time power plants, namely gas turbines should be turned on immediately. A solution to this can be increasing spinning reserve capacity so that in the case of intermittency, these reserves can act in a very short tie and maintain the system stability. However, this also adds up to the cost of electricity for the end user. Since installed wind power must be coupled with an appropriate back up power system, the target economic benefits of wind power are hard to achieve.

5.3 *Employment Economics*

Efforts to reduce global warming and CO^2 emissions and rising environmental concerns have opened a new market for employment—green jobs. Basically, green jobs refer to any kind of jobs related to the renewable energy sector as well specifically to reduce CO^2 emissions. When any kind of wind project is built, three kinds of jobs are created: direct, indirect and induced jobs. Direct jobs refer to people directly working in the production and installation of wind turbines. Indirect jobs include the suppliers who are already there, but increase their production volume or change their products due to demand in this field. For instance, wind turbine installation is a direct job, whereas cable manufacturing is an indirect job. Induced jobs are those related to the jobs created by the economic welfare distributed by the new wind installations. When first installing wind turbines employment peaks, because there is a temporary labor demand for installation, however, after finishing the installations, this first group of jobs leaves, to be replaced with a lesser number of O&M jobs.

Direct employment can be calculated according to McKinsey-2006 [19]. A peak 228 MW wind farm creates 500 jobs distributed over 5 years for installing the required equipment and 40 O&M jobs distributed over a 20-year operational lifespan. Starting from an estimated 5-year installation period until the end of a 20-year operational lifetime of a 228 MW Vestas wind farm, 2500 job-years for installation plus 800 job-years for O&M are created. All the job-years created by 228 MW wind farm running with 30% capacity factor installation divided a 25-year lifespan of the project yields 1.93 jobs/MW. The case that was mentioned above is assuming only the direct installation jobs. However, building a factory to manufacture wind turbines or adapting and boosting cable factories will create permanent jobs, where the 88,000 MW wind power capacity of Türkiye fully utilized, without any environmental concerns and regardless of whether it is applicable or not, 169,824 jobs for a 25-year period would be provided. Of course, this is an unrealistic, impractical scenario but it provides a useful description of the wind market in Türkiye.

Since there is no possible analytical way to learn and calculate the indirect employment, a few models were designed to predict indirect job generation. Renewable energy study in Germany [20] for general renewable energy and the European Wind Report [18] is highly used to analytically model the indirect jobs created associated with wind. According to these two reports, a multiplier of 0.9 is used to estimate indirect jobs created. In this case, 1.93 jobs/MW multiplied by 0.9 yields to 1.74 indirect jobs/MW. One should not forget that this is a rough ballpark figure. When this estimation is applied to Turkish total wind potential, it results in 152,856 indirect jobs. Leveraging this potential with the proper strategy and investment Türkiye can be one of the manufacturers of wind turbines.

6 Conclusions

Blessed with abundant wind potential, there is a big market for wind energy in Türkiye. However, as in the rest of the world, wind energy relies highly on governmental policies, both in terms of economics and in terms of applicability. Türkiye has showed a great deal of improvement in adapting its legislature to the fast growing and developing wind market. The future of wind will be decided by policy measures to be taken for CO^2 reduction, government subsidies and financial incentives. We have inadequate knowledge and experience to predict the long-term effects of wind penetration on grids. Hopefully, lessons learned from the Danish and German examples will make the future of wind brighter. Even with the existing uncertainties and predictable contingencies, the wind market in the world and particularly in Türkiye is developing rapidly. Türkiye has the biggest technical capacity in Europe and increasing the implementation of wind power has the potential to result in more economic power, energy security and jobs created.

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