

# Wind Energy Status in Turkey

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**Abstract**—Since large part of electricity is generated by using fossil based resources, energy is an important agenda for countries. In this context, renewable energy sources are alternative to conventional sources due to the depletion of fossil resources, increasing awareness of climate change and global warming concerns. Solar, wind and hydropower energy are the main renewable energy sources. Among of them, since installed capacity of wind power has increased approximately eight times between 2008 - November of 2014, wind energy is a promising source for Turkey. Furthermore, signing of Kyoto Protocol can be accepted as a milestone for Turkey's energy policy. Turkish Government has announced Vision 2023 (energy targets by 2023) in 2010-2014 Strategic Plan prepared by Ministry of Energy and Natural Resources (MENR). Energy targets in this plan can be summarized as follows: Share of renewable energy sources in electricity generation is 30% of total electricity generation by 2023. Installed capacity of wind energy will be 20 GW by 2023. Other renewable energy sources such as solar, hydropower and geothermal are encouraged with new incentive mechanisms. Dependence on foreign energy is reduced for sustainability and energy security. On the other hand, since Turkey is surrounded by three coastal areas, wind energy potential is convenient for wind power application. As of November of 2014, total installed capacity of wind power plants is 3.51 GW and a lot of wind power plants are under construction with capacity 1.16 GW. Turkish government also encourages the locally manufactured equipments. In this context, one of the projects funded by private sector, universities and TÜBİTAK names as MILRES is an important project aimed to promote the use wind energy in electricity generation. Within this project, wind turbine with 500 kW power has been produced and will be installed at the beginning of the 2015. After that, by using the experience obtained from the first phase of the project, a wind turbine with 2.5 MW power will be manufactured in an industrial scale.

**Keywords**—Wind energy, wind speed, Vision 2023, MILRES (national wind energy system), wind energy potential, Turkey.

## I. INTRODUCTION

ENERGY is an important indicator determining economical development for countries. In addition, energy security and dependency on natural resources are the main important issues of the 21st century. In this context, tendency to new energy sources have been popular nowadays because of exhaustion of fossil resources, climate change, and public awareness of global warming [1], [2].

Electricity consumption in Turkey increases rapidly because of industrial and technological developments, economical progress and welfare level of people. However, share of fossil resources are very high in electricity generation. As of end of

2013, fossil based resources such as natural gas, coal and lignite, etc. are used as a raw material in 72% of generated electricity in Turkey [3]. Furthermore, these resources are limited in nature and have harming effect on environment and human health. Since large part of the natural gas and coal are imported resources, these sources impose additional burden to the national economy of Turkey. Therefore, diversification of energy resources has become an important issue [4], [5].

Turkey, which is a developing country, is the sixth economy in Europe and seventeenth economy in the world and has big electricity demand. Growing of electricity demands require some changes in energy policies. In this context, signing of Kyoto Protocol in 2009 is a milestone for Turkey's energy policies. Although enactment of renewable energy law has been made in the last decade, use of renewable energy does not expand in Turkey. After the publication of 2010-2014 Strategic Plan prepared by MENR, energy targets have been announced by Turkish Government. These targets include different issues. Energy targets that have been announced in this plan can be briefly summarized as three key points. Increasing of renewable energy share in electricity generation is the first target. Second target is the reduction of imported fossil based resources in the near future. The last one is the achievement of independency of energy [4]-[6].

Turkey is located between Europe and Asia and surrounded by seas around three sides [2] and geographical location of Turkey is convenient for use of renewable energy sources such as solar, wind, hydropower. Besides, Turkey has an important wind energy potential especially in the Marmara region, Aegean region, costs of western and Southeast Anatolia.

MILRES is natural wind energy system project of Turkey which aims to encourage the locally produced equipment in wind power plants (WPP). This project is supported by Scientific and Technological Research Council of Turkey (TÜBİTAK), Sabancı University, Turkish Aerospace Industries (TUSAS-TAI) and İstanbul Technical University. Wind turbine with 500kW has been produced in the first phase of the project. Then, wind turbine with 2.5 MW will be produced with locally developed technology in the second of this project.

This paper explains the wind energy status in Turkey as of November of 2014. The remainder of the paper is organized as follows into five sections. Importance of electrical energy for Turkey, share of resources in electricity generation and increasing awareness of global warming are discussed in Section II. Section III shows wind energy status in the World, wind energy potential, annual average wind speed of districts of Turkey. Energy targets by 2023 on renewable energy sources of Turkish government prepared by MENR and one of the national projects named as MILRES (national wind energy system) and legislation process renewable energy based

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electricity generation system are discussed in Section IV. In addition, current status of MILRES is given in this section. Finally, an overall assessment and recommendations are discussed in the last section.

## II. ELECTRICAL POWER DEMAND IN TURKEY

Electrical power demand is an indicator for development level of countries. Turkey is a developing country and electrical power demand increases continuously. It is accepted that alternative sources are needed to meet this growing demand. Because, fossil based resources such as natural gas, coal, lignite etc are limited and have negative impact on nature. On the other hand, solar, wind and hydro are the main renewable energy sources which are unlimited and have not harming effect on environment. Furthermore, these sources are available in different potential in each country. Although potential of renewable energy sources are sufficient for electricity generation, technical and economical constraints are the factors which cause to reduction of this potential. Nevertheless, increase of renewable energy share in electricity generation is the main agenda for countries.

Turkey is the sixth economy in Europe. With industrial and technological development, electricity needs are increasing each passing year. Electricity demand is 242.37 TWh in 2012 and 245.48 TWh in 2013. Annual average increase in electricity demand is 5% between 2001 and 2013 [7]. According to the Turkish Electricity Transmission Company's (TEIAS), projections, annual average increase in electricity demand will be 6.4% and 7.9% for the low and high scenario in the next five years, respectively [7]. Fig. 1 shows the annual electricity consumption in Turkey between 2000 and November of 2014.

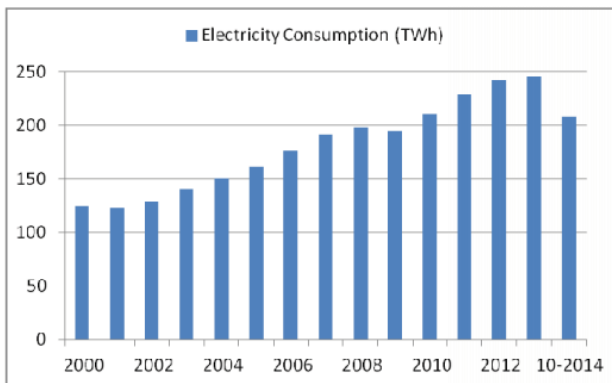


Fig. 1 Electricity needs of Turkey between 2000-10/2014

As of November of 2014, Turkey's installed power capacity is 68.72 GW. Large part of this capacity consists of fossil based power plants. Share of fossil based plants in installed power is 60%. Remains of total capacity consists of hydropower, geothermal, wind and solar. However, when it comes to share of resources in electricity generation, 80% of total electricity is generated by fossil based power plants. Because, Turkey is an energy importing country due to the

high dependency on foreign energy. However, this is an undesirable condition for sustainable development and energy security for Turkey. Fig. 2 shows the share of resources in electricity generation for the last three years.

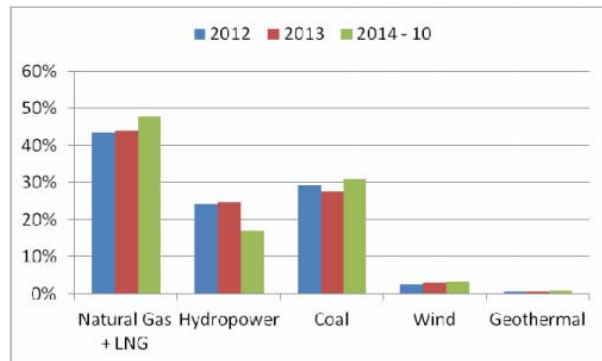


Fig. 2 Share of resources in electricity generation

2010-2014 Strategic Plan prepared by MENR explains Vision 2023 which consists of Turkey's energy targets by 2023. This plan includes various issues. Energy is one of the priorities of Turkey. After approval of the Kyoto Protocol as an Annex I country, benefits of renewable energy sources are appeared and policy makers increasingly recognize the potential role of wind power as part of the country's future energy [8]. Thus, awareness of wind energy potential is promising for Turkey's energy policy. As of November of 2014, installed power capacity is 3.51GW [9] and 20 GW is the targeted power which Turkish Government aims to install by 2023 [4]-[6].

## III. WIND ENERGY STATUS: WORLD & TURKEY

Tendency on renewable energy sources in electricity generation is an important agenda due to the depletion of fossil based resources, their dynamic prices and environmental concerns. Thus usage of wind energy, one of the renewable energy, has increased over the World in recent years. Fig. 3 presents the installed capacity of wind energy power plants in the World.

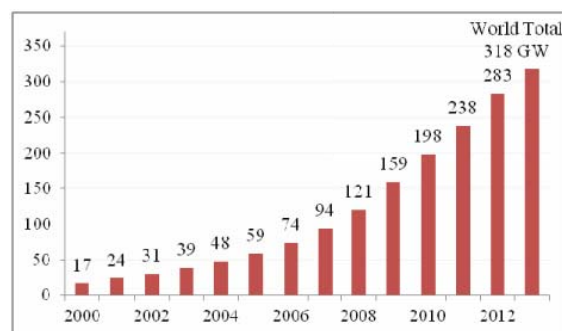


Fig. 3 Wind power total capacity [10]

Turkey has seven geographical regions. These regions have different wind energy potential. As listed in Table I, annual

average wind speed and annual average wind density are the main indicator to determine the wind energy potential. When evaluating the wind energy atlas of Turkey, Marmara region, Aegean region and Southeast Anatolia region are the promising districts as presented in Fig. 4.

TABLE I  
WIND ENERGY POTENTIAL OF TURKEY OVER VARIOUS REGIONS [1]

| Region                | Annual average wind speed (m/s) | Annual average wind density (W/m <sup>2</sup> ) |
|-----------------------|---------------------------------|---|
| Marmara               | 3.29                            | 51.91   |
| Aegean                | 2.65                            | 23.47   |
| Mediterranean         | 2.45                            | 21.36   |
| Middle Anatolia       | 2.46                            | 20.14   |
| Black Sea             | 2.38                            | 21.31   |
| Eastern Anatolia      | 2.12                            | 13.19   |
| Southeastern Anatolia | 2.69                            | 29.33   |

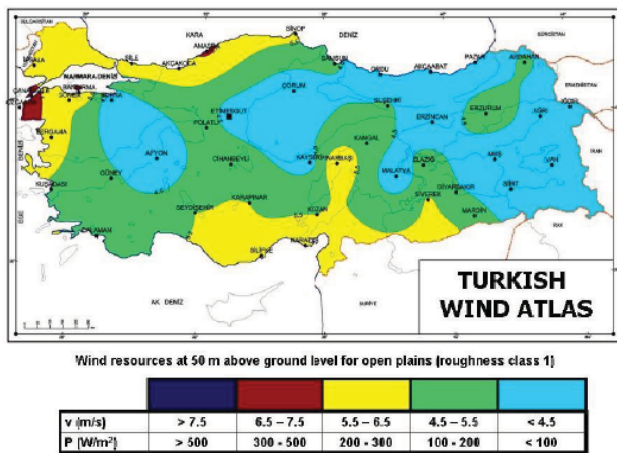


Fig. 4 Wind energy potential atlas of Turkey

Turkey has rich renewable energy sources such as solar, wind and hydro. As presented in Fig. 5, power capacity of wind power plants in Turkey has increased substantially in recent years. As of November of 2014, total installed capacity is 3.51 GW and installed capacity of wind power plants under construction is 1.16 GW [9]. Turkey, as a country with energy targets, should be constructed 1.5 GW wind power plants per year in order to realize Vision 2023 in terms of wind energy. However, realization of this target does not seem possible when considering the changes in trend of wind power plants capacity for the last five years.

MENR has prepared wind energy potential atlas of Turkey. According to this map, coastal areas are convenient for use of wind energy in electricity generation. Aegean and Marmara regions are promising areas where investors are encouraged to construct wind energy power plants. As shown in Fig. 4, since Marmara, Aegean and Mediterranean are more convenient region in terms of wind energy potential than the other regions, large part of wind power plants were installed in these regions as presented in Fig. 6. In addition, since these regions are the leader of electricity consumption due to the industrial,

technological and attractions of tourism, utilization of wind power energy systems provides energy diversification.

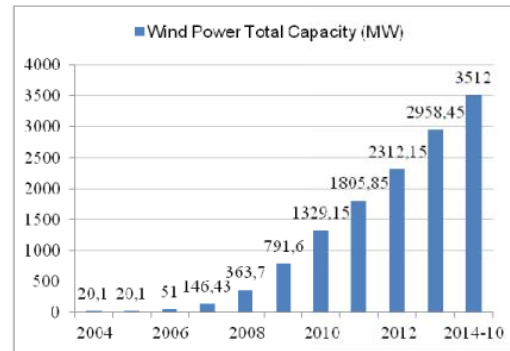


Fig. 5 Installed wind energy power plants (MW) [9]

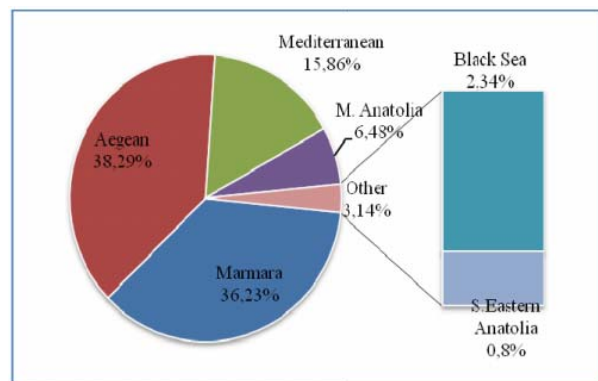


Fig. 6 Regions according to the operational wind power plants [9]

Balıkesir, İzmir and Manisa are the cities where most of the wind power plants were installed. As presented in Fig. 7, their share in wind power plants is equal to 52% of total capacity.

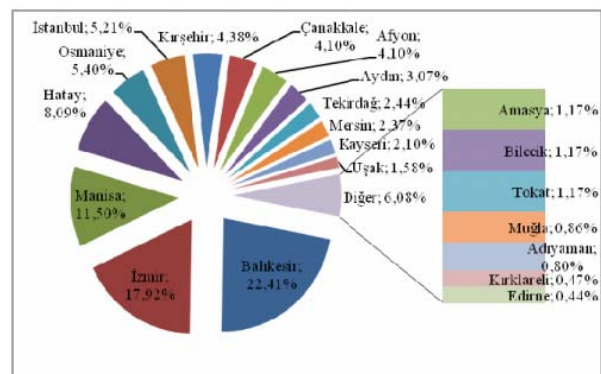


Fig. 7 Cities according to the wind power plants [9]

#### IV. VISION 2023 AND MILRES PROJECT

In order to eliminate environmental problems and maintain sustainable economic growth, Turkish Government plans to meet 30% of Turkey's electricity demand at the year 2023 from renewable energy sources [4]-[6]. Wind energy is a

promising source among renewable energy sources. Wind energy investments have started a serious trend in Turkey in parallel with the ninth development plan and Renewable Energy Law which was published in 2005. As presented in Fig. 8, legal regulations of REL is accelerated after the Energy Security Paper announced by MENR. It is mainly aimed that share of resources in electricity generation is 30% of total electricity generation by 2023. In addition, Turkish Government has announced the other energy targets. These energy targets are various and focus on natural gas consumption and importation, use of coal sources efficiently, increase the share of renewable energy source in electricity generation, reduction in the emission of greenhouse gases into the atmosphere and increase energy efficiency.

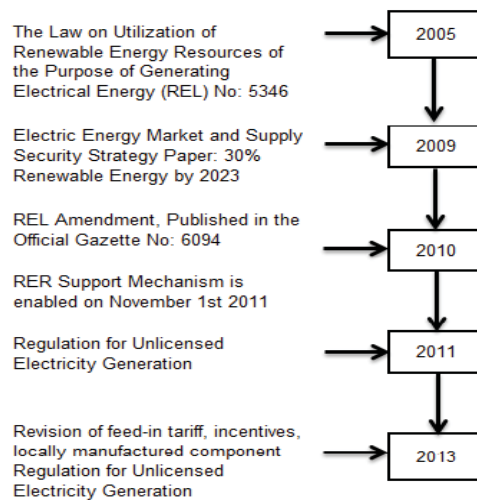


Fig. 8 Legislation process of REL

Announcing of this Strategic Paper can be accepted as a milestone for Turkey. As of November of 2014, as listed in Table II, current status of hydropower, wind, solar, geothermal and nuclear energy is very far from the targeted capacity. However, among these energy sources, wind energy investments are very promising when improvements that are realized in the last six years are considered.

TABLE II  
2023 VISION OF TURKEY: ENERGY TARGETS [4]

| Region     | Current Status (MW) | Targeted (MW) |
|------------|---------------------|---------------|
| Hydropower | 23486               | 36000         |
| Wind       | 3512                | 20000         |
| Solar      | 23.8                | 3000          |
| Geothermal | 405                 | 600           |
| Nuclear    | -                   | 10000         |

Turkey is among ten countries in the World in terms of hydropower plants. When considering the current hydropower capacity, 36 GW seems to be a reasonable goal. Although Turkey is one of the five leading countries in terms of geothermal energy potential, most of this potential is not

suitable for use of electricity generation. Because, this potential is consistent with low enthalpy and is suitable for thermal applications. Nuclear energy seems as another alternative energy sources which Turkey has not utilized yet. However, Turkish Government plans to have two nuclear power plants with a capacity of 1800 MW at the Black Sea port of Sinop and 1300 MW in Mersin Akkuyu, using imported technology from Russia. Turkey has 9129 tons of uranium reserves and 380000 tons of thorium reserves which would be important for energy independence [11], [12].

On the other hand, potential of solar and wind energy is very high. However, equipments used in wind and solar power plants are imported and have negative impact on Turkey's economy. As of November of 2014, installed capacity of photovoltaic power plants and wind power plants are 23.8 MW and 3512 MW, respectively. Furthermore, locally manufactured equipments are negligible in these power plants. Since large part of wind turbines used in wind power plants is imported, this condition causes to increase the dependency on foreign energy directly. Therefore, MILRES, which is national wind power system project, is new agenda for Turkey's energy security and independency. MILRES project, supported by TUBITAK, ITU, TAI and Sabancı University, is an important step for reducing the equipment importation [13]. In this project context, production of wind turbine with 500 kW power has been completed. Table III lists the main specifications of this wind turbine. In addition to specifications in Table III, developed wind turbine has some novel aspects. These novelties are design of double fed indicator generator, gearbox with three stage, unique turbine blades with 90% domestic materials (including fiber), more energy in low wind speed compared with other industrial wind turbine.

TABLE III  
MAIN SPECIFICATIONS OF WIND TURBINE WITH 0.5MW [14]

| Wind Turbine (0.5 MW) | Description                                      |
|-----------------------|--|
| Type                  | Horizontal axis wind turbine                     |
| Power Control Type    | Pitch  |
| Electrical Connection | Grid synchronized system                         |
| Braking System        | Aerodynamic and mechanical over speed protection |
| Rated Power           | 500 kW   |
| Mechanical Power      | 800 kW   |
| Number of Blades      | 3  |
| Hub Diameter          | 2 m  |
| Hub Height            | 55 m   |
| Rotor Diameter        | 45 m   |
| Tower Type            | 3 segments, steel                                |

After the infrastructure work, this wind turbine will be installed on the shores of Çerkos Lake in İstanbul. It is estimated that this utilization will be completed at the beginning of 2015. Generated energy from this turbine will be used by Water and Sewerage Administration of İstanbul (İSKİ). The cost of the first stage of the project is 11 million Turkish liras. Some photographs of the developed wind turbine is given in Fig. 9.



In the second stage of the project, the budget is 30 million Turkish liras. By using the experience obtained from the first stage, wind turbine with industrial scale (2.5 MW) will be manufactured domestically. By realizing the MILRES, it is aimed that developed wind turbine will be exported. Thus, new job opportunities will be provided with the help of this project.



Fig. 9 Some photographs from MILRES project

Renewable Energy Law (REL) is a milestone of Turkey's energy policy. This law leads to diversification of energy sources in electricity generation. Usage of renewable energy sources has been common after this enactment and some incentive mechanism has been announced in order to increase usage of renewable energy sources [15]. Solar, wind, geothermal, hydro and wave are assumed as main renewable energy sources. Use of these sources in electricity generation has some privileges. These privileges can be summarized as follows.

- Up to 1MW installed capacity of power generation plants are exempted from license. (Except geothermal)
- Electricity generation plants based on renewable energy sources is encouraged.
- Equipment to be used in the domestic contribution rate should be higher.
- Connection priority is given to renewable energy based electricity generation by TEIAS
- Each renewable energy sources are supported by different feed in tariff. Furthermore, solar and Geothermal power plants are supported by highest price per/kWh.

#### V.CONCLUSION

Amount of electricity consumption is one of the indicators determining the level of development for countries. Electricity demand increases continuously with technological and industrial development in the World. Turkey, as a developing country needs more electricity in parallel with economical development. Therefore, new alternative sources are needed for diversification of electricity generation and reduction of dependency on foreign energy.

Since Turkey is an energy importing country. This situation causes to have negative impact on country's economical condition and energy security. Enactment of REL in 2005 can be accepted as a milestone. Because, it changed energy policy and tendency to renewable energy sources such as solar, wind etc. increased. With having long coastal areas and being surrounded by three seas, Turkey has high wind energy potential. Annual average wind speed values are promising for especially Marmara, Aegean and Mediterranean where many wind power plants have been installed up to the present.

Among renewable energy sources, using wind energy in electricity generation has shown most progress. A great number of wind power plants have been installed especially Marmara, Aegean and Mediterranean Region in the recent six years as shown in Fig. 4. According to the Vision 2023, announced in 2010-2014 Strategic Plan by MENR, economically potential of wind energy is 48 GW and Turkish Governments aims to upgrade to 20 GW by 2023. Although this target does not seem achievable, this is promising step for improving Turkey's energy policy and security.

Lack of sufficient domestic technology is the most important obstacle for widespread use of wind energy in Turkey. Since Turkey imports the equipments used in wind energy power plants, MILRES project, which is a national wind energy power system is developed. In this project, wind turbine in industrial scale is aimed to manufacture domestically in the long term.

Geographical location of Turkey is convenient for use of wind energy. Turkey, as a developing country, should make new energy policies and new research and development studies by providing industry and university cooperation in an efficient way.

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