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Assessment of Wind Energy Potential in Cities in the Process of Combating Climate Change (The Case of Bitlis, Türkiye)

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Abstract: With the growing population and developing economy, the demand for energy is increasing both in the world and in Türkiye. If there is no change in current energy policies, non-OECD countries will be responsible for 87% of global energy demand by 2030. In this case, the fight against climate change also shows a dangerous trend. By 2050, the upper temperature increase limit of st üst indis will be exceeded if an internationally binding agreement on restricting the emission of other greenhouse gases, especially 2^0 degree emissions, cannot be established. Therefore, renewable energy sources are of strategic importance in the implementation of climate change policies in cities. Therefore, with today's developing technology and increasing energy demand, renewable energy resources should be used efficiently. The fact that fossil energy resources are both environmentally damaging and uneconomical has made these resources dispensable. One of the renewable energy sources that is environmentally friendly is wind energy. In order for wind energy to compete with alternative energy sources, various incentive policies are implemented by governments. These incentives make a great contribution to sustainable development in order to develop wind energy and expand its availability. In this context, energy efficiency is an important issue that should be examined as a priority in terms of sustainable development and should be investigated in terms of current situation and development potential. In this study, the availability and potential of wind energy in Bitlis province is examined. Then, the wind energy potentials of Bitlis province and its districts were evaluated by mentioning Türkiye's Renewable Energy Resources potential. The necessary data for the evaluation were obtained from Bitlis Province Meteorology Directorate. During the evaluation process, hourly wind speeds for January, March and August were taken in each district of Bitlis province. In the evaluation, it was seen that the wind speed was above 7 m/sec in 8 hours of 24 hours on average in the data taken only from Tatvan Nemrut Ski Center and a sample feasibility study was made for the wind power plant that could be established here.

Keywords: Climate Change, Sustainable Development, Energy Efficiency, Wind Energy, Bitlis

I. INTRODUCTION

Cities are a complex system in which numerous economic, social, cultural, institutional and natural structures and a wide range of risks are intertwined. 56% of the world's 8 billion population lives in cities and the urban population is increasing [1]. With population density and the location of industry in cities, cities are responsible for the consumption of 75% of natural resources, 60-80% of energy, and therefore at least 70% of greenhouse gas emissions [2]. In other words, human activities affect overpopulation and urbanization, industrial activities, increase in energy consumption, unplanned expansion of settlements, damage to the ecosystem and uncontrolled release of greenhouse gases into the atmosphere, which are factors in climate change [3].

Cities can be resilient and adaptive in the fight against climate change. The key agreements of the 21st century; Sustainable Development, Paris Agreement and Kyoto Protocol are considered important for sustainable development. Strategies such as green economy, green growth, green jobs, slow city strategy, bio-based economy, and strategies such as green economy, green growth, green jobs, slow city strategy to reduce greenhouse gas emissions in order to realize sustainable development in cities are considered important to ensure energy efficiency [4].

In the 2015 Paris Agreement and the 2030 United Nations Sustainable Development Goals, economic and social development was expanded with additional packages such as climate policies, international climate finance and access to clean energy, along with education and fewer resources. The 14th Conference on Sustainable Development of Energy, Water and Environmental Systems in October 2019 envisioned Smart

Communities and a biobased economy with materials and energy derived from RE and biological resources as its basis, as opposed to sectors that are difficult to decarbonize from CO2 [5].

Energy is on the world agenda due to the lack of resources as well as the damage caused to the ecosystem through its consumption. In this direction, problems such as energy efficiency are on the agenda in Turkey as in the world. Energy is, in short, the power of an object or a system to do work. The main types of energy used in Turkey can be listed as chemical energy, heat energy, electrical energy and mechanical energy. These energies can transform into each other through energy conversion systems and do work. In order to provide energy to consumers in a reliable way, the link between sustainable development and energy has been addressed. However, due to the gradual decrease in energy resources such as coal, oil and natural gas, the concept of energy efficiency has been brought to the agenda and these issues have been included in the studies on sustainable development [6].

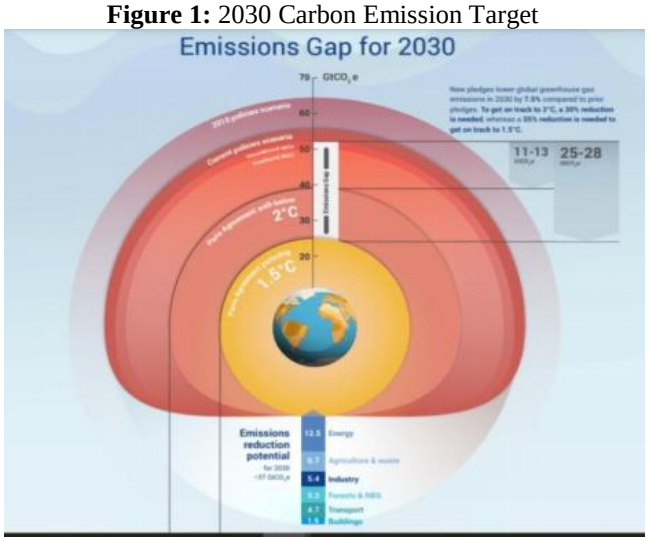
Energy efficiency is a very important issue for the future of our planet. The ever-increasing population in Turkey, our increasing need for energy with the developing industry and technology, and the fact that we are largely dependent on foreign energy with the depletion of our existing energy resources have made it compulsory for our country to work on the efficient use of energy. Using the right storage techniques for the correct and efficient use of energy is a method to make it cheaper. With the reduction of the cost, the decrease in greenhouse gas emissions caused by climate change will reveal the necessity of efficient use of energy [7].The easiest and cheapest way to ensure efficiency in the energy sector is to expand the use of wind energy.

Wind, which is abundant in nature, is the most preferred energy source among alternative energy sources as a clean energy source. Wind energy has an important role in ensuring sustainable development and efficient use of energy. As a continuous and infinite energy source, wind is a power source with rapid technological development, foreign currency earning feature, tribunes can be commissioned in a short time and dismantled in a short time [8]. Various incentive policies are implemented by governments in order for wind energy to compete with alternative energy sources. These incentives make a great contribution to sustainable development by increasing both the development of wind energy and its widespread availability throughout the country. In this study, firstly, the place and importance of wind energy as one of the renewable energy sources in terms of sustainable development will be emphasized. Then, the energy profile in Türkiye will be analyzed and the wind energy potential in Bitlis province, which is selected as a sample province, will be mentioned. . Then, the wind energy potential of Bitlis province and its districts are evaluated by mentioning Türkiye's Renewable Energy Resources potential. The data required for the study were obtained from Bitlis Province Meteorology Directorate. During the evaluation process, hourly wind speeds for January, March and August were taken in each district of Bitlis province.

II. IMPACT OF CLIMATE CHANGE ON ENERGY EFFIENCY

There are two types of energy used to date. These are non-renewable (primary) energy and renewable (secondary) energy. Coal, natural gas and oil, which are consumed as they are taken, are defined as primary energy sources. Electricity, coke, gas, etc. obtained as a result of the physical transformation process of the primary energy source is called secondary energy source. Energy sources such as solar energy, wind energy, geothermal energy, wave energy, hydrogen energy, etc. can be added as alternatives to the energy sources that are known and used in our daily lives. The economic, cultural and scientific levels of countries are measured by the amount of energy they produce and use. In our world, the population living in industrialized countries consumes about 60% of the total energy used, while the population living in developing countries consumes only 40% [9]. In 2030, it is aimed to reduce greenhouse gas emissions by 7.5%. While a 30% reduction is needed to reach 2^0C, 55% reduction is needed to reach 1.5 ^{0}C. For 2030, an emission reduction of 1.9% is targeted for buildings.

Figure 1: 2030 Carbon Emission Target



Source: [10].

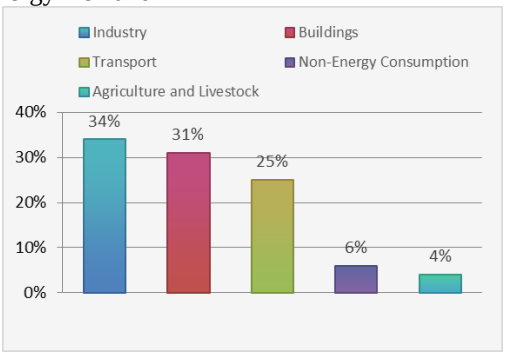
Ahead of the UN's COP28, renewable energy targets are being reviewed and a target to triple the efficiency of energy sources by 2030 has emerged [11].

Figure 2: IRENA Renewable Energy Target

Source: [12].

The report reveals that renewable energy targets are not only insufficient, but that countries are falling behind on domestic policies that exist outside the Paris Agreement framework. The report also states that countries, particularly the least developed countries and small island developing states, are planning to double their renewable installed capacity compared to 2022 to over 110 gigawatts (GW) by 2030. In line with research, renewable energy generation capacity in G20 countries should increase from less than 3 terawatts (TW) in 2022 to 9.4 TW, or 80 terawatts, by 2030. The 30% figure given in national energy plans and policies for meeting the target of tripling renewable energy sources is too low.

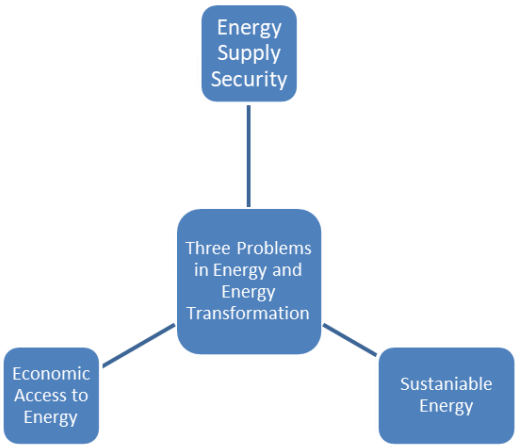
Figure 3: Shares of Sectors in Energy Demand



Source: [13].

In 2021, the final energy consumption of the sectors reached 123 mtoe, the highest share belongs to the industrial sector with 34%, and the energy used in buildings comes second.

Figure 4: Energy Transformation

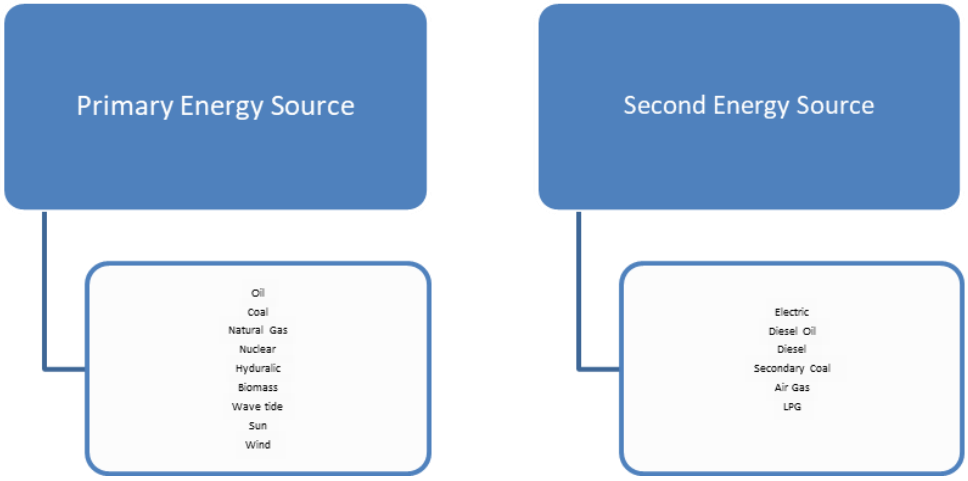


Source: Created by authors

The resources offered to us by the natural environment are decreasing day by day as a result of human activities. In order for the environment to renew itself, people need to provide it with opportunities to renew itself. Therefore, sustainable development has a very important place. Energy efficiency is at the center of societies' realization of sustainable development [14].

Due to the scarcity of primary energy resources such as oil, natural gas and coal, Türkiye is unable to meet its energy needs. Therefore, Türkiye largely meets its primary energy needs through imports. This situation raises the issue of investigating the potential of renewable energy resources in our country and utilizing this potential [15]. Energy resources are divided into two groups as primary and secondary energy resources.

Figure 5: Energy Resources



Source: Created by authors

With the Industrial Revolution, it is very important to ensure the planned use of energy resources, which are in danger of depletion as a result of increasing developments in industry. The ever-increasing need for energy has made it obligatory for us to be efficient in energy. This necessity has limited the rapid depletion of energy resources and energy production. Thus, energy saving has become mandatory [16].

In 2014, Türkiye continued to depend on other countries for its energy needs. According to the 2013 primary energy data announced by the Ministry of Energy and Natural Resources (MENR), primary energy consumption declined by 0.6% in 2013, while the share of imported resources increased from 71.5% in 2012 to

73.5% in 2013. In 2013, the share of domestic resources in primary energy consumption was 26.5%. It is stated that this ratio is likely to decrease rather than increase in the coming years [17].

Table 1: Türkiye's Electricity Production From Renewable Energy

Source Type	Share in Production (%)
Hydraulic	23.1
Natural Gas	22.4
Coal	19.7
Sun	13.7
Wind	11.1
Geothermal	1.5
Others	2.4
Total	100

Source: [18].

As seen in Table 1, the most important renewable energy source is hydroelectric power plants with a share of %16.1

III. SUSTAABLE DEVELOPMENT AND WIND ENERGY

Renewable energy is defined as an energy source that can be present the next day in the same way within nature's own cycle [19]. While these energy sources replace primary energy sources that pollute the environment and are inevitably consumed, wind energy is the most widely used and fastest developing energy source among new and renewable energy sources that do not cause environmental pollution [20]. Wind is caused by the different heating of the earth's surface by solar radiation. The different heating of the earth causes air temperature, humidity and pressure to be different, and this different pressure causes air movement. Approximately 2% of the solar energy reaching the earth turns into wind energy.

Wind turbines, which are the most important means of electricity generation in wind energy, convert renewable air currents into electrical energy. Wind, which is a regional energy source, has an important place in achieving the goal of sustainable development as it is a continuous source despite its geographical and meteorological limitations. In order to obtain continuous electrical energy from wind, the structure and characteristics of the wind must be determined with reliable measurements and wind energy turbines suitable for the regions must be established [21].

Features of Wind Energy;

1. It is a renewable and clean energy source, environmentally friendly.
2. There is no risk of depletion and price increase over time.
3. Its cost has reached a level that can compete with today's power plants.
4. Maintenance and operating costs are low.
5. The installation and operation of its technology is relatively simple.
6. Its commissioning can be completed in a short time [22].

Wind; clean, inexhaustible, free, does not create air pollution and climate change because it does not create carbon emissions, provides energy security, and does not carry a price risk because it does not have a fuel cost. Wind energy, which has these features, has an important place in ensuring sustainable development. Wind energy eliminates dependency on other countries in terms of economic, political and supply risks, and eliminates the complexity of fossil fuels due to price volatility, provides employment and regional development in cities, is a land-friendly, large-scale commercial power plants or a home-type application flexibility, and is a national and always available resource [23].

Energy is an indicator that will provide a country's economic, social and environmental development as well as production. Therefore, it is seen that it has a linear relationship with social development, economic welfare and environmental sustainability [24]. In order to ensure sustainability in the field of energy, first of all,

efficient use of energy and energy saving, and increasing the use of renewable energy sources rather than non-renewable energy sources must be ensured. In addition, it is thought that the development and dissemination of technology in this field will play a major role in achieving sustainable development goals [25].

IV. WIND ENERGY USE IN TÜRKİYE

As a result of the economic and social developments experienced in Türkiye in recent years, there has been a rapid increase in demand in almost every area of the energy sector. Türkiye constitutes 1.2% of the world population and has a share of 0.8% in energy consumption. Per capita energy consumption is three-quarters of the world average. On the other hand, Türkiye is a country with a very high import rate in terms of energy resources. According to 2000 data, it imported 90% of the approximately 76 million tons of coal it consumed annually and 93% of the 30 million tons of crude oil. Türkiye's energy consumption and imports are rapidly increasing in direct proportion to its economy [26]. Although Türkiye is a country rich in secondary (renewable) energy resources such as solar, wind, biomass and geothermal, the use of resources for energy purposes is not yet at sufficient levels. According to EIE's "Wind Energy Potential Atlasstudy, Türkiye's wind energy potential is 48 thousand MW for areas with wind speeds ≥7 m/s and it is claimed by EIE that 47,849.44 MW billion kWh of electricity can be produced from wind [27].

As of May 2007, electricity is produced with turbines with an installed capacity of 132 MW in 7 power plants, primarily in Bozcaada, Çeşme, İstanbul Hadımköy and Bandırma. It is estimated that the installed capacity will reach 5,000 MW in 2015 [28]. The areas with high wind energy potential in Türkiye have been identified as the Marmara, Aegean, Mediterranean and Black Sea coastal areas, respectively. It is also known that there are regions rich in wind energy potential in some parts of Southeastern Anatolia and Central Anatolia. It has been accepted that wind power plants with a capacity of 5 MW per square kilometer can be established in areas with a height of 50 meters above ground level and wind speeds above 7.5 m/s in Türkiye. In line with these acceptances, the Wind Energy Potential Atlas (REPA) has been prepared, which provides wind resource information produced using a medium-scale numerical weather prediction model and a micro-scale wind flow model [29].

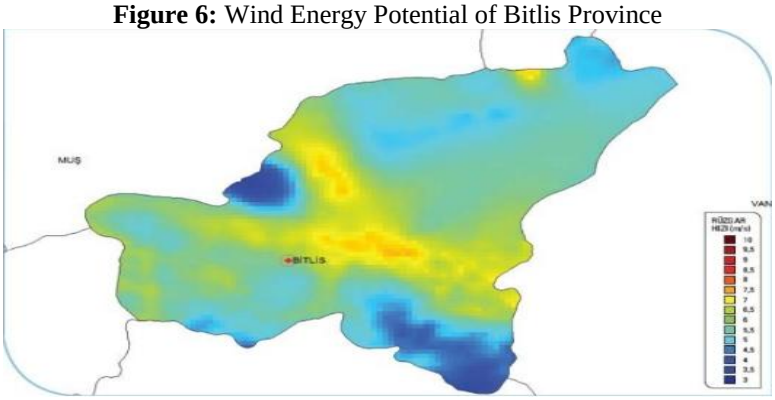
V. MATERIALS AND METODS

The total area corresponding to this potential corresponds to 1.30% of Türkiye's surface area. In Türkiye, the annual wind energy production amount as of the end of 2013 was 7,518 GWh. The installed capacity of wind energy plants operating as of the end of 2013 was 2,760 MW [30]. According to a study published by World Energy; Assuming that 4% of the regions with wind speeds over 5.1 m/s will be used due to practical and social constraints, the world wind energy technical potential was calculated as 53,000 TWh/year. The annual wind energy production in the world as of the end of 2012 was 557 TWh/year and its share in energy production was 2.6%. The installed capacity of wind energy plants operating as of the end of December 2013 was approximately 300 GW. When the installation cost of wind energy plants is examined, it is seen that it is a suitable example for the realization of sustainable development in cities and the implementation of circular economy strategies. The installation of energy plants does not make much difference with the change in size. In other words, the average production cost of 1 kW and the average installation cost of 1 MW production are the same. The average installation cost of wind energy plants is 2000 Euros per 1 kW. This decreases to around 1800 Euros in large-scale production (1 MW and above) [31].The average efficiency of wind energy plants is 20 years, and the life of the system is around 30 years. Wind energy plants start to produce electricity from 3 m/s. It continues to produce electricity up to a wind speed of 25 m/s. When the wind map of Türkiye is examined, it is seen that even the least windy places of our country receive 3 m/s more wind. Accordingly, if it is taken into account that wind energy plants produce as much as their capacity 24 hours a day, a 1 kW wind energy plant produces over 20 kW of electricity[32].

VI. RESULTS

Bitlis province, located in the Eastern Anatolia Region, is located between 41° 33' and 43° 11' east longitudes and 37° 54' and 38° 58' north latitudes. Bitlis is a province located on the border of the Upper Euphrates and Upper Murad sections of the Eastern Anatolia Region [33].

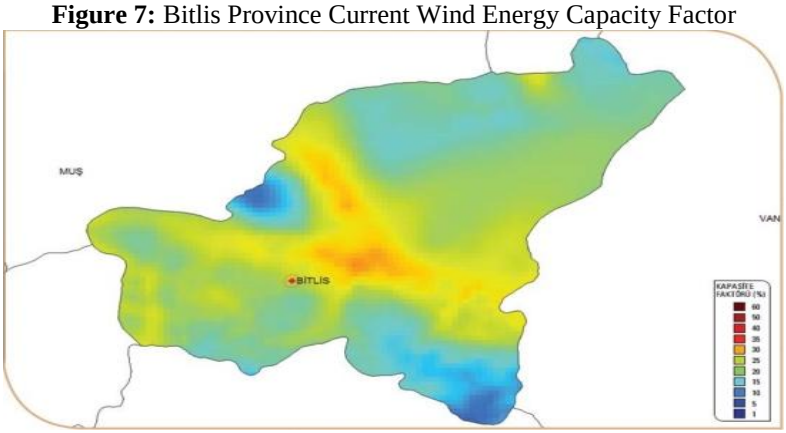
Figure 6: Wind Energy Potential of Bitlis Province



Source: [34]

Based on the visual in Figure 6, a wind speed of 7 m/s or above is required for an economic RES investment. When Figure 6 is examined, it is seen that the low-lying areas around the Bitlis province center cannot be used for wind power plants due to wind speed. In addition, since the map resolution is at the km level, it can be found in advantageous locations.

Figure 7: Bitlis Province Current Wind Energy Capacity Factor



Source: [34]

Wind power plants are one of the important building blocks in the transition to clean energy. Energy production in RES's varies depending on the wind blowing, that is, these plants are divided into two according to the way they are built on land and sea. The plants established in Bitlis are placed on land. A capacity factor of 35% or more is required for an annual economic RES investment in a power plant.

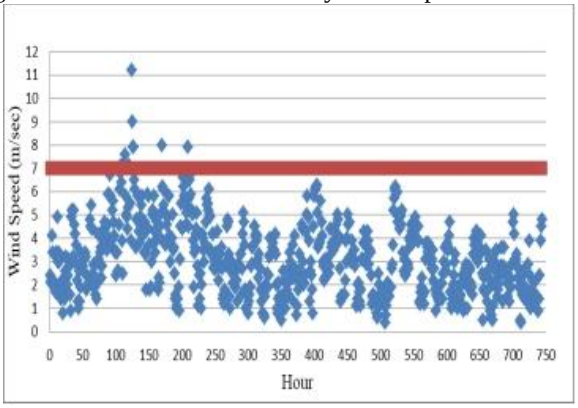
Table 2: Wind Power Plant Power Capacity That Can Be Installed in Bitlis Province

Wind Power at 50 m(W/ m²)	**Wind Speed at 50 m(m/s)**	**Wind Speed at 50 m(m/s)**	**Total Installed Power (MW)**
300 – 400	6,8 – 7,5	4,42	22,08
400 – 500	7,5 – 8,1	0,00	0,00
500 - 600	8,1 – 8,6	0,00	0,00
600 - 800	8,6 – 9,5	0,00	0,00
>800	>9,5	0,00	0,00
Total		**4,42**	**22,08**

Source: [35].

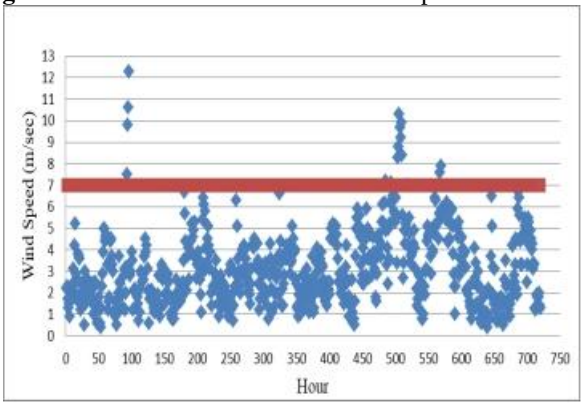
In the study, wind data covering the year 2015 measured at Bitlis meteorological station were used. Wind data consist of speed and direction values as ten-minute averages. Equal wind speeds can be observed at different dates and times in wind values measured at a certain time interval. The graphical distributions of hourly wind speed measurements of meteorological stations located in Bitlis districts for the year 2015 are as follows;

Fıgure 8: Adilcevaz 2015 January Wind Speed Distribution



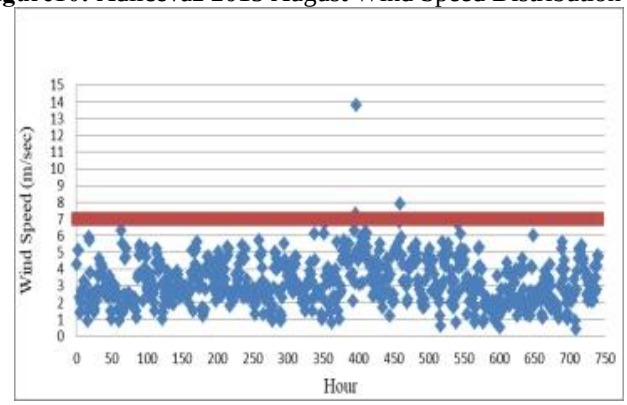
Source: [36].

Fıgure 9: Adilcevaz 2015 March Wind Speed Distribution



Source: [35].

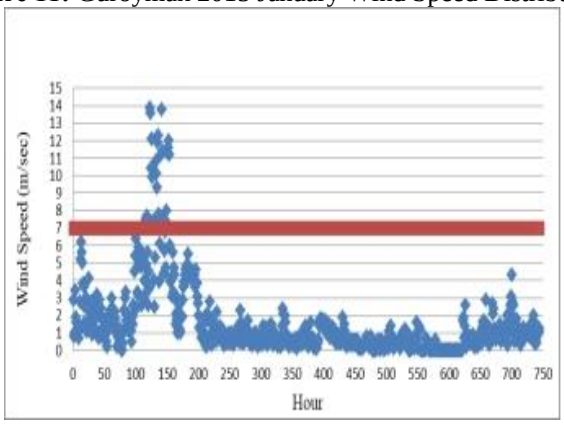
Fıgure10: Adilcevaz 2015 August Wind Speed Distribution



Source: [36].

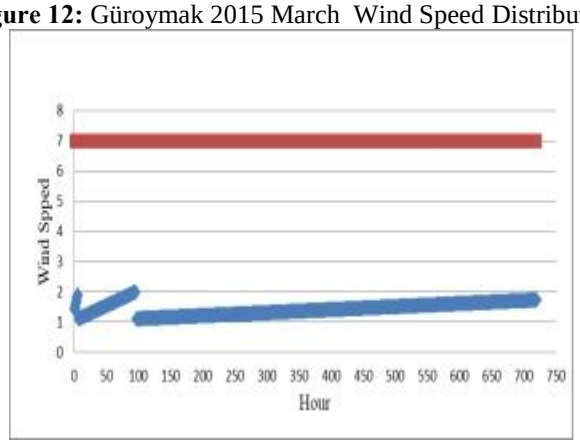
When monthly wind speed distributions are examined in Figure 8, Figure 9 and Figure 10, wind speed is 7m/s or above in 3770 of 8586 hourly data. When looked at on average basis, wind speed is 7m/s or above in 8 hours out of every 24 hours.

Fıgure 11: Güroymak 2015 January Wind Speed Distribution



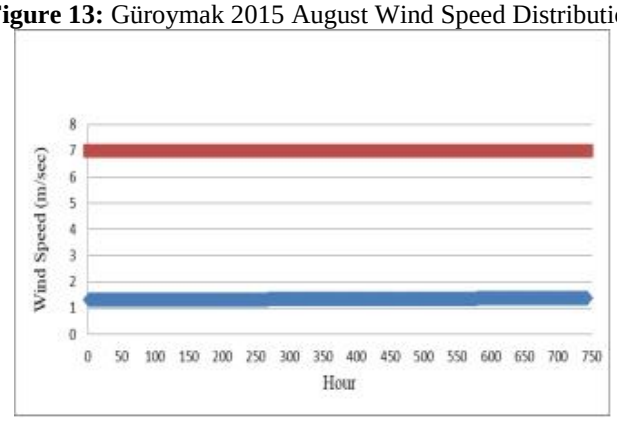
Source: [36].

Fıgure 12: Güroymak 2015 March Wind Speed Distribution



Source: [36].

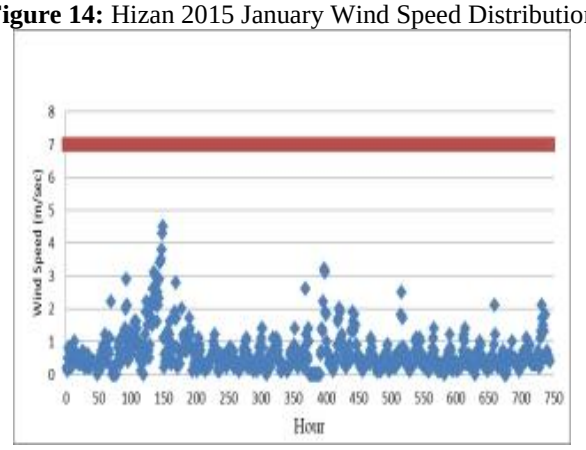
Figure 13: Güroymak 2015 August Wind Speed Distribution



Source: [36].

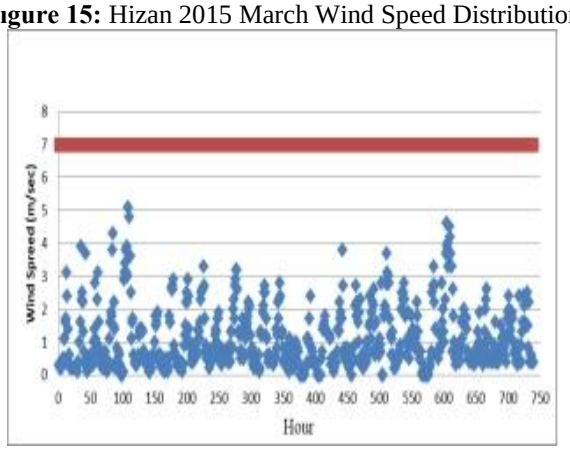
When monthly wind speed distributions are examined in Figure 11, Figure 12 and Figure 13, wind speed is 7m/s or above in 1770 of 8586 hourly data. When looked at on average basis, wind speed is 7m/s or above in 8 hours out of every 24 hours.

Figure 14: Hizan 2015 January Wind Speed Distribution



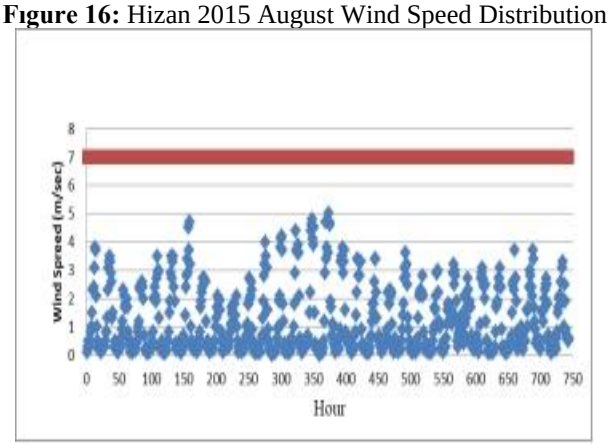
Source: [36].

Fıgure 15: Hizan 2015 March Wind Speed Distribution



Source: [36].

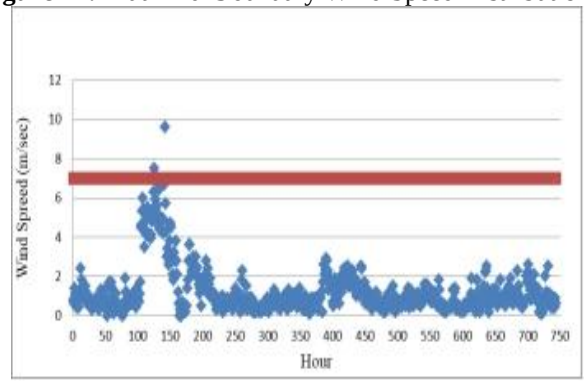
Fıgure 16: Hizan 2015 August Wind Speed Distribution



Source: [36].

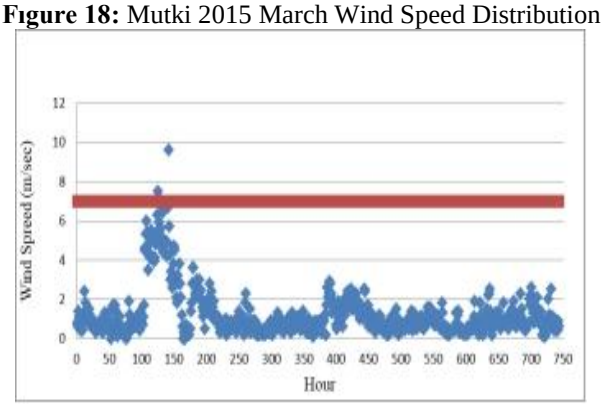
When monthly wind speed distributions are examined in Figure 14, Figure 15 and Figure 16, wind speed is 7m/s or above in 1770 of 8586 hourly data. When looked at on average basis, wind speed is 7m/s or above in 8 hours out of every 24 hours.

Figure 17: Mutki 2015 January Wind Speed Distribution



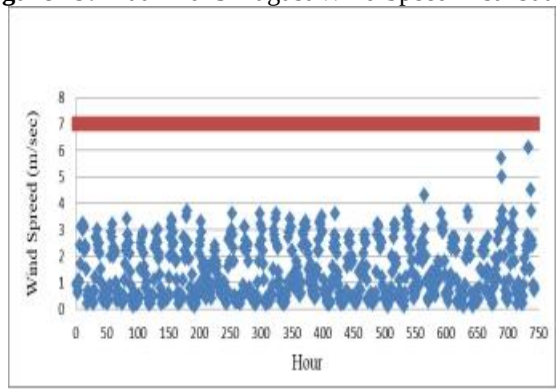
Source: [36].

Fıgure 18: Mutki 2015 March Wind Speed Distribution



Source: [35].

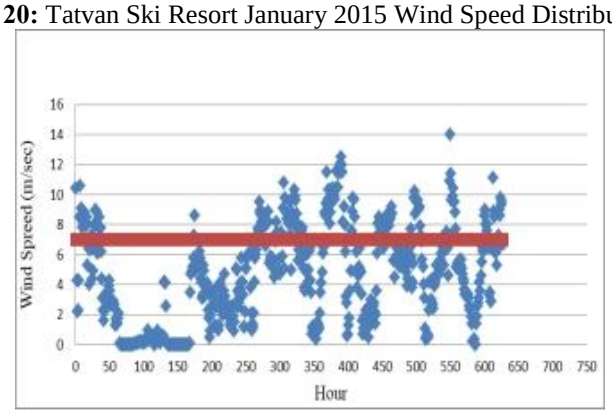
Figure 19: Mutki 2015 August Wind Speed Distribution



Source: [36].

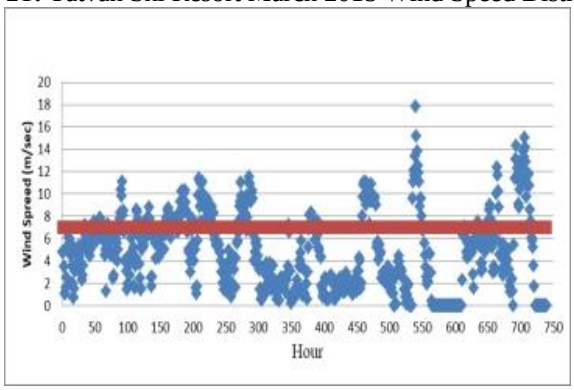
When monthly wind speed distributions are examined in Figure 17, Figure 18 and Figure 19, wind speed is 7m/s or above in 1770 of 8586 hourly data. When looked at on average basis, wind speed is 7m/s or above in 8 hours out of every 24 hours

Fıgure 20: Tatvan Ski Resort January 2015 Wind Speed Distribution



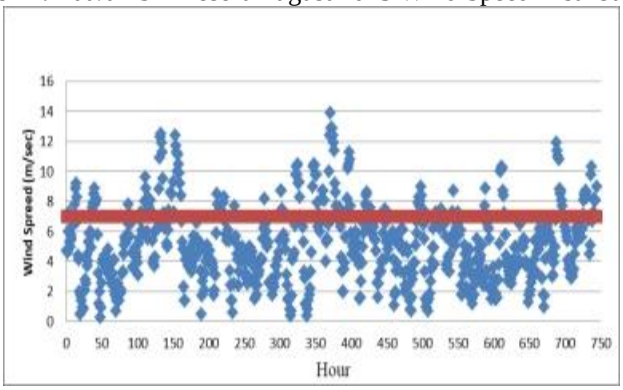
Source: [36].

Fıgure 21: Tatvan Ski Resort March 2015 Wind Speed Distribution



Source: [36].

Figure 22: Tatvan Ski Resort August 2015 Wind Speed Distribution



Source: [36].

When the wind speed data in Figure 20, Figure 21 and Figure 22 are examined, the wind speed is 7m/s or above in 2770 of the 8586 hourly data. On an average basis, the wind speed is 7m/s or above in 8 hours out of every 24 hours.

VII. CONCLUSION

Increasing energy demand and environmental negativities make it important to evaluate regions that may have good wind energy potential in terms of energy production. Energy has an important place in achieving the three basic goals of sustainable development, namely social, economic and environmental goals. Within the framework of sustainable development goals, the aim of providing energy, uninterrupted and reliable energy consumption that humanity needs, without harming the economy and the environment has begun to come to the fore. While studies to increase the use of renewable energy resources continue in the world, especially in

Europe, studies on this subject are not yet at the desired level in Türkiye, which has a serious potential in terms of renewable resources. Within the framework of sustainable development in Türkiye, it is an inevitable fact that a long-term sustainable energy policy is implemented that is suitable for the country's conditions, follows the developments in the world and is followed. It is extremely important for the country's economy to organize the necessary incentives as soon as possible for the development and spread of wind energy, which is not dependent on foreign countries, has advanced technology, has high employment generation potential, is cheap, safe and has high potential. Among Türkiye's existing energy resources, the source that best responds to the functioning of the energy-economy-environment trio is renewable energy resources with its high potential. One of these is wind energy. Türkiye should ensure that the private sector can compete in this field so that the wind energy industry can be established in the country with a solid infrastructure.

Considering the possibility of depletion of Türkiye's non-renewable resources, within the framework of sustainable development, it is necessary to address climate change adaptation strategies and implement long-term sustainable energy efficiency policies that follow developments in the world. It seems important for the country's economy to organize the necessary incentives as soon as possible for the development and spread of wind energy that is not dependent on foreign countries, has advanced technology, has high employment generation potential, is cheap, safe and has high potential.

In this study; the wind energy potential of Bitlis province was examined. Wind data obtained from Bitlis meteorological station was used in the study. Only Tatvan Nemrut Ski Center point was deemed suitable for electricity generation from wind. When the hourly wind speed data of 2015 belonging to this area was examined, the wind speed was 7m/s or above in 2770 of 8586 hourly data. When looked at on average, the wind speed was 7m/s or above in 8 hours out of every 24 hours. In this case, when making the calculation, it can be assumed that a wind farm placed at this point will produce electricity for 8 hours a day.

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