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SHORT TERM RENEWABLE ENERGY STRATEGIC VISION IN THE WORLD

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Abstract- Short term renewable energy strategic vision study is an important indicator to ensure sustainable supply security and competitive energy prices in energy markets by evaluating energy sources efficiently and environmentally. This study offers an overview on how energy demand will be met in line with Turkey's 2023 strategic vision by considering the current status and recent technological developments in renewable energy sources. Also, global renewable energy strategic vision and the policy were also presented in this study. Turkey's renewable energy strategic vision was compared with other countries that are going well in line with their goals. With International Energy Agency, total global renewable power capacity is expected to be approximately 3,585 GW in 2024. Renewables are estimated to will provide 30% of global electricity production by 2024. Parallel to this development, the Turkish government's vision is expected to rise its proportion of renewable energy in electrical energy generation to 38.8% in 2023. According to results obtained from the 2023 renewable energy strategic vision, Turkey goals 32,037 MW of installed hydroelectric power capacity, 11,883 MW of installed the wind power capacity, 10,000 MW of installed the solar power capacity and total 2,884 MW of installed power capacity for geothermal and biomass. In the next 4 years, Turkey will see strong growth and technological improvement in its installed renewable power capacity in electricity generation, up from 45,227 MW in 2019 to an estimated 56,804 MW in 2023.

Keywords: Renewable Energy, Installed Capacity, Electricity Generation, Energy Strategic Vision.

1. INTRODUCTION

World Energy demand has been increasing in the last years [1-4]. The total energy demand is estimated to increase by 21% in 2030. In addition, growing concerns over climate change are obliging government authorities worldwide to search for alternative methods to provide energy and hence prevent greenhouse emissions and other negative ecological effects. With respect to the International Energy Agency (IEA), if current policies for energy keep on, energy related CO_2 emissions in the world are expected to increase by about 50% by 2030 compared to current levels. There will also be a 40% rise in oil consumption [5]. Fossil fuels will still predominate by supplying 84% of the world's increasing gradually energy demand. By 2050, energy-based production of CO_2 is projected to be more than double, and concerns over the security of supplies will be heightened by the increased oil demand. So, applications of the renewable energy are crucial to address the environmental challenges.

As an energy source, in contrast to fossil fuels, renewable energy has a considerable potential for global reach that is concentrated in geographical regions. Many countries, at least one with a large number of renewable energy sources (RESs), have a resource portfolio [6]. Types of renewable energy cover a wide range of scale, are derived from the sun, or obtained from the heat produced in the deep earth. RESs also consist of ocean resources, geothermal, hydropower, solar, wind, biomass, liquid biofuels, solid biomass and biogas methods [7-9]. There is a quickly growing public awareness that enhances renewable energy systems necessary to reduce climate changes, resulting in economic alternatives, and covering energy demands of billions of people who are currently living without modern energy services [10]. Recently, the installed capacity of renewable electricity sources has shown a rapid upward trend. Use of renewable energy started in the 1990s and kept rising extensively in the 2000 s. As 1,000 GW of renewable energy capacity has been installed worldwide in 2007, as of 2019, renewable capacity has reached 2,537 GW.

In general, RESs record a globally growing share of the yearly investment in electricity capacity. Renewables provide around 70% of net global power additions to global capacity and indicate that far higher shares of capacity are being provided by many countries worldwide in 2017. However, energy driven global CO_2 emissions

increased by 1.4% in 2017, which did not change over the last three years. Increasing carbon emissions were the result of economic growth, low fuel prices and lower energy efficiency. By the end of the year, there were sufficient RESs to provide an estimated 26.5% of global electricity production that included 5.6% from wind power. Several countries are now keen on producing electricity from a variety of RESs, and they have achieved a high-capacity level.

Because of its location, Turkey has become an important energy transition zone for energy sources in the Caspian Sea region, the Middle East and energy markets in the West. Turkey is developing and becoming increasingly industrialized, with a growing population and economy. It has become an economic powerhouse and regional power in the Middle East. Parallel to this development, national energy demand (especially for electricity) is continuously increasing [5]. In order to meet energy demands for economic activities, to reduce environmental effects, to decrease dependence on energy import.

Developments in energy markets, access to new resources in parallel with the advances in technology, changing energy production and consumption values of countries, and increasing environmental concerns continue to affect the global energy sector. Determining the targets and policies related to energy and natural resources is critical for development and strengthening of national economies in countries. In this sense, it is necessary to ensure that energy and natural resources are researched, developed, produced, and consumed in accordance with these objectives and policies. In addition, as in the energy sector, which is a highly dynamic sector whose balances and conditions change rapidly on a global scale, the determination of a national strategy is of great importance in the natural resources sector, which has a relatively high stability.

However, this strategy can be affected by global and regional geopolitical and geostrategic developments in energy and natural resource markets, new technologies, new energy resources, changing environmental sensitivities, changing the direction of trade, global and local macroeconomic developments, changing preferences and values in energy production and consumption approaches. For this reason, countries need to constantly update their energy strategies.

Literature survey shows that energy strategic vision has an important role in planning and operation of energy sources. In recent years, many researches on the energy strategic vision have been performed in literature. For example, Tukenmez and Demireli [11] examined the regulations of renewable energy policies and frameworks since 2000 in view of Turkey's vision 2023. Melikoglu [12] developed an accurate prediction model for natural gas demand between the years 2013-2030 in Turkey. Melikoglu [13] assessed and forecasted the hydropower's rate in the annual electricity demand in the view of Vision 2023. Koc [14] discussed the difficulties in reaching Turkey's 2023 goals and presented a perspective on the contribution of the private sector to this process.

Melikoglu [15] reviewed the status and future of Turkey's geothermal sources according to 2023 energy strategic vision for Turkey. Melikoglu [16] determined capital investments in coal power plants to fulfill Turkey's Vision 2023 goals depending on the ratio of its coal and lignite. Ugurlu and Gokcol [17] presented and overviewed the renewable energy potential of Turkey in line with Turkey's Vision for 2023. Melikoglu [18] examined the accessibility of Turkey's vision 2023 target energy capacity. Sogukpinar et al. [19] discussed and investigated the energy strategy of Turkey for Vision 2023 Targets with respect to 2000 MW renewable energy agreement. Erdin and Ozkaya [20] proposed the ELECTRE (Elimination and Choice Translating Reality) method for successful decision for use of RES in reaching Turkey's 2023 Energy Strategies.

According to those above-mentioned literature studies, short term renewable energy strategic vision study is an important indicator to ensure sustainable supply security and competitive energy prices in energy markets by evaluating energy sources efficiently and environmentally. For this reason, in this study, a comprehensive overview of renewable energy sources was presented to plan Turkey's short-term renewable energy strategic vision. The novelty of this study to the literature can be primarily expressed as follows:

I. In order to achieve Turkey's vision for 2023, recent developments, the current status, the industry and technologies involved in RESs were discussed in detail according to the 2019-2023 strategic plan

II. In few years, Turkey has been faced with serious geopolitical and economic issues. Many researchers from academia and industry have doubts about Turkey's Vision 2023 electricity capacity goals. In present work, Turkey's current and updated assessment was created for renewable energy demand until 2023 and accessibility of Vision 2023 target renewable electricity capacity was examined.

III. Global renewable energy strategic vision and policy were presented. Turkey's renewable energy strategic vision was compared with other countries that are going well in line with their goals.

2. DEVELOPMENT OF ELECTRICITY GENERATION

Turkey has 17th largest economy and also is an example of an emerging and dynamic country in the world. Turkey's energy strategy aims to meet the demand without adversely affecting economic growth. While the population was 12 million in 1923, population had reached 80.8 million by 2017 [21]. It is known that Turkey is a developing country and made up largely of Anatolia in the western part of Asia and the other part in south-eastern Europe, it is surrounded by Aegean, Black and the Mediterranean Seas [22].

Due to warm climate, Turkey has many advantages for large-scale use of RESs. As a result, there are important investment opportunities and incentive investments in environmental and renewable energy. In the last decade, many global firms have made

investments and many local investors are seeking international partnerships. Turkey is an energy importing country and needs to better access and use energy resources. Renewable energy, which is both economical and sustainable as well as being environmentally friendly, is very useful to Turkey. Because of its geographical position, Turkey has opportunities for widespread use of RESs including solar, wind, biomass geothermal and hydropower [23], [24].

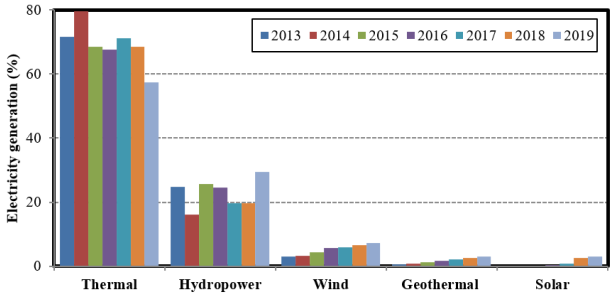

Figure 1. Energy sources in electricity production

Figure 1 presents the shares of energy sources in electricity production in Turkey. It is obvious from the figures that electrical energy in Turkey is generated from power stations. These are thermal, hydro, geothermal, wind and solar types, but there are no nuclear power plants. Thermal and hydropower have the most rapidly growing in the country. However, geothermal, solar and wind power have comparatively small installed capacities. While cumulative installed capacity and generation of electricity in Turkey was 33 MW in 1923, Turkey's overall electricity generation rose to 302,552 GWh in 2019 [10]. Keeping in mind the electricity generation of 2019, the thermal power plant share was 57.39%, corresponding to 169,534 GWh. Hydropower accounted for 29.38%, corresponding to 88,879 GWh. Currently, the Turkish market has large natural gas, crude oil pipelines and other similar projects under negotiation. Because of scarce oil and gas reserves, Turkey is rapidly changing its direction towards renewable energy sources for improved protection against energy shortages, searching for ways to produce 38.8% of its electricity demand from RESs by 2023. However, Turkey needs a wide range of investments in order to meet continuously increasing energy demand.

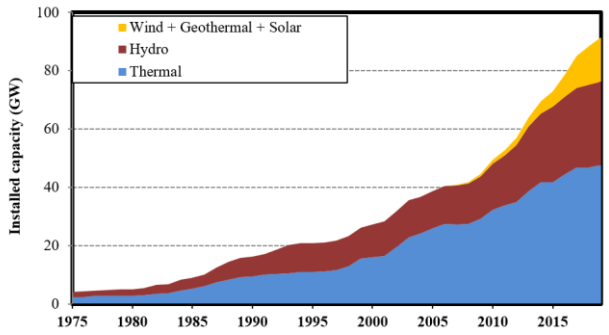

Figure 2. The installed capacities of energy sources between 1975 and 2019 for Turkey

The main fossil fuels used in electricity generation are coal and natural gas. Coal and the natural gas are imported. It is shown that in Figure 2 depicts the installed capacities of energy sources in 1975 to 2019. For 1975 years, the capacity and production of electricity in Turkey were 4.187 GW and 15,623 GWh, respectively. In 2019, the installed capacity in electricity production was 91.43 GW with the annual electricity production of 302,552 GWh [25].

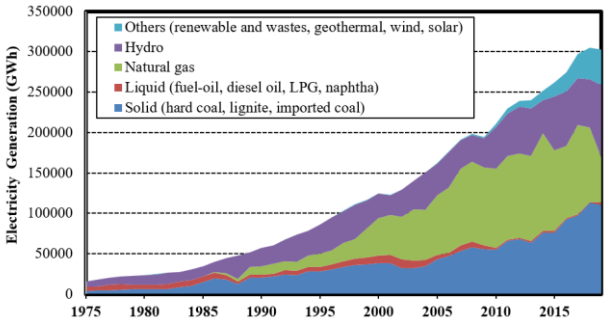

Figure 3. The primary energy resources of electricity generation between 1975 and 2019

Today, Turkey's energy demand is primarily met by natural gas and solid-fired fuels, and also renewable energy such as hydropower and wind. Figure 3 presents the development of electricity generation from 1975 to 2019. As seen in the figure, solid-fired fuels are the fastest growing for Turkey with 36.62% (110,792 GWh) in electricity generation in 2019. Natural gas accounted for 18.40% (55,683 GWh), hydropower for 29.38% (88,879 GWh), liquid for 1.01% (3059 GWh), and others 14.59% (44,139 GWh) [25].

3. DEVELOPMENT OF RENEWABLE ENERGY IN TURKEY

Over a few decades, there has been a strong belief in the need to reduce fossil fuels thanks to global politics driven by concerns about depletion of fossil resources, the need to act against climate change, environmental impacts and the volatility of prices. In addition, there are two further reasons against utilization of its energy:

I. A high contribution to the large trade deficit in energy imports and

II. The country, with its current available energy resources, cannot be self-sufficient.

Energy generation in Turkey is not enough to meet continuously growing consumption. Consequently, Turkey has become a net energy importer and this is contributing to a significant trade deficit. In other words, the dependence on energy imports is one of the main drivers for the current trade deficit and for high levels of trade. Therefore, a quick shift towards the need for RESs has emerged in Turkey [26].

Environmental factors in electricity generation are also key issues in Turkey and globally. Water scarcity, drought and shortages in agriculture, with heat waves and climate change are expected to affect Turkey negatively. This is an urgent matter and many countries make it obligatory to take serious measures to reduce the negative

impact of fossil fuels. Because of new developments that are 'green', sustainable and available at affordable prices, renewable energy and policies offer a prospective solution. It is accepted that RESs have much less negative impact on the environment. In addition, environmental impacts can be minimized by implementing some energy generation systems with careful planning. Considering all the environmental, political and economic reasons together, renewable energy seems to be a reasonable and necessary preference for Turkey in order to meet energy demands [27-29].

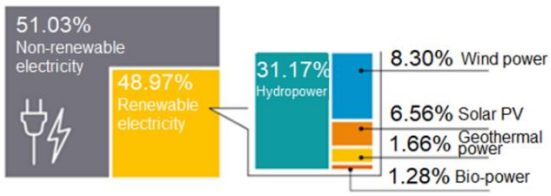

Figure 4. Shares of installed renewable power capacities in electricity generation in 2019

RESs in Turkey consist of hydropower, wind, geothermal, solar and bio-power. Turkey has great potential in hydroelectric, wind and geothermal energy sources. Solar and biomass energy are also very important RESs in Turkey [30], [31]. The promotion of the private sector and/or the investment of the government itself is crucial in facilitating renewable technologies. Government, universities and research organizations have made attempts to enhance various useable energy sources, particularly renewable energy.

Figure 4 presents the part renewables played in the energy demand for 2019. By the end of the year, RESs provided an estimated 48.97% of Turkey's electrical installed capacity, receiving 8.3% from wind power [25]. The renewable energy development in Turkey is demonstrated in Figure 5. It shows that renewable energy-based power plants and electrical resources increased rapidly during this period. Several electric power technologies, as well as power plants based on renewable energy, have greatly increased since 2008. In 2008, 14,282 MW of renewable energy was put into operation, and today, electricity generation from renewable energy has reached 45,227 MW.

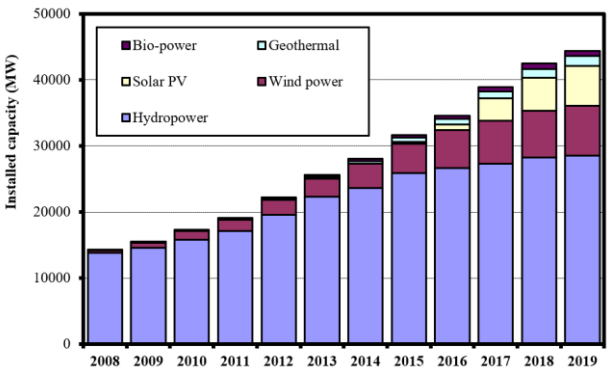

Figure 5. The installed capacity of renewable energy in Turkey

3.1 Hydropower

Turkey has the total surface area of 783,577 km^2 and its average height is more than 1,132 m. This height is greater than the average height in Asia, which is 1.050 m and is 3.5 times the average height of Europe's 330 m. Turkey has more rivers for hydropower source [32]. There are more than 120 natural lakes in Turkey along with small lakes in the mountains. Besides natural lakes, 706 dam lakes exist in Turkey. Surface areas of some of the dams are: Altinkaya 118 km^2, Hirfanli 263 km^2, Karakaya 268 km^2, Keban 675 km^2 and Ataturk 817 km^2.

Especially in mountainous regions, the rainfall is quite abundant (1,000~2,500 mm/year). The mean rainfall in Turkey is about 643 cm per year, and it corresponds to an average of 501 billion m^3 of water per year. 274 billion m^3 is returned to the atmosphere via evaporation from soil, water surfaces and plants; 69 billion m^3 is underground water, 158 billion m^3 of water flows through streams and rivers of various sizes to lakes in closed basins and the seas. Of the 69 billion m^3 of groundwater feeds, 28 billion m^3 of water rejoins the surface water through springs. In addition, there are 7 billion m^3 of water per year from other countries. The gross surface water potential of the country is 193 billion m^3 [32]. Considering the 41 billion m^3 of underground water, the total renewable water potential of the country is calculated to be a gross figure of 234 billion m^3.

However, under today's conditions, the potential for consumption of surface water for various purposes is 95 billion m^3 of water from domestic rivers, 3 billion m^3 of water from neighboring countries, 98 billion m^3 of water per a year. With a groundwater potential of 14 billion m^3, the country's disposable surface and groundwater potential is the 112 billion m^3 per year and 44 billion m^3 of that is currently assessed [32].

Hydropower, among the renewable energy resources, is a reliable, economical, and sustainable energy source for Turkey [33]. In addition, hydropower is the primary renewable energy source for Turkey [34], [35]. Black Sea region has significant hydroelectric potential in that steep and the high-altitude rivers with fast flow rates. Hydroelectric plants in eastern Black Sea region have a large-capacity utilization rate. There are 25 river basins in Turkey [36], [37]. The 14 water basins contained 97% of Turkey's total hydropower potential are usually situated in mountainous regions. Turkey's highest hydroelectric power plants are situated in the Euphrates River, which is responsible for the 30% of country's potential with a drainage area of 127,304 km^2 [32]. These facilities include the Ataturk, Karakaya and Keban hydroelectric plants with a capacity of 2,400 MW, 1,800 MW and 1,330 MW, respectively [32].

The highest hydropower source in Europe is in Turkey by 216 TWh/yr [38-40]. Turkey utilized only 41% (88.88 TWh) in 2019. The development of hydropower capacity for Turkey is presented at Figure 6 [32]. Total hydropower potential increased 13.8 GW in 2008 to 28.5 GW in 2019. Hydropower energy capacity of 7.85 GW has been built on rivers in Turkey. The others were obtained from the dams because topographical conditions make small power plant development more convenient.

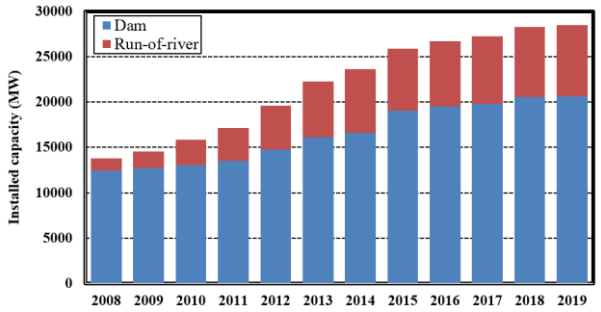

Figure 6. Installed hydropower capacity in Turkey

3.2. Wind Power

Wind turbine technology installed in Turkey has developed. The technology has formed an increasingly part of the country's electricity industry. With this development, the wind farms in Turkey have also been increasing. The first wind turbine (Vestas 55 kW) was installed in 1985 in Cesme, Izmir. However, the installation of modern and commercial wind turbine technology started in Alacati, Izmir in 1998. Wind energy in Turkey has undergone a major revolution since 2010. As of 2019, the largest commercial wind turbine available is 4 MW, with a rotor diameter of 130 m and a hub height of 126 m.

Turkey now has onshore wind power capacity of 8,056 MW. This corresponds to 3,285 grid-connected wind turbines and 198 wind power plants across 7 regions. These wind power plants in Turkey are dispersed over the Aegean, Marmara, Mediterranean, Central Anatolian, Black Sea and Southeast Anatolian regions. If we look at the provinces, the largest installed wind power plant capacity is located in Izmir. Izmir province (1,549.5 MW) is the leader in installed wind farms in Turkey in 2019, with 19.23% of the total wind turbine installations. Balikesir province (1,163.5 MW, representing 14.44% of the total installations); Manisa province (689.95 MW, 8.56%), Canakkale province (594 MW, 7.37%) and Hatay province (364.5 MW, 4.52%) are the second to the fifth largest, respectively, for installed wind power plants.

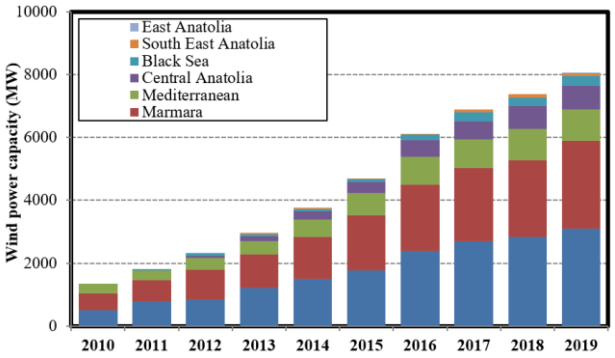

Figure 7. The regional growth in wind energy in Turkey

Wind energy is excellent, especially for Canakkale, Izmir, Balikesir and Hatay basins. The Aegean, Mediterranean and Marmara regions are more concentrated according to the geographical wind turbine distributions. As seen from Figure 7, the turbine capacity for Turkey increased from 1,329 MW in 2010 to 8,056.55 MW in 2019 thanks to growing cost competitiveness, advances in wind technology and government policies. According to MENR, 1 GW of wind capacity is put into operation every year, and 10 GW of wind investment in total for the next 10 years is reported to make Turkey among the world's leading countries in renewable energy. As of 2019, the greatest installed wind power capacity, a total of 3,098 MW was installed in the Aegean region, the second biggest capacity was installed in the Marmara region, a total of 2,796 MW and the third part was located in the Mediterranean region with a total of 996 MW [41].

3.3. Solar Power

Solar energy is a type of renewable energy whose source is the sun. Because this energy is "clean", it has no bad effects on the environment such as smoke, gas, carbon monoxide, sulfur and radiation. This is convenient in terms of cost of operation and can be easily installed wherever it is needed. In comparison to other European countries where the usage of solar energy is much greater, Turkey is more suitable for this type of energy. Because of its geographical location, there is more annual solar time. According to Turkey's solar energy potential map [42], daily sunshine duration is 7.5 hours and daily solar energy is 4.18 kWh/m^2. When the annual sunshine duration and annual solar energy are calculated, 2,741 hours and 1,527 kWh/m^2 are equivalent. Southeastern Anatolia is the richest regions for solar energy in Turkey, and total yearly solar energy is 1,460 kW/m^2, and the total sunshine duration is 2,993 hours per year. The Mediterranean region is the second biggest solar area. Turkey has almost no solar energy in the Black Sea region.

Compared to other energy investments, solar power plants have the advantage of price and special government grants since the solar energy investments is boosted day by day. Cost of state guaranteed production in solar power plants is 133 USD per MWh produced. This financial support also decreases the investment costs. Enterprises and factories that produce their own electricity are exempt from a certain amount of tax by the state and sell their surplus electricity to the electricity distribution companies. In Turkey, according to the law, solar power plants over 1 MW require permission, while production plants under 1 MW are not subject to permission. These power plant capacities (in industrial and household settings) and the power generated by these power plants are equal to 10% of the major power plants. The energy produced is not of a size to be underestimated.

Figure 8 presents development of installed solar power capacity for Turkey. As seen in this chart, solar power installed capacity increases very quickly every year. In 2017, 2.9 billion kWh of electricity was produced from solar energy. At end of 2018, collector area of the solar plants in Turkey reached 20.2 km^2. In total, the installed solar power reached 5.063 MW. This power was obtained from 4,981.2 MW unlicensed solar plants and

81.8 MW licensed power plants. At the end of the first half of 2018, the solar energy contribution to total electricity generation in Turkey increased from 2.5% to 5.4%. Also, in 2018, close to 876,720 TEP heat energy was produced by solar power plants. Within the scope of a Re-Zone competition which went to tender on 20/03/2017, the solar power plant that will be installed in Konya-Karapinar with a capacity of 1,000 MWe is considered as one of the largest solar power plants in the world. It will support 600,000 homes being built in the region. At end of 2019, the capacity of solar plants was 5,995 MW. Turkey expects to reach 10 GW of solar power by 2023. This means that an additional capacity of 4 GW will have to be deployed in the country over the next 4 years.

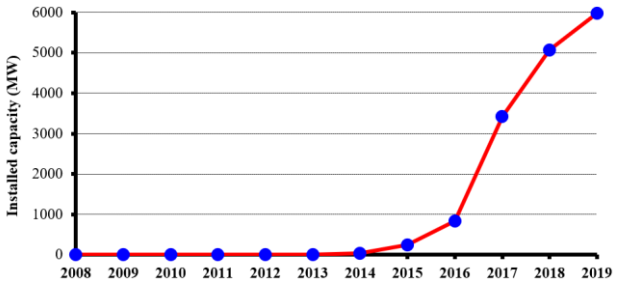

Figure 8. Development of installed solar energy capacity

3.4. Geothermal Power

As known, geothermal energy, which is preferred for direct utilization as thermal energy and electricity production, is more suitable for reducing greenhouse gas emissions in comparison to other energy sources [43]. Turkey has a complex geological area with an important geothermal energy potential that cannot be ignored and has an active tectonic plate boundary. In particular, the west of Turkey has a region showing a lot of geothermal activity [43]. Turkey is situated in Mediterranean earthquake region where the complex rock deformation results from the continental collision between Eurasian and African tectonic plates. On border of the plates, seismic belts marked by active faults and new volcano, have been formed, and in this way, provide geothermal energy, water circulation and heat flow. Distribution of hot springs is nearly same as in the regions where the new volcanic fault lines are located [44].

Since Turkey is located in Alpine–Himalayan belt, it has a significantly high geothermal potential, and this potential is 31,500 MW. Almost 80% of geothermal potential is active in the western Anatolian region of Turkey. It has been determined from the scientific studies that there are more than 186 geothermal fields that can be economically viable and about 1500 hot and mineral water resources which have temperatures ranging from 20 to 242 °C [21]. The first-time electricity generation using geothermal resources in Turkey was performed by General Directorate of Mineral and Research Institute at Kizildere-Denizli in 1968. Then, 0.5 MWe of energy power plant from geothermal resources was put into service in 1974 [45], [46].

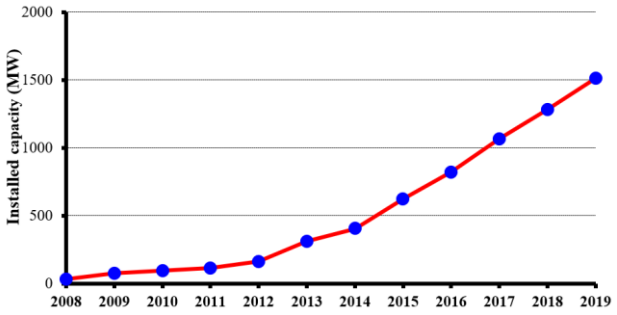

Figure 9. Development of installed geothermal power capacity

Figure 9 presents the geothermal power in Turkey. By the end of 2019, Turkey's geothermal power installed capacity was 1,515 MW, and 8,925 GWh of electricity was produced from geothermal energy. The country's largest single plant has become the first unit of Kizildere III power plant with a capacity of 99.5 MW and was launched in 2017. When completed in early 2018, the plant was Turkey's largest geothermal power plant with a capacity of 165 MW. The 33 MW Melih binary conversion facility installed in 2017 was one of the country's latest geothermal facilities [47]. Turkey has developed most of its geothermal capacity in only six years and has added over 1200 MW between 2013 and 2019. Supporting policies, which came into force more than a decade ago, are considered to be the main reason for strong growth and development in the Turkish geothermal industry.

The establishment rates of these power plants in the Western Anatolia, Central Anatolia, Marmara, Eastern Anatolia, and other regions were obtained as 78%, 9%, 7%, 5%, and 1%, respectively. While 90% of the geothermal areas have low and medium enthalpy values, it is appropriate for direct implementations such as tourism, heating, and mineral production. The remaining part can be used for indirect applications such as electricity generation.

3.5. Bio-Power

As known, biomass means the mass of organic matter of plants and animals (micro-organisms). In the biomass energy formation, the solar energy stored by plants is converted into chemical energy through photosynthesis [48]. This energy can be obtained from various animal and vegetable organic residues containing carbon atoms [49]. Examples of bio-power resources include forest residues, agricultural waste (oil seed plants, wheat straw, etc.), animal manure, household waste such as fruit and vegetable peel, food processing waste, algae, and garbage dump gas. Biomass will be one of the most important sources of energy in the near future to meet energy demand and guarantee energy supply safety and will be used in various areas due to the well-known and availability conversion systems [48]. Biomass can be assisted to address various the energy needs in three main areas, such as electricity, heat, and biofuel production (especially used for transportation) [21].

Biomass potential in Turkey, which has the potential to provide advanced rural energy services based on forest and agricultural residues, is estimated to be approximately 8.6 million tons of equivalent petrol (MTEP), and the amount of biogas produced from biomass is estimated to be 1.5 to 2.0 MTEP. The 6 MTEP of the 8.6 MTEP biomass potential is used for heating purposes. There are 4.8 million tons of material waste and 15 million tons of agricultural waste. Landfill gas extraction and exploitation have gained importance in recent years (total capacity of 162.7 million m^3/year).

Biomass, which is used in traditional and mainly domestic heating in Turkey, has started to be used in transportation and electricity production thanks to developing energy technologies, and it has entered a period of rapid development with government incentives for biomass investments. One of the recent studies into Turkey's biogas potential indicated that Turkey has 9.5 GW installed capacity of a biomass power plant to be evaluated [48]. The first biomass power plant in Turkey was established in Adana, and then they were established in Mersin and Tarsus. The facility in Adana has an installed capacity of 45 MW. The facilities in Mersin and Tarsus have a total power of 30 MW [21]. Figure 10 presents the historical development of installed bio-energy capacity in Turkey. In 2019, 4,116 GWh of electricity was generated from biomass power plants with a total installed capacity of 1162 MW.

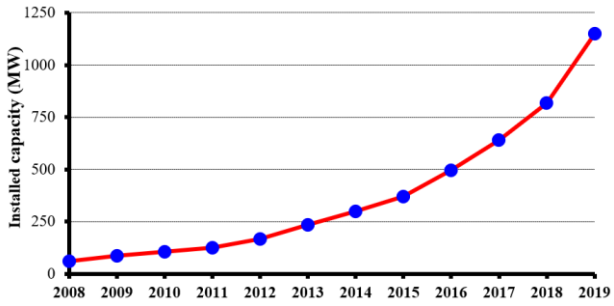

Figure 10. The historical development of installed bio-energy capacity in Turkey

4. TURKEY'S 2023 RENEWABLE ENERGY STRATEGIC VISION

The centenary of the Turkey Republic founding is in the year 2023. Turkey aims to become the world's 10th largest economy in this 100th anniversary of the foundation of its Republic. To achieve this aim, Turkey has planned and prepared many developments and attempts in the economic, political, and energy fields. One of the main objectives of the Turkish government in its 2023 strategic plan is to diminish its dependence on foreign energy imports. The 2023 Turkey strategic plan for renewable energy policies is as follows:

- to attract money required for investments
- to determine the objectives of the government related to renewable energy
- to ensure the effectiveness of energy demand in which RESs are used and to reduce costs, and
- to determine carbon emission policies

Within the scope of effective energy resources of Turkey, it is aimed to increase share of renewable electricity generation in total production. The share of imported resources will be reduced in total electricity generation, and a positive contribution will be made to the current account deficit. In order to use solar, wind, hydro, bio and geothermal energies, which has a significant potential, to be used more in electricity generation, the installed power value will be increased with new investments to be established by the private and public sectors, and thus contributing to the reduction of the current account deficit will be achieved by replacing imported resources with our natural resources.

Table 1 gives the studies on Turkey's 2023 renewable energy strategic vision prepared by the government of Turkey. Firstly, in 2009, the Turkish government reported the 2023 renewable energy strategic vision, which has a roadmap plan for the efficient development and strict planning of renewable energy. According to results obtained from this renewable energy strategic vision, Turkey aims to be 34,000 MW of installed hydropower capacity, 20,000 MW of installed wind power, 14,000 MW of installed solar power, a minimum 1,000 MW of installed geothermal power capacity and 1,000 MW of installed biomass power. With these installed power capacities, the Turkish government aims to increase share of renewable sources in the country's cumulative installed capacity to 30% by 2023. For this aim, until 2023 the total amount of investments needed to meet energy demand in Turkey is predicted to be around 110 billion dollars.

Table 1. The studies on Turkey's 2023 renewable energy strategic vision prepared by the government of Turkey

Energy indicator	First vision		Second vision		
	2009	2023	2018	2019	2023
Electric energy demand (TWh)	195.8	424.0	304.8	302.6	375.8
Total installed power capacity (MW)	44,761	120,000	88,551	91,431	109,474
Total installed renewable capacity (MW)	15,509	70,000	42,825	45,227	56,804
Share of renewable energy sources in electricity generation (%)	19.6	30	32.5	44.0	38.8
Total installed wind power capacity (MW)	792	20,000	7,369	8,056	11,883
Total installed solar power capacity (MW)	0	14,000	5,063	5,995	10,000
Total installed hydropower capacity (MW)	14,553	34,000	28,291	28,499	32,037
Total installed bio-power and geothermal power capacity (MW)	164	2,000	2,101	2,667	2,884

In 2019, energy and mining issues in the 11th Development Plan covering 2019-2023 were determined by MENR. In this development plan, 2nd 2023 renewable energy strategic vision was determined as given in Table 1. Figure 11 presents Turkey's renewable energy capacity for the period of 2018-2023 according to the 2023 vision.

It is foreseen that Turkey's vision of renewable energy sources shows interesting characteristic in terms of the planned 2023 objectives. For example, Turkey considers generation from large hydro and the wind power plants as sustainable energy. For the year 2023, Turkey aims to be 375.8 TWh of the electric power demand, 38.8% of share of renewable energy sources in electricity generation, 56,804 MW of the total installed renewable power capacity, 11,883 MW of the total installed wind power capacity, 10,000 MW of the total installed solar power capacity, 32,037 MW of the total installed hydropower capacity, and 2,884 MW of installed bio-power and geothermal power capacity.

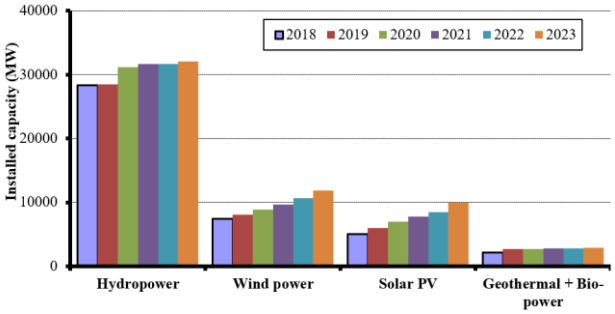

Figure 11. Turkey's renewable energy capacity for the period of 2018-2023 according to the 2023 vision

At the end of December 2019, Turkey had acquired 91,431 MW of total installed electric power capacity. A total of 28,499 MW of installed power is provided by hydropower plants, 8,056 MW of total installed power provided by wind power, 1,515 MW of total installed power provided by geothermal energy, 1162 MW of total installed power provided by biomass energy-based power plants and waste heat, and 5995 MW of total installed power provided by solar energy. By the end of 2019, renewable energy-based sources formed 49% of total installed power. Electricity generation is approximately 302.6 TWh. Renewable energy sources constitute approximately 44% of this generation. A total of 133,018 GWh of electrical energy is produced by renewable energy power.

In the last ten years, Turkey's installed renewable power capacity has seen an about 200% increase with 45,227 MW in 2019. One of the biggest reasons for this increase is the Turkish Renewable Energy Resources Support Mechanism (YEKDEM) started in 2011. In this support mechanism, renewable electricity production is mainly promoted through a guaranteed feed-in tariff (FIT). This feed-in tariff mechanism has been a key role in scaling up investments in Turkey's renewables. The scheme supported solar PV and biomass power plants at a cost of 0.133 $/kWh, hydroelectricity and wind power plants at 0.73 $/kWh, and geothermal power plants at 0.105 $/kWh costs. However currently, the country aims to reach 56,804 MW of installed renewable power capacity by 2023. Thanks to incentive programs, new technologies, private sector assistance, low renewable energy prices, this goal can be achieved. This means that the goal is achievable and realistic.

In the next 4 years, Turkey will see strong growth in its installed renewable power capacity in electricity generation, up from 45,227 MW in 2019 to an estimated 56,804 MW in 2023. Then, Turkey aims to establish a 4,000 MW capacity of solar power, 3,800 MW capacity of wind power, 3,500 MW capacity of hydroelectric power by end of 2023. In this way, share of renewable energy in electricity generation is expected to be 38.8%.

Turkey is a country that imports more than half of energy it uses, and one of the most crucial energy policy points is the improvement of wind and solar energy plants. Hence, energy politicians attach importance to renewable energy sources in order to reduce dependence on foreign sources. Increasing wind and solar energy plants, in particular, helps to reduce energy imports and the foreign trade deficit of Turkey. In order to reduce energy dependence, Turkey government should be increased use of renewable energy sources. Therefore, long-term energy demands will be supplied with help of wind and solar energy power plants.

When Turkey's renewable energy potential in hydro, wind, solar radiation, geothermal, biomass and biogas energy is taken into account, it is 160,000 GWh/year, 48,000 MW, 1,500 kWh/m^2 year, 31,500 MWt, 8.6 MTOE and 1.5 to 2 MTOE, respectively. The country also plans to boost both its wind and solar capacity by 10,000 MW each in decade through YEKA tenders. Turkish Ministry of Energy has prepared a plan for the first offshore wind energy power plant with a capacity of 1,200 MW. Additionally, Turkey has plans to produce energy from two nuclear power plants (Akkuyu and Sinop NPPs) until 2023 to reduce energy dependence on other countries and to meet growing energy needs. The construction of another nuclear power plant will be started in addition to these two nuclear power plants. When nuclear power plants in Akkuyu and Sinop start to produce energy, they are expected to generate roughly 80 billion kWh of electricity per year.

5. GLOBAL RENEWABLE ENERGY DEVELOPMENT

As of early 2016, more than 164 countries have aimed to establish targets on renewable energy, and around 145 countries have legalized renewable energy support policies [47]. A wide range of renewable energy alternatives exist. These include direct or indirect energy extraction from sun, wind or the heat stored deep in earth. Ocean waves and tides, hydropower, biomass, liquid biofuels, solid biomass, and biogas are other sources of energy [24]. Globally, growing public awareness enhances the development progress of renewable energy systems [47]. Figure 12 presents the global total installed capacity in renewable electric power. It is observed from the figure that the total installed capacity of RESs in the world is increasing rapidly. Worldwide progress of renewable energy started in the 1990s and it kept rising profoundly in 2000s. Power generation technologies as well as installed capacity have risen profoundly since then. In 2007, 1,000 GW of renewable energy capacity was established, and currently cumulative power capacity has achieved 2,537 GW worldwide.

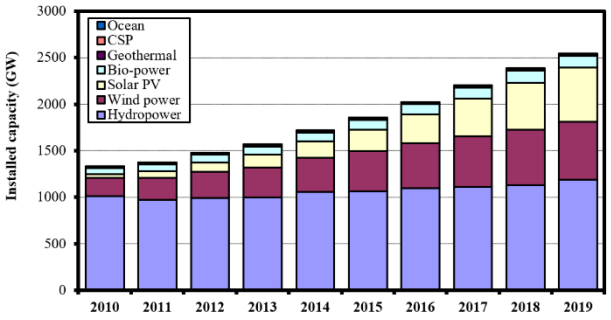

Figure 12. Installed capacity in renewable electric power

Figure 13 presents the ratio of renewable energy sources in global electricity generation. In general, RESs record global growing share of electric capacity invested yearly. By the end of 2019, it is estimated that RESs and wind power made up 27.3% and 5.9% of global electric production. Several countries are now keen on producing electricity from variety of RESs and they have already achieved high-capacity levels. For instance, contributions of renewable power generation were realized as 77% in Denmark, 42% in Germany and 38% in the United Kingdom in 2019. China, United States, Brazil, India, Germany and Japan were qualified to be the leading producers for cumulative installed renewable electric power capacity in 2019. With a total installed capacity of 789 GW, including about 359 GW hydroelectric power, China is the leader with approximately 31% of the world's renewable energy capacity. The leading countries for non-hydro power capacity are especially China, the United States and Germany followed by India, Japan and United Kingdom which all completed the year with parallel capacity levels [47].

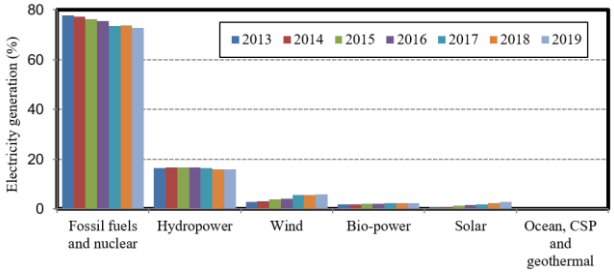

Figure 13. The ratio of renewable energy sources in global electricity generation

6. GLOBAL RENEWABLE ENERGY TARGET

In 2019, the International Energy Agency [50]. presented a market report on the current state of installed renewable power capacities and its development over the next five years. In this report, an analytical foundation that helps countries navigate their clean energy transitions in secure and cost-effective ways was provided. The global 2024 renewable energy target prepared by IEA is given in Table 2. As seen from the table, renewable energy generation capacity increased to 2,588 GW in total with a capacity increase of 210 GW in 2019. At the same time, the total installed renewable power capacity is expected to be approximately 3,585 GW in 2024. Renewables are estimated to will provide 30% of global electricity production by 2024. Results show that hydroelectricity will continue to be the largest renewable energy source in 2024. However, due to ongoing cost reductions and policy improvements for onshore and offshore wind as well as solar PV in key markets, there will be a great increase in the installed wind power capacity and especially solar PV power capacity by 40% and 90%, respectively.

Table 2. The global 2024 renewable energy target prepared by the International Energy Agency [46]

Renewable energy sources	Installed power capacity (GW)	
	2019	2024
Hydropower	1,150	1,271
Wind power	651	915
Solar PV	627	1,200
Bio-power	139	171
Geothermal	13.9	18.0
CSP	6.2	9.0
Ocean	0.50	0.56
Total	2,588	3,584.56

Table 3 gives the 2024 renewable energy capacity target by country. Sufficient policy support is given by governments to rise shares of renewables in electricity generation around the world. In the next five years, renewable power capacities will increase rapidly in many countries and regions. For example, China will see strong growth in its renewable power capacity, up from 790 GW in 2019 to an estimated 1,216 GW in 2024. In the United States, the renewable power capacity will increase from 282 GW to 392 GW between 2019 and 2024. On the other hand, Turkey's renewable power capacity will increase by approximately 46% (20 GW), particularly in solar PV, onshore wind and hydroelectric power in the period of 2019-2024. The Turkish government is approving a new framework for self-consumption and remuneration of excess generation at retail rates for commercial, residential and industrial implementations.

Furthermore, the new regulation increased the size suitable for support from 1 MW to 5 MW. Yearly competitive auctions (YEKA) are expected to encourage the growth of onshore wind power capacity, with projects that have been accepted FIT licenses but await final auction and transmission capacity. If the new distributed PV arrangement is applied properly, macroeconomic indicators are improved, and more capacity is allocated YEKA tenders, Turkey's renewable power capacity can grow 31% more rapidly [50].

Table 3. The 2024 renewable energy capacity target by country

Country	Total renewable power capacity in 2019 (GW)	Share of renewable energy in electricity generation in 2019 (%)	Total renewable power capacity in 2024 (GW)
China	790	26.4	1,216
United States	282	17.4	392
India	137	35.0	236
Germany	124	42.0	156
Japan	94	18.5	124
United Kingdom	47	38.0	58
Turkey	45	44.0	64
World total	2,588	27.3	3,584.56

7. GLOBAL RENEWABLE ENERGY POLICY AND VISION

Positive policy support given to renewable energy with more technological maturity and decreasing costs has contributed to the increase of institutional interest in renewable energy. The policy support for renewable energy can be classified as operational support, investment-oriented and consumer-oriented policies [51].

Operational support policies can be in the form of quantity-oriented and price-oriented approaches. The quantity-oriented and price-oriented policy approaches have been widely investigated and applied across the world. Quantity mechanisms determine a specific level of renewable electricity generation (quota obligations) or limit a total greenhouse gas emission level (emission limit). A tradable certification system is often used to accomplish this. Tendering, which is formed for the supplication of a definite amount of electrical energy from a certain energy system, is another quantity-oriented approach. Price-oriented approaches, which increase the cost of traditional energy sources with a carbon tax, can set a cost to be paid for renewable electricity (feed-in tariffs) [46, 51].

Feed-in tariffs (FITs), which the most widely used policy among European member countries, are one of the basic price-oriented operating support policies available. The feed-in policy usually guarantees renewable energies specified payments per unit (e.g., USD per kWh) over a fixed period. There is an obvious option that balances robust additions with dynamic learning and cost management, as policymakers think which policy, they can apply to reach the maximum rise in renewable energy capacity. Tariff guarantees have supplied all these criteria and have been successfully applied in many countries [46], [51].

Investment-oriented policies are used to reduce existing support for carbon-intensive companies or to strengthen the financial profile of renewable energy firms by governments. Tax exemptions and distinct forms of country funding such as low-interest loans, capital grants, and public benefit funds provide significant opportunities for renewable energy firms to manage their capital more efficiently. Investment-oriented policies have been usually considered less important than operational support policies. However, these policies can reduce financial risk by promoting a more supportive investment activity, thus promoting entrepreneurship in the field of renewable energy [51].

Consumer-oriented policies are mainly policies that try to change the behavior of electricity consumers by providing additional information and options on electricity sources, with the exception of net measurement. Mandatory green power options, disclosure programs, and net metering are the activities carried out under this policy [51].

8. CONCLUSIONS

Turkey, situated between Asia and Europe and also encircling the Aegean Sea, Black Sea and the Mediterranean Sea is making an effort to use its geographical position as an energy transit region. One of the main objectives of the Turkish government is to reduce on foreign energy. Various universities and government have created initiatives to increase the use of various renewable energy sources. Turkey has the highest hydroelectric potential in Europe with 216 TWh/year. Turkey's total installed hydropower capacity reached 28.5 GW in 2019. Turkey has very significant wind energy potential both on land and at sea. Turkey's wind energy potential is estimated to be 48,000 MW. However, the current wind power capacity was only 8,056 MW by the end of 2019. Turkey is one of the leading countries in the world in terms of geothermal energy potential.

Turkey's geothermal energy potential is 31,500 MW. Approximately 80% of this potential is in the Aegean region of Turkey. By the end of 2019, Turkey's geothermal installed capacity has been determined to be 1.515 MW. Among the renewable clean energy sources in Turkey, solar and biomass energy are also important because their share of the total energy consumption in Turkey has increased.

Turkey's traditional energy sources have insufficient energy capacity for its population and its economic development. In this sense, the government of Turkey has an independent energy policy thanks to the high potential of renewable energy resources in the country. Turkey is targeting its share of renewable energy production – which is 32.5% in 2018 – to be 38.8% in 2023. Turkey's 2023 targets include very important parts related to renewable energy technologies. These goals include 32,037 MW of hydroelectric power installed capacity, 11,883 MW of wind power installed capacity, 10,000 MW of solar power installed capacity, total 2,884 MW of geothermal power and bio-mass energy installed capacity.

According to the International Energy Agency, the global renewable energy generation capacity in 2019 was 2,588 GW in total, while this capacity is expected to be around 3,585 GW in 2024. This installed power is expected to provide 30% of global electricity generation. Among the renewable energy sources, hydroelectric energy is predicted to continue to be the largest renewable energy source in 2024. However, a large increase in solar PV power capacity is expected, in addition to wind energy.

The most important reason for the progress in the development and use of renewable energy technologies worldwide is shown as effective government policies. Today, the policy continues to be important in overcoming technical, economic, and institutional barriers to the development of renewable energy technologies. Many countries have adopted policies to meet their specific circumstances, including supporting increasing renewable energy capacity and production, accelerating job creation, and increasing energy access and security. Trade policy has had an impact on the development, exchange, and production of renewable energy products, as well as on renewable energy demand levels in certain countries. In addition, the reduction of climate change by developing policies in line with some of the jurisdictions of governments has directly associated with the increased use of renewable energies.

NOMENCLATURES

IEA: International Energy Agency
RESs: Renewable Energy Sources
MENR: Ministry of Energy and Natural Resources
TEP: Tonnes Equivalent to Petrol
MTEP: Million Tons of Equivalent Petrol
YEKDEM: Turkish Renewable Energy Resources Support Mechanism
YEKA: Renewable Energy Resource Areas
FITs: Feed-in tariffs

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