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Review Article

Contemporary Status and Recent Trends of Renewable Energy Certificates in Türkiye

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ABSTRACT

There is a trend towards increasing the use of renewable energy resources worldwide. In addition to countries' efforts to increase this with the help of laws, the industry is also trying to expand the use of RE since the vast majority of the emissions are produced by the industry. Although Türkiye has rich renewable energy resources, these resources cannot yet be used effectively. Renewable energy certificate is one of the latest methods to reduce greenhouse gas emissions with the help of market mechanisms. Although renewable energy certificate is a very incipient concept for Türkiye, it has a significant potential to encourage and promote the usage and investments of renewable energy. In this study, current trends, and future expectations regarding renewable energy certificate in Türkiye have been compiled in line with the opinions of renewable energy certification experts from sector. It is thought that such analysis will be a guide for the sector and lawmakers on this subject. It is expected that the increase in academic discussions on market-based carbon emission reduction approaches will both contribute to the awareness of industry and the success of policies of national certification institutions. In this way, the payments made by industrialists in Türkiye to certification institutions abroad can be prevented from increasing at a level that would affect the current account deficit in the long term.

1. Introduction

The increase in energy consumption brings air, water, and soil pollution, greenhouse gas emissions (GHGE), and many other problems. Since the gradual increase in GHGE in the world brings about global warming, it is one of the most important issues is the prevention of greenhouse gas emissions [1]. Today, many companies have started to build a green supply chain to respond both to the customer demands and to the environmental regulations in force for the goods or services they obtain through environmental sustainability [2,3]. Realizing that the sustainability will increase the profitability with the expanded market share, the companies have started to implement many environmentally friendly decisions [4].

Renewable energy (RE) plays a big role in solving air, water, and soil pollution problems and also in greenhouse gas emission increase [5]. Focusing on RE, green logistics, green production, and green products, contributes to businesses increasing their supply chain (SC) activities [6]. Renewable energy certificate (REC) is one of the latest mechanisms used to eliminate or reduce the greenhouse gas emission problem. RECs are instruments that represent the qualities of electricity produced from energy sources, reduce CO2 and other greenhouse gas emissions, and contribute to the growth of the share of RE [1,7]. RECs can be generated from solar energy (SE), wind energy (WE), hydropower energy (HE), geothermal energy (GE), and biomass energy (BE) [1]. RECs correspond to the electricity in MWh unit produced by RE resources (RERs) [8]. A REC contains information not only about the energy source but also about energy properties. Consumers with REC serves reducing GHGE by using energy [9]. The prevalence of REC has a high impact and potential to contribute to green supply chains. In addition to the benefits that REC mechanisms provide, it is foreseen that the motivation it provides to energy producers will have a locomotive effect encouraging the increase of the share of RESs in the energy production. Thus, sustainable energy transformation will be accelerated.

In the literature, there are many studies on REC from various perspectives. Gupta & Purohit [10] evaluated the mechanism of REC in India. The effectiveness of REC mechanisms was evaluated by considering cost competitiveness, decentralized distributed generation, and RE portfolio diversity in that study. A customized approach was preferred instead of the standard evaluation method. Girish et al. [8] examined REC trade in India, policies promoting RE, the obligation to purchase renewables, the role of energy exchanges in REC trading, and possible policy considerations for the future. Hulshof et al. [11] investigated the customer churn rate, certification rate, expiry performance of certificate expiry dates, and price variability of the REC markets of 20 European countries using a Guarantee of Origin (GO) between 2001-2016. It is seen that the certification rate in 2015 increased compared to 2001, but there was no change in other variables. Adamczyk & Graczyk [12] evaluated the REC system implemented in Poland since its accession to the European Union. REC certificates have also started to be bought and sold in Türkiye, but they are not widely used yet. There are many both domestic and foreign certification bodies in Türkiye. The RER guarantee system (YEK-G) is a domestic and national REC program started work by the Energy Market Regulatory Authority in 2020. This system is established and operated by the Energy Markets Operation Inc. (EXIST). Çalıkoğlu [13] analyzed the volume of REC market in terms of certificate supply and demand, and calculated the return that green certificates provide resources(RERs) including BE, HE, GE, WE, and SE to the investors. It was suggested that the power plants (PPs) within the scope of RER Support Mechanism (YEKDEM) should join the REC system to increase the REC volume. Özcan et al. [1]

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analyzed the RECs used in the world, evaluated the REC system in Türkiye, and calculated Türkiye's REC potential according to electricity consumption data. They concluded that REC was produced from 0.72% of Türkiye's current potential.

In this study, the existing patterns and forthcoming projections concerning renewable energy in Türkiye have been systematically gathered, aligning with the insights provided by renowned certification experts within the sector. This collation of information is envisioned to serve as a valuable reference for both industry stakeholders and legislative bodies. The anticipation is that by fostering this exchange of knowledge, the REC sector and policymakers can derive valuable insights. Foreseeably, the surge in scholarly dialogues surrounding REC is poised to not only heighten public consciousness but also play a pivotal role in shaping the policies of domestic certification bodies. An anticipated outcome of this heightened academic discourse is a positive impact on national certification institutions, as they stand to benefit from an increased depth of discussions. This collective understanding is likely to fortify these institutions, potentially reducing the reliance on foreign certification bodies. Such a shift can act as a preventive measure against a substantial escalation in payments made by Turkish industrialists to overseas certification entities, thereby mitigating the risk of an adverse impact on the country's long-term current account deficit. The interconnectedness of academic engagement, policy formulation, and economic sustainability is thus underscored in the context of Türkiye's REC landscape.

The rest of the paper has been arranged as follows: Overview of Türkiye's electricity market, Türkiye's RE production potential and utilization are analyzed in Section 2. The trade of REC in global is presented in Section 3, and recent trends about REC in Türkiye is analyzed in Section 4. Concluding remarks and future research directions are given in Section 5.

2. Renewable Energy in Türkiye

In Türkiye, the industrial institutions must purchase their electricity from the electricity market. Similarly, all the energy power plants must sell their electricity in the electricity market. Renewable energy power plants must also be market participants to be able to sell their electricity. The following subsection gives brief information about the electricity market.

2.1. Overview of the Türkiye Electricity Market

It is possible to talk about 3 types of markets in electricity trade in Türkiye. These markets are (i) day ahead market (DAM), (ii) intraday market (IDM), and (iii) balancing power market (BPM). These markets are explained in the following subsections.

The DAM is the market used for balancing activities and electricity trading, on the day before the delivery day of electricity. These markets are operated by the market operator [14]. In the DAM, electricity supply and demand are summed every hour for the next day of the current date, these supply and demand amounts are matched, and the hourly market clearing price (MCP) is determined [15]. Transactions are executed on a daily, hourly basis. Participants can submit these offers starting from the next day of the current day and up to 5 days later. Since prices and quantities are determined on a daily basis and for each hour in DAM agreements, offers consist of different quantities and price information for different hours. The DAM has flexible bids, hourly offers, and block offer structures. Hourly offers consist of 64 levels, 32 in the buy direction and 32 in the sell direction. At the same price level, both an hourly buying offer and an hourly selling offer cannot coexist. Block bids consist of price, quantity, and time frame elements. This time zone consists of consecutive and full-time zone offers. Block bids that do not cover at least 3 and at most 24 hours are either accepted or not accepted within the time frame they cover. In the block bid, the bid limit for one day is 50. Flexible bids consist of quantities that can change for a given bid period within a given bid period, and single price information depending on the quantities. It can be given in the direction of buy and sell, but a flexible offer does not have both a buy and a sell amount within the bid period. Participants can submit a maximum of 6 bids in the same or different time intervals [16].

In the IDM, the participants inform the market operator about their offers for the next day, starting from 18:00 until the closing time of the IDM. The transactions take place hourly, as in the DAM, between 00:00 and 23:59. Transactions carried out in this market can be made at any time until the closing time of the IDM. In the IDM there were hourly and block bid structures, but block bids have been abolished as of January 1, 2024, with the new regulation. When the difference between hourly and block contracts is investigated, it is seen that offers for hourly contracts are divisible but offers for block contracts are not. The IDM is an ongoing market, and participants can bid up to 1 hour before physical delivery. At the same time, they can update and cancel their offers. In the IDM, block and/or hourly offers can be made for a certain time period. These offers consist of different quantities and price information for different hours. Hourly offers in the IDM can be partially or fully matched. In hourly bid structures, one of the types of active orders, immediate or cancel (IoC), expiration time and fill or kill (FoK) is selected. Block orders are not fragmented, so they are traded as a whole. Each block order is accepted or rejected for the total duration of the contract. The block order structure is selected as one of the active order and expiration time types [17].

BPM provides the System Operator with spare capacity for real-time connectivity. Although a balanced market for production and consumption quantities is presented to the IDM, DAM, and BPM, there are deviations in real-time. All BPM participants are obliged to submit their available generation capacity. In the BPM, the up-regulation instructions capacity (URIC) and down-regulation instructions capacity (DRIC) are expressed as shown in Eqs. (1-2) [18]:

$$URIC = Available\ Capacity - Final\ Day\ Ahead\ Generation\ Schedule \quad (1)$$

$$DRIC = Final\ Day\ Ahead\ Generation\ Schedule \quad (2)$$

Market participants can submit their offers/bids at 15 levels of volumes for offer and bid directions [18].

Energy is very important for the security of life and the returns of economic and social development all over the world [19]. Türkiye energy market is one of the fastest growing ones in the world. There are many reasons for this situation to occur. The increase in energy demand per capita with the increase in population in the last 20 years, the development of the economy, and the rapid growth of urbanization and industrialization are among these reasons [20].

2.2. Renewable energy resources support mechanism incentive

The regulations about RERs were made in the recent past. First regulation enters into force with the name "The Law on the Use of Renewable Energy Resources for the Purpose of Electric Power Generation" in 2005 and this law was updated in 2011 to define the duties of the relevant regulatory bodies more clearly [21]. With this law, incentives are given to RERs according to their locality rate and source type. A new law with the name "Regulation on Certification and Support of Renewable Energy Resources" was published in 2013 to regulate the establishment and operation of YEKDEM, and the issuance of RECs for generation license holders. There are a total of 5 agreed RE, the operating power of YEKDEM participants is 21,622.4 MW. At the same time, the production of the participants was 74.16 million MWh (74.16 TWh) in 2021 and increased by 0.92%

compared to 2020.

In Table 1, prices for 2021 are given based on resources and type of Energy Production Facilities (EPFs) [22].

According to the market development report published by EMRA in 2022, the annual generation amount of YEKDEM participants was increased in 2021 compared to 2020 and was realized as 74,156,245 MWh. In 2021, the generation within the scope of YEKDEM was mostly obtained from WE. The distribution of YEKDEM production by resources for 2021 is given in Figure 1 [22].

Table 1. Prices and times within the scope of YEKDEM [22]

Type of EPF Based on RER		YEKDEM Price (TL/kWh)	YEKDEM Price Implementation Period (year)	Local Content Price (TL/kWh)	Local Content Price Implementation Period (year)
Hydropower		40	10	8	5
Wind		32	10	8	5
Geothermal		54	10	8	5
Biomass	Waste products of the landfill gas or waste tires	32	10	8	5
	Biomethanization	54	10	8	5
	Thermal disposal	50	10	8	5
Solar		32	10	8	5

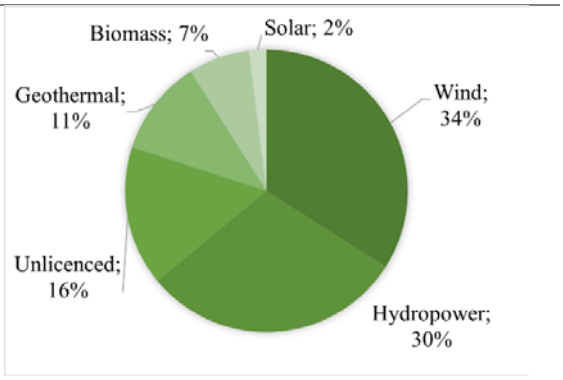


Fig. 1. Distribution of 2021 YEKDEM production by resources [22]

2.3. Utilization of renewable energy resources in Türkiye

Although Türkiye is in a very convenient geographical location in terms of RERs, it is a foreign-dependent country in energy since almost more than half of the energy in Türkiye is imported [20, 23]. In Figure 2, production rates based on resources for 2022 are given.

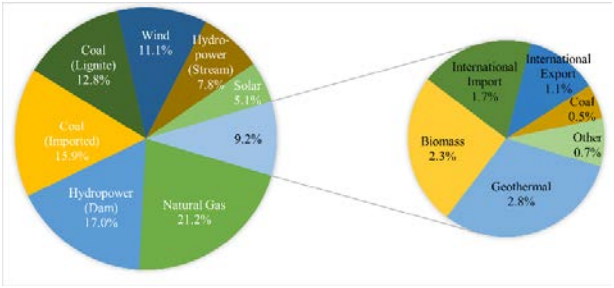


Fig. 2. Resource-based electricity production rates in Türkiye, 2022 [24]

The most significant growth in production in 2022 is seen in natural gas, hydropower, imported coal, and lignite production. According to Figure 2, it is seen that traditional fossil fuels are produced more than RERs to meet Türkiye's energy demand. However, it can be interpreted that the share of hydroelectricity in production is higher than other RERs. Türkiye's economic HE power potential is forecasted as 16% of the economic potential of Europe. Its theoretical HE potential is forecasted as 1% of the world's theoretical potential. Considering the production rates in 2022, it is seen that HE occupies an important place among RERs for Türkiye. The economic HE potential of Türkiye's hydraulic resources is 160 million MWh/year, the technical usable potential is 216 million MWh/year, and the total HE potential is 433 million MWh/year. As of the end of June 2022, the installed power based on HE was 31,558 MW and its ratio to the total installed power was 31%. When the change in the last 10 years is examined, it is seen that the installed power based on HE has increased. Hydraulic-based electricity generation reached 35.2 million MWh by the end of May 2022. Figure 3 shows the changes in power based on HE, WE, SE, BE, and GE over the last 11 years [25].

Türkiye has various renewable energy sources. In Figure 4, the wind map, solar radiation map, precipitation map, and GE sources map are given [25-26].

As seen in Figure 4, some areas of Türkiye has potential for the wind energy. In 2006, it was decided to establish a wind energy PP (WEPP) with a power of 5 MW per square kilometer in areas 50 meters above ground level and with annual average wind speeds of over 7.5 m/s and the total capacity of the WEPPs to be established should be 47,849.44 MW. As of the end of June 2022, the installed WE power was 10,976 MW and its ratio to the total installed power was 10.81%. When the change in the last 10 years is examined, it is seen that both the installed WE power and the ratio in the total installed power has increased [25]. Türkiye aims to increase its WE and SE by at least 1.000 MW per year in the coming years [23].

Türkiye has a high potential in terms of SE thanks to its geographical location. Turkish Solar Energy Potential Atlas (SEPA) reports that, the average annual sunshine duration is 2,741 hours, and the average annual total radiation is 1,527.46 kWh/m2. At the end of the first half of 2022, the installed SE power was 8,479 MW and its ratio to the total installed power was 8.35%. When the change in the last 10 years is examined, it is seen that both the installed SE power and the ratio in the total installed power has increased [25]. According to the Biomass Energy Potential Atlas (BETA) prepared by the TR Ministry of Energy and Natural Resources, the total economic energy equivalent of the wastes that can be collected is approximately 3.9 million tons of oil equivalent (MTOE) per year. As of the end of June 2022, the installed BE power was 2,172 MW and its ratio to the total installed power was 2.14%. When the change in the last 10 years is examined, it is seen that both the installed BE power and the ratio in the total installed power has increased [25].

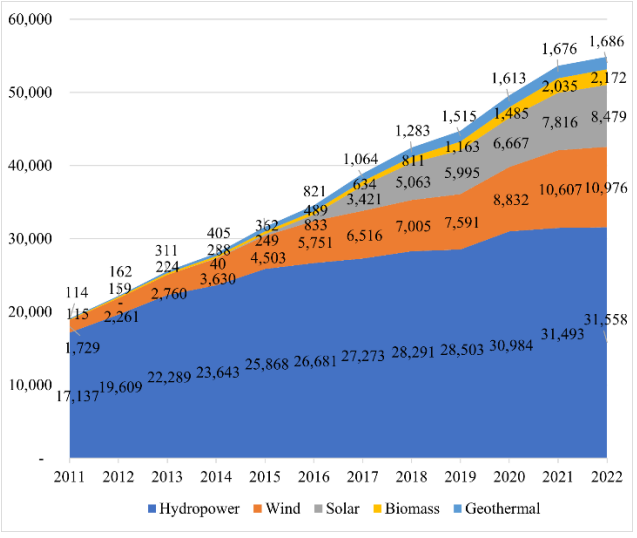


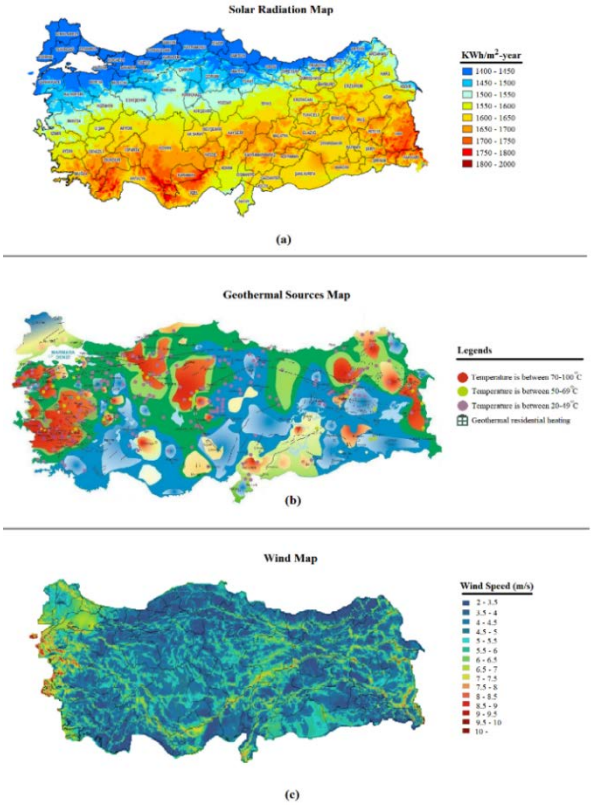
Fig. 3. Installed power based on RERs [25]

Since Türkiye is located on an active tectonic belt, it is in a

very good position when compared to other countries in terms of GE. It is the first country in Europe in terms of GE potential and the 4th country in the world in terms of installed power. There are 1,000 GE resources in total in Türkiye. 78% of these resources are located in Western Anatolia region, 9% in Central Anatolia region, 7% in Marmara region, 5% in Eastern Anatolia region, and 1% in other regions. As of the end of June 2022, the installed GE power was 1,686 MW and its ratio to the total installed power was 1.66%. When the change in the last 10 years is examined, it is seen that the installed GE power has increased. However, it is seen that the ratio in the total installed capacity is lower than in 2020 and 2021 [25].

The total installed renewable energy power is increasing in Türkiye. In line with this increase, the relative shares of the RERs are changing based on years. As seen in Table 2, wind and solar energy investments are more popular than the other RERs. There are several reasons for this tendency. Wind and solar resources are more abundant than the other sources. They also have less initial investment requirement than the others. It is expected that the share of solar and wind energy will continue to increase compared to other RERs.

In Figure 5, resource types and energy production rates in 2022 are given. Conventional energy sources consist of widely utilized streams, fossil fuels such as wood, coal, oil, natural gas, and nuclear fuels consisting of elements such as uranium and thorium. Keeping the amount of production under control and being able to be produced continuously are among the most important and common features of conventional energy sources [27]. The increase in Türkiye's energy demand in recent years is satisfied by fossil fuels such as coal, oil, and natural gas. The most important reason for this situation is that Türkiye is located in an important geographical region rich in oil and gas reserves [23]. This can be clearly seen in Figure 5.



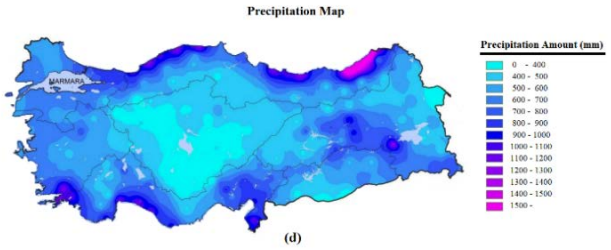


Fig. 4. (a) Solar radiation map, (b) Geothermal sources map, (c) Wind map, (d) Precipitation map [25, 26]

Within the scope of its 2023 energy vision, Türkiye aims to use RERs most effectively and to increase the share of RERs in electricity generation to 30% by 2023. With the commissioning of the first nuclear PP in 2023, the fuel mix will diversify. Türkiye has managed to exceed 38.8% of its target of electricity generation from RERs within the scope of the Eleventh Development Plan (2019-2023). It is targeted that electricity consumption will be 530 million MWh in 2023 and 160 million MWh will be provided from RERs [25].

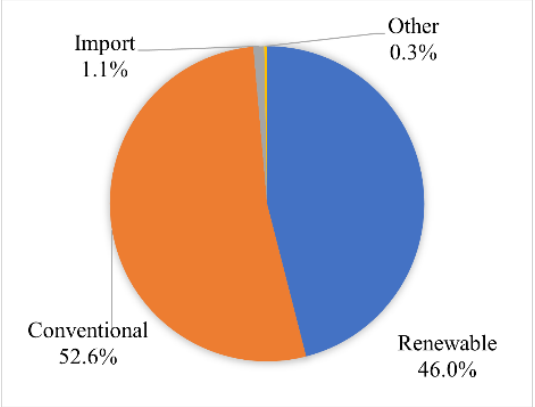


Fig. 5. Types of resources and energy production rates in 2022 [24]

Table 2. Installed power ratio based on RERs [25]

Year	Hydropower	Wind	Solar	Biomass	Geothermal
2011	89.7%	9.1%	0.0%	0.6%	0.6%
2012	88.4%	10.2%	0.0%	0.7%	0.7%
2013	87.1%	10.8%	0.0%	0.9%	1.2%
2014	84.4%	13.0%	0.1%	1.0%	1.4%
2015	81.8%	14.2%	0.8%	1.1%	2.0%
2016	77.2%	16.6%	2.4%	1.4%	2.4%
2017	70.1%	16.7%	8.8%	1.6%	2.7%
2018	66.6%	16.5%	11.9%	1.9%	3.0%
2019	63.7%	17.0%	13.4%	2.6%	3.4%
2020	62.5%	17.8%	13.4%	3.0%	3.3%
2021	58.7%	19.8%	14.6%	3.8%	3.1%
2022	57.5%	20.0%	15.5%	4.0%	3.1%

When the share of resources in the total installed power is examined by considering the data of previous years, it is seen that some resources have not changed in terms of quantity, while others have increased. Based on the data in 2015 and 2020 in Figure 6, it has been forecasted how much the share of resources in the total installed power will be in 2025. The share of lignite, imported coal, natural gas, and hydraulics will decrease compared

to other years; It is expected that the share of wind and sun will increase compared to other years [28].

3. Renewable energy certificate trading in global

In nature, there exists an unparalleled carbon cycle, and for millions of years, the world has maintained equilibrium through this cycle, providing a habitat for numerous species. The disruptor of this immaculate balance is the tendency of humans to produce and consume beyond necessity. This imbalance is exacerbated by rapid developments and changes in areas such as industrialization, transportation, and agriculture, primarily contributing to an increase in carbon emissions into the atmosphere. While the energy sector and fossil fuels are typically the first thoughts that come to mind, this issue is not singularly confined to the energy sector. It is a global problem directly or indirectly influenced by various stakeholders. The most crucial keyword here is the global nature of the problem. Excess carbon emitted into the atmosphere in any part of the world impacts not only that region but the entire globe. Therefore, nations endeavored to address this global issue by coming together to sign a framework agreement named the Kyoto Protocol. The Kyoto Protocol emerges as the initial focal point of the historical development of RECs. This attempt can be emphasized as "endeavored" because, unfortunately, the attitudes of global powers persist in either not signing this agreement or failing to fulfill its conditions, even in the present day. Signed in 1997, the goal of this protocol is to reduce the carbon emissions to the levels of 1990. As the agreement reached 55% of the emitting countries by 2005, it came into effect in the same year.

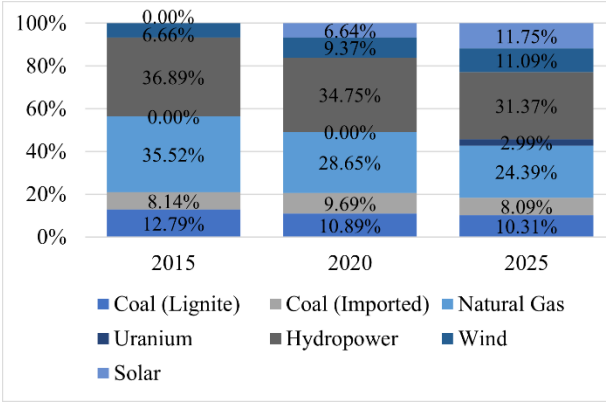


Fig. 6. Share of resources in total installed power [28]

Bringing back the amount of carbon accumulated in the atmosphere is not a goal that can only be achieved by generating electricity from renewable sources since RE plays a big role in solving the greenhouse gas emission increase. The carbon retention capacity of nature and soil also needs to be increased. Applications in the field of energy efficiency and agriculture are very critical. What we call energy efficiency already includes all sectors. In terms of progress on carbon emission reduction, countries can be classified as “mandatory countries” and “others”. From another perspective, it can also be classified as “developed” or “developing”.

REC is one of the latest mechanisms used to eliminate or reduce the greenhouse gas emission problem. RECs are instruments that represent the quantities of electricity produced from energy sources, reduce CO2 and other greenhouse gas emissions. The prevalence of REC has a high impact and potential to contribute to green transition. RECs are demanded by energy-intensive industries. Large industries may force their suppliers to obtain RECs as well.

Renewable Portfolio Standard regulations have been established in most countries in the world and it is aimed to produce energy through RERs [29]. Governmental agencies are of great importance in the successful implementation of RECs. In most countries, these mechanisms and institutions have recently been established and have just begun to function. REC standards applied in the world may vary in regions and countries. RECs, Guarantees of Origin (GO), and International REC (I-REC) are examples of these standards.

The authorized institutions in the I-REC regulation, including Türkiye, and the countries for which the certificate is issued are given in Table 3 [1]. Since RECs are implemented in many countries, it is very important to ensure cohesion between these countries. For this reason, the Central Agency unit has published a guide titled “Model Procedure/Guidelines for Accreditation of Renewable Energy Project for REC Mechanism by State Agency” [30]. Information on how REC trade is carried out in some countries is given below.

Table 3. I-REC regulatory authorities and certificate issuing countries [1]

Authorized Institutions	Certificate Issued Countries
Dubai Carbon Centre of Excellence	United Arab Emirates, Jordan, Morocco, Oman, Saudi Arabia
The Center for Studies in Systemic Economics	Colombia
Electricity Generating Authority of Thailand	Thailand
Energy Peace Partners	Democratic Republic of the Congo
Goal Number Seven	Russia
Green Certificate Company	China, Costa Rica, Egypt, El Salvador, Guatemala, Honduras, India, Indonesia, Nigeria, Malaysia, Mexico, Panama, Peru, Philippines, Sri Lanka, South Africa, Taiwan, Türkiye, Uganda, Vietnam
Green Energy Services	Israel
Instituto Totum	Brazil
Santiago Climate Exchange	Chile
Singapore Power	Singapore
The Green Certificate Company (until 2020) FOTON (since 2021)	Türkiye

REC trading started in India in 2011. The trade is operated through 2 exchanges, Indian Energy Exchange (IEX) and Power Exchange India Limited (PXIL), whose activities are regulated under the Electricity Market Regulations and that trading day ahead and forward electricity [31]. In both exchanges, buying and selling transactions are made on the last Wednesday of the month [32]. Each REC is allowed to be sold as separate products on the energy exchange and the electricity sold on the energy exchange is allowed to be sold at the market-determined price [33]. While determining the selling price of RECs, the floor prices and forbearance prices for solar and non-solar RECs are used. The selling price must be between these two prices. The amount of REC offered for sale to a RE producer must not exceed the total amount of REC given to that producer. For this process, necessary controls are made after the trade [30].

In many countries, RECs are issued to consumers and in some countries to producers. India is a country that recommends that RECs be issued to RE producers. However, in countries such as England, the USA, and Australia, contrary to India, RECs are given to the majority of producers. RECs in Australia is equivalent to a one-megawatt hour of electricity and are only given to authorized RE producers. Organizations can trade with certifying producers to obtain RECs [34].

REC trade in the USA comes in two forms: compliance markets and voluntary markets. Policy decisions are essential in compliance markets. The most important of these policies is the Renewable Portfolio Standards (RPS). RPS policies and goals are different for each state. According to the report published in 2021, RPS policies are implemented in a total of 30 states, accounting

for 58% of total retail electricity sales in the country. In voluntary markets, consumer demand is essential. These markets allow consumers to procure RE at levels different from those determined by policy decisions. At the same time, these markets support the purchase of RE. The Netherlands was the last country among other European countries to adopt the "full consumption disclosure" plan supported by RECs [35].

4. An Analysis on Renewable Energy Certificates in Türkiye

In this section, available REC mechanisms in Türkiye are described, current trends and future provisions are presented. To make the analysis clear, a general overview of the REC trading in global is presented.

4.1. Recent trends on renewable energy certificates

Globally, various binding measures, including market-oriented approaches, are being explored to reduce carbon emissions. Market-oriented approaches are generally built on REC. These efforts involve implementing carbon pricing mechanisms, such as Emission Trading Systems (ETS), carbon taxes, and voluntary initiatives like the voluntary carbon market. There are two basic approaches to creating markets. In the first approach, "emission right trading" (cap and trade schemes/emissions trading systems) is used, while in the second approach, emission rights are purchased in return for the amount of carbon with reduced emissions (baseline-and-credit/offsetting), that is a kind of balancing system. Carbon balancing, a non-mandatory market-based measure, is particularly relevant in countries like Türkiye, where mandatory carbon pricing is absent. However, even in nations with mandatory market-based carbon reduction measures, balancing mechanisms are employed.

Carbon credits, known as Verified Emission Reductions (VER), signify units used to communicate each ton of CO2 equivalent greenhouse gas reduction achieved by emission-reducing activities. These credits reference an activity of equivalent capacity that would have emitted greenhouse gases. Projects earning carbon credits span various categories, including Agriculture, Industrial production, Energy efficiency, Forestry and land use, Renewable energy, Transportation, and Waste disposal. Carbon credit creation is grounded in RECs.

Organizations emitting carbon gases need to calculate Scope 1, Scope 2, and optionally Scope 3 emissions per the Greenhouse Gas Protocol to offset their carbon emissions. This process requires the inclusion of Scope 1 and Scope 2 emissions. Organizations with more stringent reduction policies can also calculate and include Scope 3 emissions. To offset emissions, organizations can acquire carbon credits from entities holding VER certificates, achieving carbon neutrality when offsetting their total GHGE.

In Türkiye, projects reducing GHGE could initially obtain carbon credits through Verified Carbon Standard (VCS) and Gold Standard (GS). GS and VCS are available for Scope 1 and 2. I-REC and YEK-G are only available for Scope 2. However, since 2020, GS and VCS no longer accept new project registrations from Türkiye. The Global Carbon Council (GCC), a new standard, accepts registrations for projects initiated in Türkiye from 2016 onwards, facilitating a retrospective 5-year certification process. Project owners can independently coordinate the certification process or enlist the services of a carbon consultancy firm. This process comprises three key stages: Listing, Registration, and Verification.

There are differences between carbon credit reduction methods. Purchasing emission reduction rights is a future-oriented transaction. Companies purchase the determined emission amount for countries through auction. Each emission certificate is returned to the government after that amount has been emitted. This serves the purpose of reducing total emissions by being reflected in the prices of products with intense carbon emissions. The certificate that can be purchased in total is limited by country.

The reduced carbon amount (balancing) method is the trading of an amount that has already been prevented from being emitted, that is, it is a transaction that covers the past. Since it is designed with a zero-sum game logic, companies are allowed to oscillate as much as they want. That's why this scenario is criticized by environmentalists. It serves to reduce total emissions, but since it is more vulnerable to environmental factors such as economic growth, it is not as consistent as the first scenario and is more difficult to control.

Although the method of selling emission rights serves the main purpose better, the majority of markets established to date work with the balancing method. Markets where carbon credits obtained from projects/production facilities with a certain certification are purchased/changed by companies that have exceeded the carbon emission limit are called carbon markets. Companies have the following motivations for participating in carbon markets: sustainability, environmental awareness, increasing brand value, competitive advantage, social responsibility.

Just as mandatory markets have been established for countries subject to limits determined by international agreements, there are also voluntary markets, including developing countries that make mitigation investments without obligation. The markets are not at the expected level, prices were expected to reach the 80 USD band in 2020, this figure was in the 40 - 60 USD band in some studies. These prices have still not been reached.

The motivation of companies to invest in renewable certificates generally appears as to benefit from energy incentives for certificate issuers, marketing, obligation for commercial activities, brand awareness, advertising, etc. for certificate recipients. The tendency for REC is rapidly increasing in Türkiye. While the number of VCS projects from Türkiye was 152 according to August 2020 data, it increased to 232 in August 2023. Similarly, while the number of GS projects from Türkiye was 286 according to August 2020 data, it increased to 307 in August 2023.

VCS's processes are easier compared to GS. On the other hand, not only the positive contribution to the environment, but also the fact that the project does not have a negative impact on the environment is taken into consideration. However, Verra, the largest certification body implementing VCS, has been subject to criticism from academia, claiming that more than 90% of its carbon offsets are worthless [36]. GS is the most expensive certification standards compared to others.

Türkiye is one of the countries using I-REC standards. I-REC is the lowest cost among the globally recognized certificates. Although YEK-G is cheaper than I-REC, it is only valid in Türkiye. YEK-G certificates are also supported by the Green Tariff, which aims to encourage and popularize the use of renewable energy. There are different certificates in Europe and America.

4.2. I-REC and YEK-G mechanisms and current issued volumes

In order to address the issue in a holistic manner, it is useful to mention the I-REC and YEK-G mechanisms and the number of certificates issued.

In countries using the I-REC standard, there is a local certification body, and the procedure is applied in this way. However, in countries where there is no local certificate issuer, the procedure is carried out with the Green Certificates Company (GCC). Türkiye carries out this procedure with the GCC

organization. However, this situation has changed in 2020, and Foton Energy has started to act as a local certification body. Registrations with I-REC are valid for 5 years. If the certification process is completed before August of the applied year, retrospective certification can be done as of January of the previous year. However, if the application is made after August of the year in which the application is made, only retrospective certification of the previous months of that year can be made [37]. In Türkiye, the first REC implementation with International Renewable Energy Certificates (I-REC) was carried out.

On 14 November 2020, renewable energy resources guarantee certificate regulation in the electricity market was published [21]. The purpose of the regulation is to promote the use of RERs, is to follow, prove and disclose in an objective and transparent manner that a certain part of the electrical energy supplied to consumers is produced from RERs by licensed legal entities. This regulation does not cover unlicensed manufacturers. As of June 1, 2021, YEK-G Certificates have been issued within the national renewable energy certificates system [1]. In the YEK-G system, the market operator (EXIST) is responsible for establishing, operating, and managing the registration database with the YEK-G system. At the same time, 1 YEK-G certificate is issued for each 1 MWh production amount in the system. Generators within the scope of the unlicensed electricity generation regulation in the electricity market cannot be YEK-G system users however, electricity generation license holders can participate in the YEK-G system and the organized YEK-G market if all of their energy resources are renewable. A EPF that has an active registration in other certificate markets and aims to provide information on the quality of energy cannot register to the YEK-G system within the same calendar year [38]. The operation of the YEK-G system is given in Figure 7 [39].

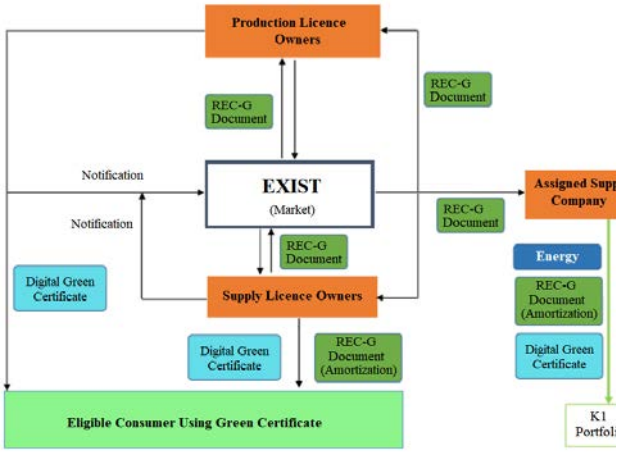


Fig. 7. Mechanism of the YEK-G system [39]

In the YEK-G system, producers will create RE plants, while consumers will create suppliers that receive RECs. Consumers are required to notify EXIST of the certificates they have received through bilateral agreements. Participants registered in the YEK-G system must renew their registration every year and pay their participation fees. After completing the registration procedures, the participants will be able to perform the EPF registrations and request the export of the YEK-G certificate according to their production amount [37]. In 2022, and a total of 14 million MWh YEK-G loans were issued. The distribution of these certificates according to the resources is as follows in MWh [40]:

- Wind: 35,433
- Hydropower: 13,257,467
- Geothermal: 683,551
- Biomass: 44,739

In 2022, the number of active power plants registered to I-REC system in Türkiye reached to 390. The total installed power exceeded 7 GW, and a total of 15.8 million MWh I-REC loans were issued. Of these loans, 9 million MWh were created for production in 2021 and 6.8 million MWh in 2022 [41]. In Figure 8, the report of 2022 on the Foton Platform is shown graphically [41].

"Bayramhacılı" Hydroelectric Energy PP (HEPP) is the first project operating with an I-REC certificate in Türkiye. The PP was established in "Nevşehir" and has an installed power of 47.5 MW. "Blue Flag" Biomass Energy PP (BEPP), "Alaşehir" Geothermal Energy PP (GEPP), "Andırın" HEPP, "Koru" WEPP, "Kuyucak" GEPP, "Yedigöl" HEPP, "Burgaz" WEPP, "Bafa" WEPP, "RA Güneş Mardin" Solar Energy PP (SEPP), "Dayıcık" SEPP are some of the projects operating with I-REC certificate. There are many organizations registered with the Foton Platform. "Alarko Altek", "Astroenergy Solar Türkiye Enerji", "Bio Solutions Renewable Energy and Consulting Services", "Bordo Enerji", "Perfect Solutions Enerji Danışmanlığı", and "Enerjisa Enerji Üretim" are just a few of these organizations. "Alarko Altek" HEPP, "Bordo Enerji" GEPP, "Enerjisa Enerji Üretim" HEPP/SEPP establish and operate.

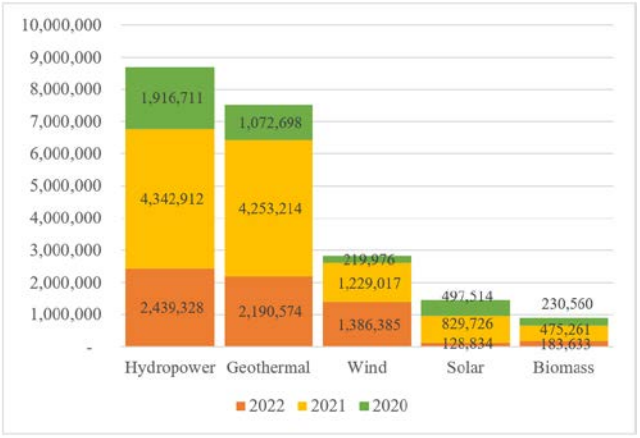


Fig. 8. I-REC Türkiye certificate amounts based on resource [41]

In Figure 9, I-REC certificates by sectors are given in MWh [41].

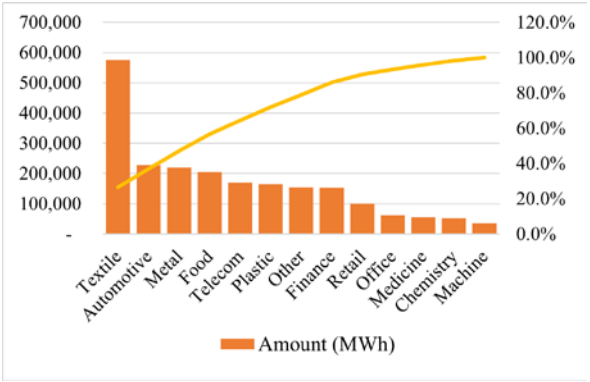


Fig. 9. I-REC certificates by sector (MWh) [41]

Existing trade conditions and development areas.

As a final part of the analysis, it is beneficial to discuss the capabilities of the market to enable efficient trade between producers and consumers. Especially for I-REC, the trade is currently taking place in the OTC (Over the Counter) market. In other words, energy trading departments (or brokers) purchase these certificates by making phone calls to generation plants. Energy-intensive factories (or consumers for short) that need these certificates decide to buy them by doing price research through their connections that may have I-REC certificates. The fact that the structures to transparently display prices and monitor supply and demand have not yet been established is a significant obstacle to effective trade. Large players may purchase the certificates issued by power plants, creating high volumes of

stocks and monopolizing the market. In order to prevent this, it would be beneficial to establish trading markets or platforms. As a matter of fact, this need in the market is paving the way for new initiatives. For example, in September 2023, “Erguvan”, an investment that established a carbon trading platform, received investment from Emirates National Bank of Dubai [42]. The establishment of these and similar platforms will contribute to the visibility of prices for consumers and the creation of a fair market.

5. Conclusion

With the increase in the world population and the spread of technology, the need for energy in the world is increasing. Most of the energy produced is used by industry. Conventional energy sources are insufficient in terms of sustainable energy supply, because of the damage they cause to the environment and the risk of exhaustion. One of the most important damages to the environment is greenhouse gas emissions, which cause climate change. Since supported by the regulations, the tendency towards renewable energy sources has increased all over the world. However, the conversion to renewable energy is a difficult and long process that requires time and capital. All countries are at the beginning of this transformation and are developing various policies to accelerate it. Although Türkiye is also a country that still provides most of its energy from conventional sources, it has a high potential to successfully complete the renewable energy transformation. It is hoped that the data obtained will be a guide for determining the Türkiye’s REC policy and for the supplier preference and planning of domestic and foreign companies that implement green supply chains.

In this study a comprehensive overview of market-oriented approaches employed for the reduction of carbon emissions in Türkiye aligning with insights from RE certification experts in the sector is provided. The global context of carbon reduction strategies is discussed, encompassing market-based mechanisms such as Emission Trading Systems (ETS), carbon taxes, and voluntary initiatives like the voluntary carbon market. The relevance of carbon offsetting, especially in the absence of mandatory carbon pricing in Türkiye, is highlighted. The concept of Verified Emission Reductions (VER) and their role in representing greenhouse gas reduction achieved through various activities is explored. The process of offsetting emissions through the acquisition of carbon credits from entities holding VER certificates is detailed, emphasizing the importance of calculating Scope 1, Scope 2, and optionally Scope 3 emissions per the Greenhouse Gas Protocol. Furthermore, Türkiye's specific context, detailing the evolution of certification standards like VCS, GS, I-REC, and YEK-G and the certificate issuing volumes are presented. Differences between carbon credit reduction methods, including future-oriented transactions through the purchase of emission rights and the trading of already prevented emissions are examined. A holistic overview of I-REC and YEK-G mechanisms is also presented to emphasize the significance of certificate issuance in addressing the carbon emissions reduction challenge comprehensively.

As a future study, REC incentive policies and mechanisms can be focused on to promote green transition better. In addition, practices in other developing countries can be analyzed within dynamics of Türkiye to build more effective policies and strategic roadmaps.

Declaration of conflicting interests

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Abbreviations

BE	Biomass energy
BEPP	Biomass energy power plant
BETA	Biomass energy potential atlas
BPM	Balancing power balancing market
CO2	Carbon dioxide
DAM	Day ahead market
DRIC	Down-regulation instructions capacity
EMRA	Energy market regulatory authority
EPF	Energy production facility
ETS	Emission trading systems
EXIST	Energy markets operation inc.
FoK	Fill or kill
GCC	Global carbon council
GE	Geothermal energy
GEPP	Geothermal energy power plant
GHGE	Greenhouse gas emissions
GO	Guarantee of origin
GS	Gold standard
GWh	Gigawatt-hour
HE	Hydropower energy
HEPP	Hydropower energy power plant
IDM	Intraday market
IEX	Indian energy exchange
IoC	Immediate or cancel
I-REC	International renewable energy certificate
kWh	Kilowatt-hour
MCP	Market clearing price
MTOE	Million Tons of Oil Equivalent
MW	Megawatt
MWh	Megawatt-hour
OTC	Over the counter
PP	Power plant
PXIL	Power exchange India limited
RE	Renewable energy
REC	Renewable energy certificate
RER	Renewable energy resource
RPS	Renewable portfolio standards
SC	Supply chain
SE	Solar energy
SEPA	Solar energy potential atlas
SEPP	Solar energy power plant
TL	Turkish lira
TWh	Terawatt-hour
URIC	Up-regulation instructions capacity
USD	United states dollar
VCS	Verified carbon standard
VER	Verified emission reductions
WE	Wind energy
WEPP	Wind energy power plant
YEKDEM	Renewable energy resource support mechanism
YEK-G	Renewable energy resource guarantee system

References

[1] Özcan, M., Ergün, B., and Ocaklı, E., 2021, *Türkiye'de kullanılan yenilenebilir enerji sertifika sistemlerinin değerlendirilmesi,* EMO Bilimsel Dergi, 11(21): 29-41.

[2] Murray, G.J., 2000, *Effects of a green purchasing strategy: The case*

of Belfast City Council, Supply Chain Management, 5(1): 37-44.
[3 Green, K., Morton, B., and New, S., 1998, *Green purchasing and supply policies: do they improve companies' environmental performance?*, Supply Chain Management, 3(2): 89-95.
[4] Min, H. and Kim, I., 2012, *Green supply chain research: past, present, and future*, Logistics Research, 4(1): 39-47.
[5] Hamelinck, C., Suurs, R.A.A., and Faaij, P.C., 2005, *International bioenergy transport costs and energy balance*, Biomass and Bioenergy, 29(2): 114-134.
[6] Saavedra, M.R., Fontes, C.H., and Freires, G.M., 2018, *Sustainable and renewable energy supply chain: A system dynamics overview*, Renewable and Sustainable Energy Reviews, 82: 247-259.
[7] Shereef, R.M. and Khaparde, S.A., 2013, *Current status of REC mechanism in India and possible policy modifications to way forward*, Energy Policy, 61: 1443-1451.
[8] Girish, G.P., Sashikala, P., Supra, B., and Acharya, A., 2015, *Renewable energy certificate trading through power exchanges in India*, International Journal of Energy Economics and Policy, 5(3): 805-808.
[9] Chuang, J., Lien, H.L., Den, W., Iskandar, L., and Liao, P.H., 2018, *The relationship between electricity emission factor and renewable energy certificate: The free rider and outsider effect*, Sustainable Environment Research, 28(6): 422-429.
[10] Gupta, S.K. and Purohit, P., 2013, *Renewable energy certificate mechanism in India: a preliminary assessment*, Renewable and Sustainable Energy Reviews, 22: 380-392.
[11] Hulshof, D., Jepma, C., and Mulder, M., 2019, *Performance of markets for European renewable energy certificates*, Energy Policy, 128: 697-710.
[12] Adamczyk, J. and Graczyk, M., 2020, *Green certificates as an instrument to support renewable energy in Poland— Strengths and weaknesses*, Environmental Science and Pollution Research, 27(6): 6577-6588.
[13] Çalıkoğlu, Ü., *Türkiye enerji piyasasinda yeşil elektrik ve yeşil sertifika talebinin incelenmesi*, Hacettepe University, 2017.
[14] Web Page: Yarıcı M., 2018, *Gün öncesi piyasasi*, https://www.dunyaenerji.org.tr/wp-content/uploads/2018/07/MustafaYARICIGOP.pdf, Last access date: 18.12.2024.
[15] Dursun, A., Eke, İ., and Tezcan, S.S., 2020, *Gün öncesi piyasasi için yapay sinir ağlari ile Türkiye enterkonnekte sistemi iletim hatlari kayiplarinin tahmini*, International Journal of Engineering Research and Development, 12(2): 549-564.
[16] Web Page: Energy Exchange Istanbul (EXIST), 2016, *Day ahead market general principles*, https://www.epias.com.tr/en/day-ahead-market/general-principles/, Last access date: 18.12.2024.
[17] Web Page: Energy Exchange Istanbul (EXIST), 2016, *Intraday market general principles*, https://www.epias.com.tr/gun-ici-piyasasi/genel-esaslar/, Last access date: 18.12.2024.
[18] Web Page: Energy Exchange Istanbul (EXIST), 2016, *Power balancing market general principles*, https://www.epias.com.tr/genel-esaslar/, Last access date: 18.12.2024.
[19] Kaygusuz, K. and Sarı, A., 2003, *Renewable energy potential and utilization in Turkey*, Energy Conversion and Management, 44(3): 459-478.
[20] Sagir, O. and Bahadir, A., 2017, *Renewable energy potential and utilization in Turkey*, Journal of Engineering Research and Applied Science, 6(1): 577-582.
[21] Web Page: T.R. Presidency of Administrative Affairs General Directorate of Law and Legislation, 2022, *Laws*, https://www.mevzuat.gov.tr/mevzuatmetin/1.5.5346.pdf, Last access date: 18.12.2024.
[22] Web Page: Republic of Türkiye Energy Market Regulatory Authority (EMRA), 2022, *2022 yılı elektrik piyasası gelişim raporu*, https://www.epdk.gov.tr/Detay/Icerik/3-0-24/yillik-sektor-raporu, Last access date: 18.12.2024.
[23] Kapluhan, E., 2021, *Evaluation of Turkey's renewable energy potential in terms of 2023 energy vision*, Bulletin of Dnipropetrovsk National University Series Chemistry, 2(135): 71-87.
[24] Web Page: Energy Exchange Istanbul (EXIST), 2022, *Injection quantity*, https://seffaflik.epias.com.tr/transparency/uretim/gerceklesen-uretim/uevm.xhtml, Last access date: 18.12.2024.
[25] Web Page: Republic of Türkiye Ministry of Energy and Natural Resources, 2022, *Energy*, https://enerji.gov.tr/bilgi-merkezi-enerji, Last access date: 18.12.2024.
[26] Çağlıyan, A. and Ayhan, G., 2018, *Türkiye'de yağışın mekansal analizi*. TÜCAUM 30. Yıl Uluslararası Coğrafya Sempozyumu, Ankara.
[27] Tuncer, G. and Eskibalcı, M.F., 2003, *Türkiye enerji hammaddeleri potansiyelinin değerlendirilebilirliği*, İstanbul Üniversitesi Mühendislik Fakültesi Yerbilimleri Dergisi, 16(2): 81-92.
[28] Web Page: Republic of Türkiye Energy Market Regulatory Authority (EMRA), 2023, *Electricity production capacity projections*, https://www.epdk.gov.tr/Detay/Icerik/3-0-66/elektrikuretim-kapasite-projeksiyonlari#, Last access date: 18.12.2024.
[29] Shrivats, A. and Jaimungal, S., 2020, *Optimal generation and trading in solar renewable energy certificate (SREC) markets*, Applied Mathematical Finance, 27(1-2): 99-131.
[30] Soonee, S.K., Garg, M., Saxena, S.C., and Prakash, S., 2012, *Implementation of renewable energy certificate (REC) mechanism in India*, Power Engineer Journal, 14(2): 11-18.
[31] Kumar, R. and Agarwala, A., 2013, *Renewable energy certificate and perform, achieve, trade mechanisms to enhance the energy security for India*, Energy Policy, 55: 669-676.
[32] Shrimali, G. and Tirumalachetty, S., 2013, *Renewable energy certificate markets in India—a review*, Renewable and Sustainable Energy Reviews, 26: 702-716.
[33] Narula, K., 2013, *Renewable energy certificates (RECs) in India – A performance analysis and future outlook*, Renewable and Sustainable Energy Reviews, 27: 654-663.
[34] Goyal, M. and Jha, R., 2009, *Introduction of renewable energy certificate in the Indian scenario*, Renewable and Sustainable Energy Reviews, 13(6-7): 1395-1405.
[35] Web Page: RECS Energy Certificate Association, 2022, *Annual report*, https://recs.org/download/?file=REC23030_annual-report-2022-FINAL.pdf&file_type=documents, Last access date: 18.12.2024.
[36] Greenfield, P., 2023, *Revealed: more than 90% of rainforest carbon offsets by biggest certifier are worthless, analysis shows*, The Guardian.
[37] Web Page: Life Climate, 2021, *Gönüllü yenilenebilir enerji sertifikaları*, https://www.life-climate.com/bilgi-bankasi/goenuellue-yenilenebilir-enerji-sertifikalari, Last access date: 18.12.2024.
[38] Web Page: Republic of Türkiye Energy Market Regulatory Authority (EMRA), 2020, *Renewable energy source guarantee certificate regulation in the electricity market*, https://www.resmigazete.gov.tr/eskiler/2020/11/20201114-2.htm Last access date: 18.12.2024.
[39] Web Page: Özata, H., 2020, *YEK-G yönetmeliği*, https://www.shura.org.tr/wp-content/uploads/2020/08/Sunum-Dr-Hakki-Ozata.pdf, Last access date: 18.12.2024.
[40] Web Page: Energy Exchange Istanbul (EXIST), 2023, *Issued quantity of YEK-G documents*. https://seffaflik.epias.com.tr/transparency/piyasalar/yekg/ihrac-edilen-yekg-belge-sayisi.xhtml, Last access date: 18.12.2024.
[41] Web Page: Foton, 2022, *Market reports*, https://fotonplatform.com/, Last access date: 18.12.2024.
[42] Web Page: Emirates NBD Bank, 2023, *Emirates NBD Group makes strategic equity investment in sustainability start-up Erguvan*, https://www.emiratesnbd.com/en/media-center/emirates-nbd-group-makes-strategic-equity-investment-in-sustainability-start-up-erguvan., Last access date: 18.12.2024.

Appendix – Energy Production Related Charts

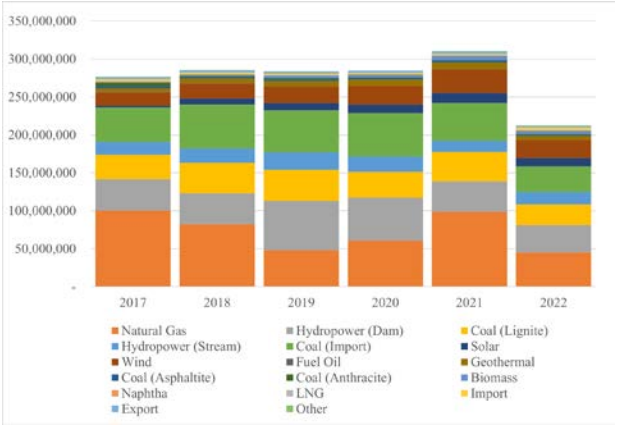

Fig. 11. Resource based energy production in yearly basis (MWh)

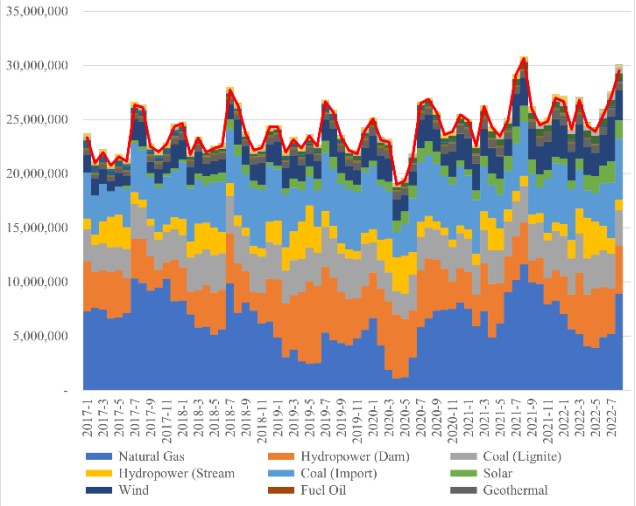

Fig. 12. Resource based energy production in monthly basis (MWh)

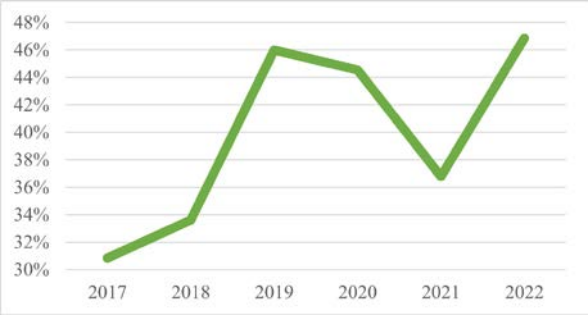

Fig. 13. Renewable energy production ratio in yearly basis

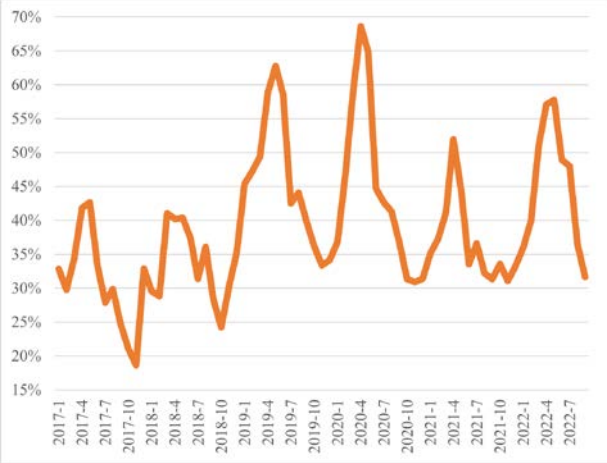

Fig. 14. Renewable energy production ratio in monthly basis