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Increasing voluntary carbon credits potential via renewable energy projects in Turkey

Türkiye'nin yenilenebilir enerji projeleri ile geliştirebileceği karbon sertifikası potansiyeli

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Abstract

Turkey's renewable energy sources (RES) can be utilized to increase the amount of electricity generation and significantly reduce emissions from the energy sector. Voluntary carbon markets encourage electricity generation using RES and make greater use of these sources. In this study, the amount of emission reduction and carbon credits to be obtained from the renewable power plants to be connected to the Turkish electricity grid and the revenue to be obtained from carbon credit trading have been calculated. Emission reduction amount has been calculated by using combined margin CO_2 emission factors. The amount of CO_2 emission reduction that can be achieved through the renewable electricity generation between 2021-2024 is estimated as 454.94 $MtCO_2$. Voluntary carbon credit revenue that can be obtained for the period between 2016 and 2024 is \$1.116 billion. A very small part of the carbon reduction potential generated by renewable projects has been the subject of trade through voluntary carbon certificate issuing organizations. Turkey's rich RES potential has not been adequately utilized. The volume of carbon offsets that Turkey can generate by renewable projects is considerably high.

Keywords: Renewable energy, Grid emission factor, Combined margin emission factor, Carbon certification, Voluntary carbon market.

Öz

Türkiye'nin yenilenebilir enerji kaynakları (YEK) ile elektrik üretim miktarı artırılarak, enerji sektörü kaynaklı emisyonları önemli miktarda azaltılabilir. Gönüllü karbon piyasaları, YEK kullanılarak elektrik üretiminin özendirilmesi ve bu kaynaklardan daha fazla yararlanılmasını sağlarlar. Bu çalışmada; Türkiye elektrik şebekesine bağlanacak YEK ile elektrik üretimi yapan tesislerden sağlanacak emisyon azaltım ve karbon kredisi miktarları ile karbon kredi ticareti ile elde edilecek olan gelir hesaplanmıştır. Emisyon azaltım miktarı hesaplaması; birleşik marj CO_2 emisyon faktörleri kullanılarak gerçekleştirilmiştir. 2021-2024 yılları arasında YEK kullanılarak gerçekleştirilecek elektrik enerji üretimi ile sağlanabilecek CO_2 emisyon azaltım miktarı 454,94 $MtCO_2$'dir. 2016-2024 yılları arasında elde edilebilecek gönüllü karbon kredisi geliri 1.116 milyar dolar'dır. Türkiye'nin YEK ile elektrik üretimi yapan tesisleri ile sağlanan karbon azaltımın çok düşük bir bölümü gönüllü karbon sertifikası ihraç eden kuruluşlar aracılığıyla ticarete konu olmuştur. Türkiye'nin zengin YEK potansiyeli yeterince değerlendirilmemiştir. Türkiye'nin yenilenebilir enerji projeleri ile geliştirilebileceği karbon kredisi hacmi yüksektir.

Anahtar kelimeler: Yenilenebilir enerji, Şebeke emisyon faktörü, Birleşik marj emisyon faktörü, Karbon sertifikası, Gönüllü karbon piyasası.

1 Introduction

Due to the increasing use of fossil fuels, global greenhouse gas (GHG) emissions have continued to increase and reached 59.1 $GtCO_2$ equivalent (eqv.) in 2019. 65% of total GHG emissions were caused by CO_2 emissions due to fossil fuels, and 38.0 Gt of CO_2 emissions were reached in 2019 due to fossil fuel use [1]. Due to the rise in anthropogenic CO_2 emissions, the average earth temperature has increased by an average of 1 °C compared to the pre-industrial period. It is estimated that the global temperature rise will be approximately 1.5 °C between 2030 and 2052 [2].

With the Paris Agreement (PA) implemented in 2016, a new epoch has begun in the struggle against climate change. The agreement envisages a climate regime in which all interested parties, public and private, take responsibility voluntarily. In order to reduce the risks and effects of climate change, the PA aims to keep the world average temperature increase below 2 °C, if possible, below 1.5 °C compared to the pre-industrial period by the end of this century. The parties to the agreement have determined and stated their goals and policies in combating global climate change in their national contribution statements to the United Nations Framework Convention on Climate Change (UNFCCC) [3]. However, the declarations of national contribution statements submitted to the UNFCCC secretariat fall short of limiting the global temperature rise to the desired level [1],[4]. To limit the global temperature rise to 1.5 °C, the number of countries that set net-zero emissions targets should increase [1].

In order to limit global temperature rise to 1.5 °C for a sustainable and climate-safe future, green enegy transition should be accelerated and the number of investments made in renewable energy sources (RES) and energy efficiency should be increased [1],[5]. RES, especially wind and solar have been increasingly displacing fossil fuels in the power sector [6]. Carbon market mechanisms are mechanisms that can be used in the field of energy transition and contribute to low-carbon growth. Carbon markets exist as mandatory programs and as voluntary markets. Mandatory and voluntary carbon markets play an active role in reducing GHG emissions at low cost. Issuing carbon certificates constitute an example of a carbon market mechanism which encourages low carbon growth in

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institutions and organizations. Individuals, public and private sector organizations, countries and regional governments contribute to the struggle against climate change by purchasing carbon certificates traded in the voluntary carbon market. Carbon certificates can be used by an institution to meet the emissions reductions required under the carbon tax law or emissions trading system implemented on a national basis. Carbon certificates produced in the voluntary carbon market enable companies to make voluntary contributions to the fight against climate change within the scope of corporate social responsibility. By trading carbon credits, countries achieve their goals in national contribution declarations [7]. Carbon credits produced in the voluntary carbon market were initially used only for voluntary emission offsetting. However, in the proceeding years, voluntary carbon credits that meet certain standards have also been recognized by mandatory carbon markets [8]. In addition to reducing GHG emissions, carbon credits produced in the voluntary market provide many socio-economic and environmental co-benefits to carbon credit users. In recent years, the demand for carbon credits with high socio-economic and environmental benefits has been increasing. The co-benefits of carbon credit projects increase their value. Many buyers are willing to pay more for carbon credits with such co-benefits [8].

Carbon credits can be developed by carrying out various kinds of projects. Renewable energy projects are among those that are in highest demand. After 2016-2017, the demand for carbon credits obtained by commissioning of wind power plants have increased, and wind power plants have become one of the types of projects that produce highest amount of carbon credits [8]. Currently, carbon credits are mostly used on a voluntary basis by unregulated sectors, large companies and regulated regional and national carbon pricing enterprices [9]. In the near future, the incentive to fulfill voluntary commitments will be the most important reason behind increasing demand for carbon credits [7]. The voluntary carbon market has been developing since the early 2000s, while interest in carbon credits produced by voluntary carbon crediting standards has increased in the recent years [9]-[11]. The percentage of voluntary carbon credits among total credits has increased from 17% to 65% between the years 2015 and 2019. In 2019, the amount of carbon credits obtained through renewable energy projects increased by 78% [9]. Between 2002 and 2019, 616 $MtCO_2$ eqv. credits were issued in the voluntary carbon market. The volume of issuance in 2020 increased by 30% and reached 803 $MtCO_2$ eqv. Between 2002 and 2019, the issuance volume of compulsory market mechanisms was 2,874 $MtCO_2$ eqv. and reached 2,948 $MtCO_2$ eqv. issuance volume in 2020 with an increase of 3% [4].

There are several factors that are influential in the development of the voluntary carbon market. Campaigns and protests organized as a consequence of improving global awareness on the effects of climate change increase interest in the voluntary carbon market and increase the market volume [8]. The new climate regime, which is linked to the PA; provides an opportunity for the growth of the voluntary carbon market by allowing all parties to contribute to the struggle against climate change, besides the efforts of individual governments [8]. Increasing number of emissions trading mechanisms worldwide increase the demand for carbon credits [9]. In the meanwhile, the newly established carbon crediting standards reinforce the demand for carbon credits developed with renewable energy projects [4]. Companies and organizations that set more strict targets to improve emissions reductions are increasingly interested in voluntary carbon markets [10],[11]. As a result of their growing awareness of climate change, companies and individuals prefer to reduce emissions regardless of their country's policies [8]. The willingness of companies and organizations to achieve the strict emissions targets they have set at a lower cost and in shorter time leads to price increases in mandatory carbon markets on a global scale, and in parallel, to the development of voluntary carbon markets [10]. The multinational companies' demand for carbon credits produced in the voluntary market has been increasing [8]. The hike in the number of companies that set net-zero emissions targets increases the demand for the voluntary carbon market. As of October 2020, 1565 companies operating in different sectors from around the world have committed to net-zero emissions. This demand is expected to increase in the coming years [4]. The number of -multinational companies that come together under various initiatives created to combat climate change have also been increasing [8].

Due to the intensification of efforts to achieve low-carbon economic growth on a global scale, the demand for voluntary carbon credits is expected to increase [11]. Demand from non-regulated sectors and the tendency of multinational companies to use carbon credits in the context of corporate social responsibility policies increase the demand for voluntary carbon credits. It is estimated that in the future these demands will increase the prices of carbon credits and enable the realization of costly projects. Starting in 2021, aviation sector emissions will be offsetted using carbon credits. Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), organised by the International Civil Aviation Organization (ICAO), aims for carbon neutral growth in the aviation sector starting in 2020. This voluntary plan is expected to last until 2035 [9]. The total demand for carbon offsetting credit over this 15-year period is 2,000- 2,700 $MtCO_2$ eqv. [9],[12]. Many voluntary carbon crediting standards produced by international, national and voluntary carbon standards by the ICAO council have been validated under CORSIA [8].

In order to prevent the negative effects of climate change, the emissions released into the atmosphere should be reduced to net-zero by 2050. All institutions and organizations around the world must act and work together if we are to achieve this goal [13]. Private sector organizations that have an important role in the decarbonization process can be an important participant in the national effort to combat climate change by decarbonizing their production, distribution and supply chain emissions.

In the years to come; airlines, multinational corporations, national and regional governments will want to see a voluntary carbon market with high standards and regulation. If transparency can be improved and standardization of crediting processes can be achieved, consumer confidence will increase, market volume will grow and a truly functioning market will be formed [8],[9]. The quality of carbon credits in the voluntary carbon market should be evaluated and improved. Assessing and improving the environmental quality of carbon credits developed in the voluntary carbon market will increase transparency [4].

Efforts are underway to set a global carbon price to reduce GHG emissions. In Turkey, renewable energy certificates and carbon certificates are used within the scope of voluntary carbon market mechanisms. Carbon certification is developed with renewable energy projects in voluntary carbon markets. In this study, the amount of emission reductions that can be achieved by renewable energy projects in Turkey and the corresponding amounts of voluntary carbon credits by source have been calculated. The calculations are based on electricity generation data for the period 2016-2020, and Turkish Electricity Transmission Corporation (TEİAŞ) generation capacity projection for the period 2021-2024 based on combined margin (CM) CO_2 emission factors. The utilization of Turkey's voluntary carbon credit potential has been evaluated in the study.

This study consists of six sections. In the second section, studies on carbon markets in Turkey have been examined. The third section describes the carbon pricing mechanisms and voluntary carbon mechanisms. The fourth section of the study explains the emission reduction methodology and grid emission factor used in the trade of voluntary carbon credits. In section five; the amounts of emissions reductions provided / to be provided by Turkey's RES projects for 2016-2024 and the amount of credits that can be traded in voluntary carbon credit mechanisms have been calculated. Estimations of possible voluntary carbon certificate revenues between 2016 and 2024 are also made. In addition, an analysis of carbon credits traded between 2016 and 2020 using voluntary carbon offsetting schemes was carried out. The sixth section of the study comprises of the conclusion and discussion.

2 Literature review

Studies carried out on carbon markets in Turkey are mostly in the form of a description of carbon markets and an analysis of the projects carried out in the voluntary carbon market implemented in the country. In these studies; after analyzing the functioning of the world carbon markets, various recommendations have been made regarding the development of carbon markets in Turkey. Binboğa [14] has examined the carbon markets, revealed Turkey's situation in these markets and has concluded that Turkey should take part in carbon markets. Çıtak [15], examined the carbon markets and carried out a performance evaluation of carbon prices and markets based on the related literature. In the same study, he discusses the proposal for the establishment of a global carbon central bank. Çelikkol and Özkan [16] analyzed the world carbon markets and the financial products traded in these markets, and evaluated the carbon markets in terms of the Turkish financial markets. As a result of their work, they concluded that either a carbon market should be established in Turkey or existing markets should be utilized. Tunahan [17] examined the financial mechanisms used to reduce carbon emissions and the structure and performance of carbon markets formed by the use of these mechanisms. His study evaluates the factors affecting carbon prices, and explains the benefits of participating in the carbon markets for Turkey. Çetintaş and Türköz [18] have examined international studies developed against climate change and the problems caused by this change. Their study evaluates the positive and negative consequences that Turkey may face if it is involved in the carbon markets. According to the study, if Turkey is involved in the carbon market, it will be able to use RES more effectively and provide financial support for GHG emission reductions using carbon markets. Unlike the above mentioned studies that have many common aspects, Can [19] emphasized the importance of stakeholder participation in the context of environmental policies in his work. In his study, the processes of ensuring stakeholder participation in projects developed in voluntary carbon markets in Turkey were examined and evaluated. He concludes in the end that the impact of stakeholder participation processes on the process has been minimal. In his study Ari [20] calculated Turkey's emissions reduction potential that can be achieved through energy efficiency, renewable energy and solid waste management projects. The calculations made for the 2013-2020 period include the income to be obtained if the carbon credits corresponding to the emission reductions are traded in the carbon markets. As a conclusion, He has stated that Turkey can achieve significant emission reductions by trading carbon in voluntary carbon markets and therefore should encourage these markets. In the study of Bayazıt [21], the emission reduction potential of a hydroelectric power plant (HPP) has been determined, and the cost of carbon trading has been calculated with the emission reduction to be achieved by this project. Akbaş and Canikli [22] conducted a study to determine the reasons for companies to disclose voluntary GHG emissions in Turkey. According to the results of the study; the size and institutional ownership structure of companies that disclose voluntary GHG emissions are important factors that are effective in decisions concerning disclosure. Highly profitable companies tend to be more willing to disclose their GHG emissions.

3 Carbon pricing mechanisms

Carbon pricing is a mechanism used for decarbonization by setting a value to GHG emissions. A properly set carbon price promotes low-carbon growth [4]. In order to achieve the 1.5 °C temperature target, at least 100 $/t$CO_2$ [23] and to achieve the 2 °C target, a carbon price of $40-80/t$CO_2$ eqv. [4] must be set on a global scale. There are various mechanisms used in mandatory and voluntary carbon markets for the purpose of carbon pricing. Mandatory markets consist of an emission trading (ET) system and carbon tax, while voluntary markets consist of renewable energy certificates and carbon certification mechanisms. As defined under the Kyoto protocol (KP); the aim is to reduce emissions through joint implementation (JI), clean development mechanisms (CDM) and ET flexibility mechanisms. After a record-breaking drop in the prices of CDM credits in 2012, crediting activities have stabilized and companies have continued to be active in voluntary markets. Approximately two-thirds of total carbon credit issuances in 2019 were made using voluntary carbon crediting mechanisms. More than half of the carbon credits produced to date have been produced by CDM [7]. The PA has adopted the voluntary Nationally Determined Contributions (NDCs) of the countries that are parties to the agreement and their emissions reductions. Article 6 of the PA has set out different mechanisms for accessing the national contribution statements determined by the countries that are parties to the agreement by cooperating with each other. The relevant paragraphs of article 6 define three different market-based and non-market-based mechanisms based on voluntary cooperation [3].

Carbon crediting mechanisms are divided into three categories; international crediting mechanisms, voluntary crediting mechanisms and regional, national and subnational crediting mechanisms.

3.1 International crediting mechanisms

Mechanisms regulated by international climate agreements or bilateral agreements or other agreements, and usually managed by international institutions. CDM and JI within the scope of the KP and the new mechanism defined under Article 6.4 of the PA are included in this scope [7],[8].

3.2 Voluntary crediting mechanism

Mechanisms established and managed by non-profit organizations or private sector companies that are not regulated by a national or international agreements [7],[8]. Gold Standard (GS) and Verified Carbon Standard (VCS) voluntary carbon schemes are the most important voluntary carbon crediting mechanisms in terms of carbon sales volume [7],[8]. Voluntary carbon credits are used to reduce carbon tax with regional and national ET systems [8]. Voluntary carbon credits with certain standards are also accepted by some mandatory carbon market standards [8].

3.3 Regional, national and subnational crediting mechanisms

Mechanisms regulated and operated by regulatory legal regulations made by regional/national and subnational governments [7]. Standards created by some governments allow carbon credits produced by individuals' and institutions' voluntary carbon standards to be used for carbon offsetting [8].

Carbon credit prices vary depending on parameters such as type of energy source, GHG abatement and transaction costs, the project´s co-benefits, the project location, to what extent project developers market their credits, and the size of the transaction. The cost of small volume carbon credits is higher with carbon credits obtained from projects in countries with limited infrastructure and resources. The co-benefits of carbon credit projects increase the credit price [8]. The average price of voluntary carbon credits for 2019 is \$2.7/tCO_2 eqv. [9].

4 Emission calculation methodology

The electrical energy emission factor is an indication of the amount of GHG emissions generated by a unit of electrical energy produced or consumed. The emission factor varies according to the point of calculation for different voltage levels of electricity from the generation phase to the consumption phase. Due to the increasing losses from the generation phase through the consumption phase, the available electrical energy value decreases, while the emission factor increases [24]. As of the end of 2019, the emission factor of 28 European Union (EU) countries' electricity generation was calculated as 265 gCO_2 eqv./kWh [25]. The units of the emission factor vary depending on the input or output parameters of the activity being performed. For any given power plant, the unit of the emission factor according to the output parameter is gCO_2 eqv./kWh [26].

There are two effects that a power plant to be connected to the grid can have an impact on the grid. The first of these effects is the impact of the project on the operation of existing power plants that are operating connected to the same network. This effect is expressed as Operating Margin (OM). OM has a near-time effect [27]. OM refers to the generation of electricity from existing power plants whose output changes in response to a project activity. OM emissions are estimated using methods that attempt to approximate the emissions from the specific power plants whose operation is displaced. What is important when making this estimate is how to identify power plants (which will be deployed last or first) that supply electricity in the margin during the project activity. OM emissions vary by time depending on load change, plant types in the network, and the order in which the requested energy is met [28]. The second impact of the project being carried out on the network is on capacity expansion. This effect is expressed as a Build Margin (BM). The effect on capacity expansion may be in the form of delaying the addition of new capacity, changing the amount of capacity to be added, or not adding new capacity. BM has a long-term effect [27]. If the demand is met by the project being carried out without installing a new power plant or by installing a lower capacity power plant, the additional capacity prevented and the energy for this capacity is called BM. BM emissions are estimated using GHG emissions of newly-commisioned (in some cases planned and built) additional capacity [28].

OM and BM emission factors are used in emission factor calculations for existing plants running on the grid and new plants to be connected to the grid. OM emission factor is used in the emission value calculation of operating plants to meet the current demand, while the BM emission factor is used to calculate the emission value of plants that are engaged to meet the sudden change in demand. When a new facility is connected to the grid in a time period without increased demand (no supply requirement); the requested energy is met with existing production facilities and in the calculation of the emission value in this case; the OM emission factor value is used. In case of a sudden increase in demand, the new demand is met by existing production facilities, alternative/new production facilities and other facilities interconnected to same the grid. In this case, BM value is used in the calculation of emission value for alternative/new production facilities [29].

The amount of electricity generated by a project (GHG project) developed to reduce GHG emissions can be easily determined by meters and observation. However, determining how a GHG project's generation will affect the operation or construction of other power plants on an interconnected grid is difficult. If we accept that a project A carried out to reduce GHG emissions prevents the electrical energy produced by plant B in operation (prevented production), It is easy to calculate the amount of emissions prevented by the implementation of project A. In this case, the emission reduction value of project A can be calculated by taking into account the type and quantity of fuel burned in plant B together with the emission factor value of this fuel and the energy production technology. However, it is not easy to make this calculation in the grid structure consisting of many power plants and consumer points [29]. Therefore, when performing emission factor calculations for power plants connected to the grid; the CM emission factor value based on the weighted average of OM and BM is used for the plant to be newly connected to the grid [30]. CM emission factor, or grid emission factor in other words; is the emission factor that indicates the emission values of the plants operating and planned to operate connected to the grid [26]. The CM emission factor value is used to calculate the emission value of emission reduction projects in the electricity sector [27]. Margin-based calculations give a more accurate answer to the question "What would have happened otherwise?" [29].

The methodological tool employed in the calculation of carbon credits under the CDM is used to determine the CO_2 emission factor that will be caused by the GHG project that will co-produce the energy produced by the power plants in the electricity system through calculating the CM emission factor of the system. Using this tool; the power grid CM emission factor, BM emission factor and OM emission factor values in any given year can be calculated [31]. This calculation methodology can be used to calculate emission factors of grid-connected projects as well as off-grid projects [31]. The CM, BM and OM emission factor values required for baseline emission calculations for any year are estimated using the given methodology [31]. The CM CO_2 emission factor is calculated by using Equation 1 [31].

$$EF_{CM,t} = EF_{OM,t} * \omega_{OM} + EF_{BM,t} * \omega_{BM} \tag{1}$$

In Equation 1:

$EF_{CM,t}$: CM CO_2 emission factor in year t (tCO_2/MWh),
$EF_{OM,t}$: OM CO_2 emission factor in year t (tCO_2/MWh),
ω_{OM} : Weighting of OM emissions factor (%),
$EF_{BM,t}$: BM CO_2 emission factor in year t (tCO_2/MWh),
ω_{BM} : Weighting of BM emissions factor (%).

For wind and solar power projects which have intermittent and non-dispatchable nature, ω_{OM} =0.75 and ω_{BM} = 0.25 can be used for the first crediting period and for subsequent crediting periods. For all other projects, unless otherwise specified, assuming ω_{OM} = 0.50, ω_{BM} = 0.50 are suggested for the first crediting period, and ω_{OM} = 0.25, ω_{BM} =0.75 for the second and third crediting periods. Alternative emission factor weights can be proposed, as long as $\omega_{OM} + \omega_{BM} = 1$ [31].

In the calculations of National GHG Emission Inventories carried out according to the Intergovernmental Panel on Climate Change (IPCC) guidelines; two different emission factors are calculated: the CM emission factor for intermittent electricity generation and the CM emission factor for firm electricity generation. CM emission factor for intermittent electricity generation is used in the calculation of emission values of plants producing intermittent electricity such as solar, wind and wave energy. The CM emission factor for firm electricity generation is used in the calculation of emission values of hydro, geothermal and fossil power plants [30]. Table 1 gives the CM emission factor values for some countries. The emission factors given in Table 1 neglect the effects of GHG emissions other than CO_2. Therefore, the emission factors given can be considered as CO_2 eqv. [30]. Among the six countries given in Table 1, China has the highest CM emission factor, reflecting its complete dependence on fossil fuels for electricity generation. Higher CM emission factor also means that more carbon credits can be issued. Germany, United Kingdom (UK), Denmark, United States and Turkey have CM emission factors ranging from 358 gCO_2/kWh to 619 gCO_2/kWh for intermittent generation. The UK has the lowest CM emission factor for intermittent generation, reflecting the low dependence of the country on fossil fuels for electricity generation and this value means that less carbon credits can be issued compared to other countries.

Table 1. CM emission factors for some countries [30],[32].

Country	CM emission factors (gCO_2/kWh)	
	Intermittent Electricity Generation	Firm Electricity Generation
Germany	596	366
UK	358	252
Denmark	384	235
United States	418	285
China	775	494
Turkey	619	540

The baseline emission must be calculated to determine the emission reduction amount for a GHG emission reduction project and emission credits that can be obtained as a result of this reduction. This calculation is carried out hypothetically, and the answer the question "What would have happened otherwise?"is searched [29]. For a renewable energy plant that has just started operating, this involves answering the question "What would be the amount of emissions that would occur if this renewable energy plant had not gone into operation, and the same amount of energy was produced by plants already connected to or will be connected to the grid?". Based on this explanation, calculating the baseline emission means calculating what the emission value would be if the project was not implemented. The amount of emission that would occur if the emission project was not carried out is referred to as the "amount of emissions prevented". It should be known whether the amount of emissions prevented will affect the BM or the OM [29]. Since this calculation is not easy in the grid structure consisting of many power plants and consumer points, it is recommended to use the CM emission factor in the calculation of the prevented emission amount [29]. The baseline emission is expressed as tCO_2 / MWh for electrical projects and is used in the calculation of emission credits that can be obtained from a project [29]. Emission reduction amount of any GHG project is calculated by using Equation 2 [28].

$$ER_t = BE_t - PE_t - LE_t \tag{2}$$

In Equation 2:

ER_t : Emission reduction in year t (tCO_2),
BE_t : Baseline emission in year t (tCO_2),
PE_t : Project emission in year t (tCO_2),
LE_t : Leakage emission in year t (tCO_2),

Project emissions are specific to be carried out. These emissions are determined using project specific documents. For all RES projects within certain limits, this emission value is generally considered zero [26]. Leakage emissions are emissions that occur outside the project's designated limits. These emissions are generally not considered in calculations [26]. According to these statements, the emission reduction amount for any GHG project is equal to the baseline emissions. The baseline emission value is calculated by using Equation 3 [28].

$$BE_t = EF_{CM,t} * G_{P,t} \tag{3}$$

In Equation 3:

BE_t : Baseline emission in year t (tCO_2),
$EF_{CM,t}$: CM CO_2 emission factor in year t (tCO_2/MWh),
$G_{p,t}$: Electricity genaration as a result of project activity in year t (MWh).

5 Emission reduction amount, carbon credit amount and revenue calculation

The mainstage in the process of developing carbon credits is to determine the amount of emissions reduction that can be credited. After determining the amount of emission reduction that can be credited, credits corresponding to the reduced amount of emissions are issued and traded.

For the period 2016-2024, the values of Turkish electricity generation (including unlicensed production) by source types are given in Table 2 [33],[34]. The data in Table 2 was obtained based on the project production values [34] of plants that will start operating between 2020 and 2024, which are calculated on the basis of actual electricity generation values for the years 2016-2019 [33], an optimistic estimation of the dates (Sceneario 1) the plants will go into operation according to T.C. Energy Market Regulatory Authority (EMRA) progress reports and the baseline demand scenario. The emission factor of Turkey's national electricity grid is calculated annually by the Ministry of Energy and Natural Resources (ETKB) using CDM methodology. The CM emission factor of the Turkish national electricity grid is calculated as 0.6198 tCO_2/MWh for solar and wind projects, and as 0.5403 tCO_2/MWh for other renewable energy projects [32]. In this study, emission reduction calculations were performed using source-based CM CO_2 emission factors [35]-[43] used in emission calculations for Turkey's production values in 2016-2020, and CM CO_2 emission factor values [32] calculated by MENR for the 2021-2024 period. The source-based CM CO_2 emission factors used in baseline emission value calculations are given in Table 3.

The CM CO_2 emission factors given in Table 3 and the source-based CO_2 emission reduction values calculated using the electrical energy production values of plants producing electrical energy with the RES in Table 2 are given in Table 4.

According to the data in Table 4, within the period 2016-2020, 300.59 $MtCO_2$ emission reduction was realized with electricity generation carried out using RES. CO_2 emission reduction amount, which can be achieved by electricity generation to be carried out using RES between 2021-2024, is 454.94 $MtCO_2$. The total emission reduction between 2016 and 2024 would be 755.54 $MtCO_2$. According to these calculations, in the period from 2016 to 2020, 300.59 million voluntary carbon certificates can be issued if electricity generation projects are realized with RES and 454.94 million can be issued between 2021 and 2024. Between 2016 and 2024, the amount of voluntary carbon certificates that can be issued is 755.54 million units.

Since 2005, carbon credit trade has been carried out in voluntary carbon markets in Turkey.

The source-based emission reduction values of renewable energy projects in two voluntary carbon schemes widely used in Turkey are cumulatively given in Table 5 [44]-[46].

Table 2. Turkey's electricity generation by source [33],[34].

Source	Electricity Generation (TWh)								
	2024	2023	2022	2021	2020	2019	2018	2017	2016
Hydro	104.288	104.288	102.117	101.002	97.755	88.885	59.937	58.414	67.309
Imported coal	70.128	70.128	70.128	60.228	60.228	60.381	62.989	51.172	47.742
Natural gas + LNG	185.634	185.634	185.634	185.634	184.993	56.523	91.639	108.839	88.288
Lignite	66.126	66.126	66.126	66.126	65.991	46.894	45.087	40.581	38.544
Wind (Onshore)	43.281	39.145	36.139	32.335	28.893	21.75	19.939	17.897	15.509
Geothermal	15.538	15.538	15.316	14.379	13.109	8.93	7.431	5.969	4.819
Biomass	17.267	16.812	15.684	14.072	12.716	4.522	3.447	2.078	1.683
Hard coal + Asphaltit	9.397	9.397	8.425	8.425	8.425	5.843	5.173	5.849	6.166
Fuel oil	2.238	2.238	2.238	2.238	2.238	733	329	958	1.054
Solar (PV)	29.401	27.151	24.276	21.401	18.509	9.62	8.246	2.861	1.034
Diesel	7	7	7	7	7	1	0	1.009	1.554
Uranium	17.395	8.698	0	0	0	0	0	0	0
Total	560.700	545.162	526.09	505.847	492.864	304.081	304.216	295.627	273.701

Table 3. CM CO_2 emission factors.

Plant Type	CM Emission Factors (tCO_2/MWh)								
	2024	2023	2022	2021	2020	2019	2018	2017	2016
Wind	0.6198	0.6198	0.6198	0.6198	0.5890	0.5727	0.5670	0.5514	0.5670
Geothermal	0.5403	0.5403	0.5403	0.5403	0.5403	0.4850	0.4850	0.4840	0.4740
Biomass	0.5403	0.5403	0.5403	0.5403	0.5403	0.4850	0.4850	0.4840	0.4740
Solar	0.6198	0.6198	0.6198	0.6198	0.5890	0.5727	0.5670	0.5514	0.5670
Hydro	0.5403	0.5403	0.5403	0.5403	0.5403	0.4850	0.4850	0.4840	0.4740

Table 4. Prevented emission amounts for 2016-2024.

Source	CO_2 Emissions ($MtCO_2$)								
	2024	2023	2022	2021	2020	2019	2018	2017	2016
Wind	26.83	24.26	22.40	20.04	17.02	12.46	11.31	9.87	8.79
Geothermal	8.40	8.40	8.28	7.77	7.08	4.33	3.60	2.89	2.28
Biomass	9.33	9.08	8.47	7.60	6.87	2.19	1.67	1.01	0.80
Solar	18.22	16.83	15.05	13.26	10.90	5.51	4.68	1.58	0.59
Hydro	56.35	64.64	55.17	54.57	52.82	43.11	29.07	28.27	31.90
Total	119.12	123.21	109.37	103.25	94.69	67.60	50.33	43.61	44.37

Table 5. Emission reduction amounts of the power plants included in the voluntary carbon schemes(cumulative).

Source	Emissions Reduced/Avoided ($MtCO_2$-eqv.)				
	2016	2017	2018	2019	2020
Wind	6.28	6.95	7.39	7.87	7.87
Geothermal	0.16	0.16	0.20	0.20	0.33
Biomass	0.05	0.05	0.23	0.23	0.26
Solar	0.01	0.04	0.07	0.08	0.13
Hydro	8.48	8.71	8.71	8.71	17.42
Total	14.98	15.91	16.59	17.09	26.01

The values of the source-based CO_2 emission reduction potentials given in Table 4 and the amounts of emission reductions of the plants included in the voluntary carbon schemes given in Table 5 together with the amounts of emission reductions that are traded can be determined. The source-based ratios of the amounts of carbon reduction subject to trade found as a result of the calculations made are given in Table 6.

Table 6. Source-based ratios of traded carbon reduction amounts.

Source	Amount traded / Exploitation rate(%)				
	2016	2017	2018	2019	2020
Wind	71.40	70.40	65.38	63.19	46.25
Geothermal	6.91	5.46	5.57	4.63	4.61
Biomass	6.87	5.45	13.49	10.29	3.80
Solar	1.25	2.63	1.40	1.52	1.18
Hydro	26.59	30.81	29.96	20.20	32.98
Total	33.77	36.48	32.97	25.28	27.46

According to the data in Table 6, in the period 2016-2020, a very small part of the carbon reduction provided by Turkey's renewable power plants has been the subject of trade through voluntary carbon certificate issuing organizations.

The prices of carbon certificates vary depending on many parameters. For instance, they vary by year depending on supply and demand. Annual changes in the average credit price of RES projects which can be traded using voluntary carbon reduction schemes are given in Table 7 [47],[48]. The price in 2016 was accepted as the same as in 2017, and the price in 2020 was accepted as the same as in 2019.

The total prevented emission amounts for the years given in Table 4 and the amount of revenue that can be obtained by voluntary carbon certificate trade with the price values given in Table 7 were calculated. The amounts of revenue that can be obtained by voluntary carbon certificate trade are given in Table 8.

According to the data in Table 8, the voluntary carbon certificate revenue that can be obtained between 2016-2024 is $1.116 billion.

6 Discussion and conclusion

To achieve the 1.5°C climate target, antropogenic CO_2 emissions must be net-zero by 2050. The NDCs made under the PA are not sufficient; more emission reductions should be achieved and the number of countries setting net-zero emissions targets should increase. The price decline of electricity from RES, the development of the sector and the growth of the market have made RES an important option for low-carbon economic growth. Turkey's GHG emissions have been increasing, and the energy sector emissions have the highest share in Turkey's GHG and CO_2 emissions [49]. The country's emissions can be significantly reduced with the energy transition to be carried out in the field of electricity generation. Making better use of Turkey's rich RES potential for the production of electrical energy will contribute significantly to energy transition. An increase in the value of electricity generation carried out with RES; will lead to improvements in the fields of environment, economy and public health.

The increased use of RES will reduce Turkey's dependence on other countries for primary energy sources, and therefore will have the added benefit of reducing its current account deficit as well as providing new employment opportunities. Turkey's effective use of RES will also protect its trade volume with the EU, and disrupt the parallel between economic growth and GHG emission increase. Reductions in GHG emissions will in turn reduce environmental and human health concerns related to them.

Turkey has devoted an important place to RESs among the resources it will use to limit GHG emissions in its NDCs to the UNFCCC. The country has achieved significant success in the generation of electricity from RES over the years, but it has not been utilizing its RES potential sufficiently, especially regarding solar and wind energy. Despite its rich RES potential, Turkey has been able to utilize only 36.5% of its electrical energy production potential with RES. The rate of utilization of electricity generation potential with wind and solar energy is well below the total available potential. Turkey's solar energy utilization rate is 13.9% and wind energy utilization rate is 19.5%. According to renewable energy goals set for 2023 in the national policy documents, Turkey was able to reach 82.7% of its electricity generation targets. When we consider installed power development in the field of wind energy, it is seen that the attainment rate of the 2023 target is only 46.8% [50]-[53].

Although Turkey did not ratify the PA until October 2021, it has had a significant trade volume with the EU, which is abides by international climate policies. The EU green deal and the regulation of a carbon border tax will have a significant impact on the Turkish economy. Turkey's export market, which is worth about $90 billion, will be affected if a carbon tax is introduced at the border with the European green deal [54]. Such an arrangement will expose sectors exporting to the EU to the burden of carbon tax [55]. In the new climate regime shaped by the PA and the EU green deal, Turkey must ensure low-carbon economic growth and reduce GHG emissions. The arrangements to be made within the scope of the EU green deal can be seen as an opportunity for Turkey's low-carbon economic growth and can serve energy transition goals. With a low-carbon economic transition strategy based on RES and energy efficiency, GHG emissions can be reduced while national income and employment rate can be expected to go up [55]. Compliance with the EU regulations for low-carbon growth under the new climate regime will increase Turkey's exports and competitiveness [54].

Table 7. Average prices of RES projects traded in voluntary carbon markets.

Price (USD/tCO_2eqv.)	Year								
	2024	2023	2022	2021	2020	2019	2018	2017	2016
	1.4	1.4	1.4	1.4	1.4	1.4	1.7	1.9	1.9

Table 8. Carbon certification revenues by year.

Carbon revenue (mUSD)	Year								
	2024	2023	2022	2021	2020	2019	2018	2017	2016
	166.77	172.49	153.12	144.55	132.57	94.64	85.55	82.86	84.30

The voluntary carbon crediting mechanism is the mechanism that encourages generation of electricity from RES. Turkey can reduce its emissions from electricity generation by using its rich RES potential, and the emission reductions to be achieved can be traded in order to obtain revenue from them. The actively functioning voluntary carbon market will ensure the determination of the carbon price.

The private sector's interest in voluntary carbon certifications has been growing in the context of producing sustainability reports. The number of companies voluntarily disclosing GHG emissions to the public has been steadily increasing over the years. Large scale companies with high levels of institutionalism and profitability have a greater willingness to disclose GHG emissions [22]. Demand from non-regulated sectors and the tendency of large companies to use carbon credits in the context of corporate social responsibility policies increase the demand for voluntary carbon credits. It is estimated that the hike in future demands will increase the price of carbon credits and make it possible for expensive projects to take place. CORSIA, which will be implemented between 2020 and 2035, will increase the demand for the new carbon offset credits. In the reduction periods, which will be voluntary between 2021-2023 and mandatory after 2024, aviation sector emissions are projected to be offsetted by using carbon credits.

Emissions can be reduced with carbon credits obtained through renewable energy projects. Turkey's high CM emission factors (619 gCO_2/kWh and 540 gCO_2/kWh) reflects the country's dependence on fossil fuels for electricity generation and this value also means that higher number of carbon credits can be issued with renewable energy projects.

From 2016 to 2020, 300.59 Mt CO_2 emission reduction was realized with renewable energy projects in Turkey. The amount of CO_2 emission reduction which can be achieved by electricity generation from RES between 2021-2024 is 454.94 $MtCO_2$. A very small part of the carbon reduction achieved by Turkey's renewable power plants has been the subject of trade through voluntary carbon certificate issuing organizations. The estimated voluntary carbon certification revenue between 2016 and 2024 is $1.116 billion. Demand from non-regulated sectors and the aviation sector is expected to increase the prices of carbon credits as a result of the increasing tendency among multinational companies to use carbon credits in the context of corporate social responsibility policies, and efforts by companies to achieve their set strict emissions targets at the least cost in the short term [9]-[12],[56]. With the increasing efforts of companies concerning the struggle against climate change, the voluntary carbon market is expected to grow 5 to 10 times in the next 10 years, with average carbon credit prices reaching 20-50 $/$tCO_2$ eqv. in 2030 [56]. Carbon credit prices vary depending on parameters such as the type of energy source, the transaction price, the location of the project, the volume of transactions, the age of the project and the carbon crediting standards [8],[56]. In addition to reducing GHG emissions, carbon credits produced in the voluntary market provide many socio-economic and environmental benefits to carbon credit users. The demand for carbon credits with high socio-economic and environmental benefits is on the rise. The co-benefits of carbon credit projects increase the price of carbon credits with these characteristics. Many buyers are willing to pay more for carbon credits of this particular feature [8]. While the price is 1 $/$tCO_2$ eqv. in old projects with little co-benefits, the price goes up to 20 $/$tCO_2$ eqv. in new projects with more co-benefits (protecting biodiversity, providing employment opportunities for local people, etc.) [56].

Some improvements should be made taking into account the expected demand in the carbon market and the effect of co-benefits obtained during the credit development process on credit prices. Emission reduction projects should be developed using carbon crediting standards which ensure credibility with proper monitoring and vetting. Carbon credits with high socio-economic and environmental benefits should be developed taking into account the demand for carbon credits with such benefits and the high value of these credits [4],[8],[9].

The role of private sector organizations in the decarbonization process is important. These organizations can be important participants in the international efforts to combat climate change by decarbonizing production, distribution and supply chain emissions. The voluntary carbon credit market needs to be made more attractive and functional. Awareness-raising campaigns should be carried out to encourage companies to use voluntary carbon credits within the scope of sustainability reporting. Corporate buyers should be directed towards new and high-quality renewable energy projects.

7 Author contribution statements

Mustafa OZCAN conceived and designed the article, conducted the literature review, collected the data, performed analyzes, discussed the results and wrote the article.

8 Ethics committee approval and conflict of interest statement

There is no need to obtain permission from the ethics committee for the article prepared. There is no conflict of interest with any person/institution in the article prepared.

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