

The Transition of CO₂ Emission and Employment Multipliers from Brown to Green Under a Renewable Energy-Based Economic Growth Scenario in Türkiye:2053 Vision

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Abstract- In this study, the changes in employment and CO₂ emission multipliers caused by economic growth and the transition to renewable energy are calculated under two scenarios in Türkiye. In the first scenario, employment and CO₂ emission multipliers are calculated for every 1 million dollars of final demand for all sectors in the Turkish economy with the current use of energy resources. Extended input-output analysis is applied using employment and CO₂ emission data published on dates consistent with Türkiye's most recent input-output table. The findings show that employment in all sectors would increase by 828 persons (14 persons in the energy sector), and CO₂ emissions would increase by 29,323 (MtCO₂) (5548.2 (MtCO₂) in the energy sector). Then, the second scenario analysis was conducted for Türkiye's COP29 commitments. Considering Türkiye's COP 29 target of increasing the share of renewable energy to 69.1% in 2053, it is assumed that CO₂ emissions will decrease at the same rate. In this framework, the same analysis was used to calculate how much CO₂ emissions would decrease in case of a demand of 1 million dollars for each sector separately. As a result, it was concluded that the CO₂ emissions caused by the production of all sectors would decrease by 20262.4 (MtCO₂) (2119.43 (MtCO₂) in the energy sector). Regarding employment, it is estimated that 10 people will work in the renewable energy sector.

Keywords: Renewable energy, economic growth, employment multiplier, CO₂ emission multiplier, production multiplier, extended input-output analyses.

1. Introduction

Each society and government has made massive efforts to reach a higher standard of life. Within this objective, policymakers have addressed and determined the initiatives, policies, and agendas for economic development. The projections and reflections of the economic development programs have been changed and reshaped regarding the current and future missions, challenges, and issues. Within this scope, two catastrophic phenomena, global boiling and climate change, have been considered: the issues that have a detrimental influence on the current economic and social system and lead the future generation to survive at the misery level [1]. Global boiling and climate change have been the leading challenges and are among human history's most harmful and dangerous experiences. Water scarcity, floods,

droughts, melting glaciers, rising sea levels, degraded fertile soil and lands, mitigating fishing stocks, and annihilating biodiversity have been reported culprits of global warming and climate change. Greenhouse emissions (mainly CO₂ emissions, which are the most significant contributor of greenhouse emissions, approximately 70%) are the primary driver of global warming and climate change. Utilizing nonrenewable energy resources to fulfill the energy requirements of anthropogenic activities has been a prominent reason for greenhouse emissions. About 85 percent of energy is still provided by nonrenewable energy resources, which induces another challenge in terms of development projects because the life of fossil energy resources is limited, and oil and natural are expected to last up to approximately 50 years. Regarding these challenges, renewable energy resources are outstanding solutions to

mitigate the detrimental effects of global boiling and climate change and render energy security.

Detecting, designing, and implementing accurate and effective economic development projects have been massively challenging as anthropogenic activities have already operated beyond the planet's capacity, in addition to the effect of global warming and climate change [2]. Renewable energy plays an essential role in decreasing the cost of production and consumption caused by sustainable and cheap energy supply and expansion. However, sufficient human capital and capital stock are required to advance in renewable energy projects, and many humans are also needed to construct, install, and operate renewable energy projects [3].

As underlining the significance of renewable energy in protecting the environment, expanding economic welfare, and sustainability, all governments should focus on the policies aiming at expanding the portion of renewable energy resources in total energy. Although achieving sufficient renewable energy resources to fulfill the energy demand of anthropogenic activities is vital for whole countries, the importance of renewable energy has become more visible. It has been an irreplaceable initiative for nonrenewable energy-imported countries. Türkiye is accepted as one of the most critical cases in this context. Over the past two decades, Türkiye has been ranked the fastest-growing energy demand among the OECD countries. Türkiye is the second country to China in the global upsurge in electricity and natural gas demand. On the other hand, imported fossil energy resources supply nearly 74% of total energy demand [4], which induces the Turkish economy to become more vulnerable to global energy supply shocks and fluctuations in energy prices, mitigating global combativeness. The heavy reliance on fossil fuels is a primary culprit of the current account deficits in Türkiye.

CO₂ emissions and waste generation have accompanied the economic growth. The dominant share of the nonrenewable energy resources in the Turkish energy mix makes Türkiye the fastest-growing OECD economy with acceleratingly rising CO₂ emissions [5,6]. In addition to the severity of greenhouse emissions, Türkiye has been experiencing an ecological deficit since the 1980s; in other words, the Turkish economy is unsustainable [7]. Despite encountering many bottlenecks Türkiye caused by the dependence on nonrenewable energy resources, Türkiye has continued its massive addressed initiatives toward increasing the portion of renewable energy resources in the energy mix. Türkiye connects excellently to the development of renewable energy sources. The installed capacity (MW) of renewable energy is presented in Figure 1 [8].

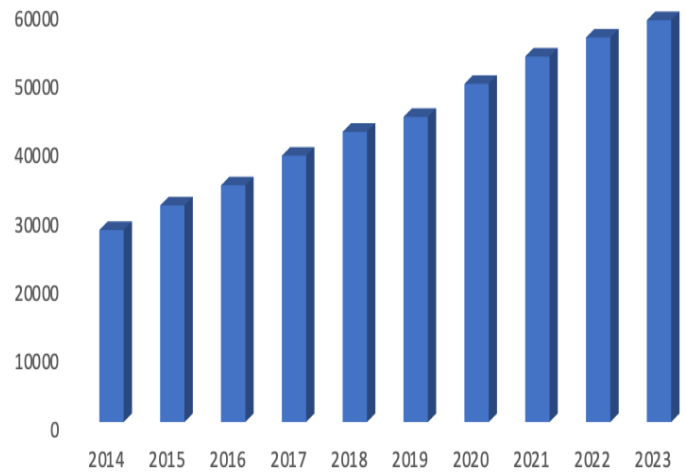


Fig. 1. The installed capacity of renewable energy (MW) [4].

As seen in Figure 1, Türkiye's installed renewable energy capacity is increasing. For this reason, directing investments to renewable energy provides employment possibilities for young people and minimizes dependence on foreign energy. Continuously reducing CO₂ emissions ensures environmental sustainability. Each step towards renewable energy improves the probability that many side objectives can be accomplished together.

The emissions trading system (ETS), implemented by the European Union countries to prevent carbon leakage in their trade among themselves, was expanded, and CBAM was introduced on May 16, 2023. According to the CBAM practice, all countries exporting to EU countries must pay taxes on the CO₂ emissions generated while producing the products they export. Since about 40% of Türkiye's exports are to EU countries, it is necessary to increase renewable energy production to reduce CO₂ emissions [9-11]. Moreover, Türkiye is dependent on imports for fossil energy use. In the first eleven months of 2024, total energy imports amounted to 165158000 dollars [10]. A significant portion of the current account deficit is due to fossil energy imports. Therefore, reducing CO₂ emissions and switching to renewable energy favor for the Turkish economy.

The United Nations Framework Convention on Climate Change (UNFCCC) came into force in 1994 to reduce and control global warming, the leading cause of climate change. Subsequently, the Conference of Parties (COP) Conference of Parties (COP) of the countries that are parties to the convention started to come together regularly every year. Türkiye joined the Conference of Parties (COP) in 2004 by ratifying the United Nations Framework Convention on Climate Change (UNFCCC) to reduce CO₂ emissions. The road map of the COP conferences where important decisions were taken and the critical decisions taken for Türkiye at the COP conferences are shown in Figure 2.

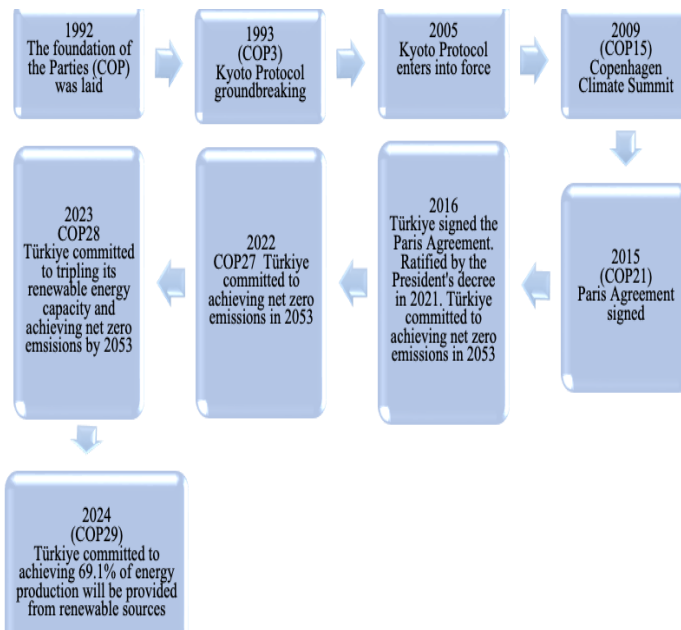


Fig. 2. Map road on CO₂ reduction for Türkiye.

As seen in Figure 2, while a carbon neutrality target for 2053 existed until the COP29 summit, this target was deemed unrealistic at COP29, and a more consistent target was set[†]

A rise in each sector's overall demand results in economic growth and stimulates production via the production multiplier. Economic growth creates a positive externality by increasing employment. However, it also increases CO₂ emissions, causing negative externalities. This study considered two scenarios to examine the impact of transitioning to a renewable energy-based economy in Türkiye. The first scenario investigates how much employment and CO₂ emissions will increase due to a final demand of \$1 million for all sectors in Türkiye.

Comprehensive restructuring within the energy sector is necessary to achieve cleaner production, encompassing social, environmental, and economic dimensions. This transformation requires reducing CO₂ emissions at all stages of energy generation and consumption [12,13]. For instance, a sector dedicated to renewable energy production can be developed to achieve this goal. Then, understanding the potential impact of establishing a renewable energy production sector on employment dynamics and CO₂ emissions reduction will be crucial. Few studies address this issue. These studies generally attempt to answer this question

[†] Since the renewable energy scenario is applied in the study, the COP29 target that "69.1% of energy production will be provided from renewable sources and installed solar and wind energy capacity will be quadrupled" is considered. In addition, COP 29 set a target of "99% carbon emission reduction in the iron and steel sector, 93% in the cement sector, 75% in the aluminum sector and 75% in the fertilizer sector". However, these targets could not be included in the analysis in this study. This is because these sectors are not included as a single sector in the input-output tables. The iron-steel and aluminum sectors are sub-sectors of the "basic metal" sector, the cement sector of the "Other non-metallic mineral products" sector, and the fertilizer sector of the "Pharmaceuticals, medicinal chemical and botanical products" sector.

by introducing a new renewable energy production sector into the input-output table [14-21].

There is insufficient data to add the renewable energy sector to Türkiye's input-output table. The study needed to implement the second scenario to solve this problem. Türkiye's target to reduce CO₂ emissions by 69,1% by 2053, COP 29 commitments, inspired the second scenario [22]. In this context, it is investigated how much CO₂ emissions will decrease for each 1 million dollars of final demand for all sectors separately until 2053, while on the other hand, it is investigated how many people can work in green jobs with a final demand of 1 million dollars in the energy sector [23].

Energy imports will decrease, and investments will increase with renewable energy conversion in Türkiye. The increase in investments will positively affect the economy in two ways. First, employment will increase in the invested sectors. Thus, renewable energy production will transform employment in the energy sector to green and increase employment in other sectors. Secondly, by ensuring energy security, the goal of becoming an energy hub will be achieved for Türkiye.

This study used applied analytical techniques to determine the results of the policies to be implemented at the COP 29 Conference.

Numerical data substantiate the plausibility of this transformation, revealing the potential for converting some employment roles from ecologically harmful to ecologically beneficial ones.

The results obtained in the scenario are instructive for policymakers, including future calculations. However, since economics is affected by many factors, all foresight about the future also brings along the concept of uncertainty. Therefore, the study has a "ceteris paribus" assumption in the study [24].

This study comprehensively assesses the impact on all sectors in Türkiye if the 69,1% renewable energy transition target set in the COP29 conference is realized by 2053. Thus, there will be a contribution to the literature by getting information about the employment provided by renewable energy and how much CO₂ emissions will be decreased.

The remainder of this article is structured as follows: Section 2 comprehensively reviews the available literature on production, employment, and CO₂ emission multipliers. Section 3 presents the data and methodology. Section 4 evaluates and discusses the results of scenario-based input-output analysis. Finally, Section 5 presents this study's main findings and conclusions.

2. Literature Review

The multiplier concept is based on Quesnay's [25], "Tableau Economique" and was used by Kahn [26], who examined the effect of employment growth in one sector on employment growth in all sectors. Then, Keynes [27], transformed the multiplier developed by Kahn into what it is today. However, this new multiplier model of Keynes, generally accepted in macroeconomics, accepts the marginal

propensity to consume as the same for all sectors and cannot determine the effects of economic transactions on all sectors separately. This deficiency was addressed by the factor calculation obtained by the input-output analysis of Leontief [28] and Rasmussen [29], who calculated the Leontief inverse matrix and brought the total linkage effects to the literature. Consequently, Rasmussen [29] established the groundwork for a calculation methodology based on a production multiplier. The first study on the employment multiplier belonged to Hazari and Krishnamurty [30], who examined the effect of India's industrialization on employment. Subsequently, Meller and Marfan [31], revealed employment changes in Chile's small and large industry sectors. Leontief [32] revealed the employment created by mechanization in all sectors in Austria within the framework of the blue and white-collar distinction. Valadkhani [33] identified sectors with high employment rates in Australia. Günçavdi et al. [34] examined the effect of a large-scale structural adjustment program implemented in Türkiye on employment. Bekhet [35] examined the effect of development policies on the Malaysian economy by calculating output, income, and employment multipliers. Ernst and Sarabia [36] studied the employment created by the construction sector worldwide and the effect of the employment multiplier on international trade. In this context, James and Fujita [37] studied Indonesia, Lurweg et al. [38] examined Germany, Portella-Carbó [39] researched the United Kingdom, Spain, USA, Italy, France, Japan, Germany, and China, and Feenstra and Sasahara [40] focused on the USA.

As the devastating effects of climate change increase, another necessary effort is determining the multipliers of CO₂ emissions and developing policy recommendations. The

primary work on the CO₂ emissions multiplier was conducted by Leontief [41]. Many studies have been conducted in this area, focusing on China, which is the largest CO₂ emitter in the world. Some studies belong to Chang [42], Hubacek and Sun [43], Li et al. [44], Su et al. [45], Lin and Xie [46], Wang and Wang [47], Ling et al. [48], Xu et al. [49], Jiang et al. [50], Steblyanskaya et al. [51], Wu et al. [52], Guo and Pang [53], Ünal and Managi [54], Lin et al. [55], and Zhou et al. [56], Wang et al. [57]. Studies focusing on other countries include Hetherington [58] on the UK, Alcántara and Padilla [59] on Spain, Ziebig and Gladysz [60] on Poland, O'Sullivan and Edler [61] and Ulrich and Ulrike [62] on Germany, Güler [63] on Türkiye, Baltruszewicz et al. [64] on Zambia, Gue et al. [65] on the Philippines, Abbas et al. [66], on Pakistan, Weidong et al. [67], on China, Guionie et al. [68], on France, and Sri and Banerjee [69], on India.

Some studies have conducted scenario analysis on increasing economic growth while reducing CO₂ emissions: Hamilton and Kelly [70], studied Saharan Africa, Nikolaev and Konidari [71], examined Bulgaria, Nguyen et al. [72], reported on Vietnam and Sheraz et al. [73] focused on the economies of G20 countries. Researchers have also examined the role of hydrogen in economic development. Chun et al. [74] analyzed the Korean economy, Hienuki [75] focused on Japan, while Lee et al. [76] examined the impact of biohydrogen on the development of the American and Chinese economies.

Table 1 summarizes the literature through studies that calculate the employment multiplier and CO₂ emission multiplier resulting from using renewable energy resources with extended input-output analysis.

Table 1. Summary of empirical literature on the employment multiplier and CO₂ emission multiplier

EMPLOYMENT MULTIPLIER		
Author(s)	Countries	Aim(s) and Conclusion(s)
Tourkolias and Mirasgedis [77]	Greece	The employment that the use of clean energy resources would provide was estimated. It has been determined that, compared to fossil fuel use, renewable energy will make it possible to achieve a cleaner environment and contribute to economic development and increased employment.
Markaki et al. [19]	Greece	Analysis was carried out to determine the economic effects of renewable energy investments on employment and production. It has been determined that the investments made will increase the national product by an average of € 9.4 billion annually and create 108,000 jobs.
Garrett-Peltier [15]	USA	It was investigated whether green energy will generate more jobs than are lost in brown energy. It has been calculated that every \$1 million spent on fossil fuels will create approximately 2.65 full-time jobs. In comparison, the same amount of investment in green energy will create 7.72 full-time jobs. Therefore, it has been determined that five persons will be employed for every \$1 million transferred from nonrenewable energy to renewable energy.
Wang et al. [21]	China	It was investigated how much employment, economic incentive and energy savings that bioethanol production would create in 28 different scenarios. The results showed that compared to oil refining, bioethanol production is more effective for economic stimulation and energy savings but has less impact on job formation
Gelo et al. [17]	Croatia	It was aimed to analyze the macroeconomic effects of investments in renewable energy sources regarding electricity production. The results showed that investments in renewable energy have relatively lower macroeconomic impacts on the Croatian economy.

		It was estimated that every 1 million Euro investment in electricity generation capacities from renewable energy creates directly and indirectly only 0.336 million Euro of added value and 0.410 million Euro of GDP. Also, it was predicted that the 1 million Euro investment will provide 14 new employment opportunities.
O'Connor [20]	Australia	Analysis was carried out to estimate the economic contributions of the hydrogen sector to GDP and employment until 2040. In the most optimistic scenario, the hydrogen sector will generate over \$14 billion in GDP and support 57,000 jobs.
García Vaquero et al. [16]	Spain	Green business opportunities offered by political economic and labor economic policies were investigated. Consequently, it was emphasized that 356,000 green job opportunities would be provided, and it was determined that worker skills needed to be updated to carry out green jobs.
Gupta et al. [18]	Switzerland	The macroeconomic results of green hydrogen production on employment, GDP and greenhouse gas emissions were analyzed. It was determined that in the three cases of 'Equal Cost', 'Equal Energy', and 'Equal Service', each kg of green hydrogen generated increases GDP by approximately 106%, 28% and 45%. At the same time, it provides more full-time equivalent jobs by 163%, 43%, and 65% and lastly causes 45%, 18%, and 29% lower greenhouse gas emissions compared to diesel and other industries, respectively.
Caiafa et al. [14]	Brazilian state of Ceará	A framework was formed to calculate the jobs that will be created about to onshore wind, offshore wind, and solar photovoltaics in a large-scale green hydrogen hub, which is expected to provide 15 of European Union (EU) imports by 2030, by added-value, income and gender. It is envisaged that scenarios dominated by multinational companies will not only provide local benefits but also may exacerbate existing income and gender inequalities according to the distribution of employment types.
CO₂ EMISSION MULTIPLIER		
Li et al. [78]	Germany	Analysis was carried out to determine CO ₂ emissions by applying two trade scenarios under the pollution haven hypothesis. The first result was that if Germany did not contribute to reducing emissions, CO ₂ emissions would raise by an average of 1.53%. The second is that Germany's participation in international trade supports decarbonization in developing countries, especially China and Russia. The last one is that changes in CO ₂ emissions originate from the "manufacturing" and "electricity, gas, and water resources" sectors.
Liu et al. [79]	China	A study covering the periods between 2012-2017 and 2017-2018 was conducted to examine China's key drivers of CO ₂ emissions. It was determined that the CO ₂ emissions components caused by final demand in 2012, 2017, and 2018 were 85.5%, 85.6%, and 84.7%, respectively. The findings showed that the increase in CO ₂ emissions in China was due to intersectoral pull effects and that the construction sector had a more significant pull effect on the CO ₂ emissions of other sectors. As a result, it was again proven that it is necessary to change the current energy structure to diminish carbon dioxide emissions.
Zhou et al. [56]	Guangdong province of South China	The effects of different environmental policies on economic and energy activities were examined over a long-term planning horizon (2021-2050). Key sectors affecting CO ₂ emissions and economic development were identified as equipment, construction, transportation and storage, and other services. It was determined that CO ₂ emissions will peak in the 2025-2035 period and decrease with the effect of renewable environmental policies in the 2036-2050 period.
Wimmer et al. [80]	Austria	Based on "Austria's Renewable Expansion Act", it was aimed to estimate input coefficients for energy sector by 2030. Accordingly, renewable energy policy plans have been taken into consideration. In the energy sector, it is predicted that input coefficients will be high while mining input coefficients will decrease. It was argued that increasing the portion of green energy sources will significantly reduce the share of labor inputs.
Wen et al. [81]	New Zealand	In New Zealand, it is aimed to purify the agricultural sector from CO ₂ emissions. It was determined that the critical factors affecting the shift in the emission profile due to energy use from 2007 to 2013 are emission intensity, consumption volume, and population. It was determined that carbon emissions in the transportation sector must first be eliminated in order to achieve zero CO ₂ emissions.

In Table 1, while some studies calculated only the employment multiplier, some examined only the CO₂ emission multiplier. However, the economy must be addressed with a holistic approach. A multiplier effect in the economy triggers many factors. In this context, Kolsuz and Yeldan [82], Hienuki [75], Bai et al. [83], and Dell'Anna [84] calculated both employment and CO₂ emission multipliers in their studies. This study calculates how much green employment will provide a \$1 million final demand in the energy sector and how much a \$1 million final demand in each sector will reduce CO₂ emissions by 2053. In addition, the production multiplier that emerges while applying the analysis is also shared. A separate calculation reveals the effects of green transformation on employment and the environment, considering the carbon emission reduction targets that Türkiye has committed to until 2053. Thus, the results that will be obtained if the targets set by policymakers in Türkiye, which is rich in renewable energy, are achieved are presented empirically.

When the sources available in the literature are examined, no study investigates the increase in green employment and CO₂ emission reduction if the targets set inside the COP 29 conference are realized. This study aims to fill this gap in the literature.

3. Data and Methodology

The study performs an extended input-output analysis with employment data and CO₂ emission data, assuming a final demand of 1 million dollars for all sectors. In the analysis, employment and CO₂ emission data published in the same year are used to be compatible with Türkiye's most current input-output table for 2018 [85]. Preparing input-output tables takes a long time. Therefore, this analysis used these data, assuming that all economic factors (e.g., relative prices, technology, and input coefficients) are constant [86].

This study faced a particular constraint in incorporating new sectors due to insufficient data on renewable energy production in Türkiye. For this reason, by creating a second scenario in the study, it is assumed that 69,1% renewable energy conversion will have occurred in Türkiye by 2053. Under these circumstances, the impact of green energy transformation is reflected separately in the findings obtained from the expanded input-output analysis in terms of both employment and environmental aspects. Hence, green environment multipliers showing green employment and reduction in CO₂ emissions were found.

Table 2. Data Set

Variable	Source
Input-Output Table	OECD Statistics, 2021a [85]
Employment	Republic of Türkiye Social Security Institution, 2022 [87]
CO ₂ Emission	OECD Statistics, 2021b [88]

This research used input-output analysis, introduced to the literature by Leontief (Nobel Prize winner in 1973). He

said, "the procedure employed by input-output analysis in improving the grasp of economic theory upon the facts with which it is concerned in every real situation" [89]. In this context, input-output analysis is based on calculating guiding coefficients.

The input-output analysis calculated through Turkey's input-output table provides coefficients that prove the relationships between all sectors in Turkey. The extended input-output analysis, on the other hand, provides the CO₂ emission multiplier resulting from the production of all sectors separately when CO₂ emission data are used and the employment multipliers of all sectors separately when employment data are used. This analysis presents the economic contribution of sectors, CO₂ emission multipliers, and employment multipliers together.

The input-output tables available on the OECDStat platform have 45 specific sectors. However, in the case of Türkiye, the categories labeled "activities of households as employers" and "undifferentiated goods and services producing activities of households for own use" are not considered distinct sectoral activities. Therefore, the coefficient in the input coefficient matrix was set as 0. Consequently, this sector was excluded from the computation, and the final input-output table became a 44x44 matrix. The unit value of all coefficients in the table is US dollars (Millions). The analysis proceeded as follows.

First, matrix A was calculated. "The quantity of the output of sector i absorbed by sector j per unit of its total output j is described by the symbol "a_{ij}" and is called the input coefficient of product of sector i into sector j" [89].

Then the A matrix is;

$$a_{ij} = \frac{x_{ij}}{x_j} \tag{1}$$

Then the A matrix is;

$$a_{44 \times 44} = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{144} \\ a_{21} & a_{22} & \dots & a_{244} \\ \vdots & \vdots & \ddots & \vdots \\ a_{441} & a_{442} & \dots & a_{444} \end{bmatrix} \tag{2}$$

To solve the necessary amount of production for every economic sectors, not only for the final demand (F_i), but also the other sectors' input requirements (X_{ij}), the linear equation system given below must be solved simultaneously by using A matrix in Equation (2).

$$\begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_{44} \end{bmatrix} = \begin{bmatrix} a_{11}X_1 & a_{12}X_1 & \dots & a_{144}X_1 \\ a_{21}X_2 & a_{22}X_2 & \dots & a_{244}X_2 \\ \vdots & \vdots & \ddots & \vdots \\ a_{441}X_{44} & a_{442}X_{44} & \dots & a_{444}X_{44} \end{bmatrix} \begin{bmatrix} F_1 \\ F_2 \\ \vdots \\ F_{44} \end{bmatrix} \tag{3}$$

Where,

F_i: final demand of sector I

Solving the simultaneous equation system in Equation (3) with respect to variables X_i , we reach the final solution in Equation (4),

$$\begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_{44} \end{bmatrix} = \begin{bmatrix} (1-a_{11}) & -a_{12} & \cdots & -a_{144} \\ a_{21} & (1-a_{22}) & \cdots & -a_{244} \\ \vdots & \vdots & \ddots & \vdots \\ -a_{441} & -a_{442} & \cdots & (1-a_{444}) \end{bmatrix}^{-1} \begin{bmatrix} F_1 \\ F_2 \\ \vdots \\ F_{44} \end{bmatrix} \quad (4)$$

Or the matrix notation;

$$X = (I - A)^{-1} F$$

Here, $(I - A)^{-1} F$ matrix is named Leontief inverse matrix.

Equation (4) was used to acquire the total output vector [29]. The calculation technique is presented in Equation (4) [30].

In the Leontief inverse matrix, $(I - A)^{-1}$, the total backlink coefficients (production multiplier) can be calculated using the column sum of each sector separately, while the total forward link coefficients can be calculated using the row sums. The column for each sector in the Leontief inverse matrix shows the partial backward linkage effect, that is, the production multiplier, of the relevant sector [29].

In light of classical input-output theory, final demand induces economic growth by increasing the production multiplier [28].

The employment vector (I) was computed to determine the impact of economic growth on employment. The calculation technique is presented in Equation (5) [30].

$$I = \frac{\text{The employment generated by the total output of sector } i}{\text{The total output of sector } i} \quad (5)$$

The expanded input-output analysis calculation technique with employment data is presented in Equation (6) [30].

$$\begin{bmatrix} I_1 & 0 & \cdots & 0 \\ 0 & I_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & I_4 \end{bmatrix} = \begin{bmatrix} a_{11}X_1 & a_{12}X_1 & \cdots & a_{144}X_1 \\ a_{21}X_2 & a_{22}X_2 & \cdots & a_{244}X_2 \\ \vdots & \vdots & \ddots & \vdots \\ a_{441}X_{44} & a_{442}X_{44} & \cdots & a_{444}X_{44} \end{bmatrix} \begin{bmatrix} F_1 \\ 0 \\ \vdots \\ 0 \end{bmatrix} \quad (6)$$

The CO₂ emission vector (C_i) is calculated by dividing the total CO₂ emissions caused by the inputs that sector i receives from all sectors to produce one unit (c_i) by the sum

of the inputs that sector i receives from all sectors to produce one unit (x_i). The calculation technique is presented in Equation (7) [30,90].

$$C_i = \frac{c_i}{x_i} \quad (7)$$

Then the environmentally extended input-output analysis calculation technique is shown in Equation (8) [30].

$$\begin{bmatrix} I_1 & 0 & \cdots & 0 \\ 0 & I_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & I_4 \end{bmatrix} = \begin{bmatrix} (1-a_{11}) & -a_{12} & \cdots & -a_{144} \\ a_{21} & (1-a_{22}) & \cdots & -a_{244} \\ \vdots & \vdots & \ddots & \vdots \\ -a_{441} & -a_{442} & \cdots & (1-a_{444}) \end{bmatrix} \begin{bmatrix} F_1 \\ 0 \\ \vdots \\ 0 \end{bmatrix} \quad (8)$$

Each sector's employment multiplier (I) and CO₂ emission multiplier (C) were calculated using the data obtained from the analyses carried out considering the first scenario. Using the C/I ratio for each sector, the CO₂ emissions required to employ one person were calculated.

The second scenario was applied to Türkiye's COP29 commitments. Within the framework of Türkiye's target of increasing the share of renewable energy to 69.1% in 2053, CO₂ emissions are projected to decrease at the same rate. In this framework, the amount of CO₂ emission reduction in the case of a demand of 1 million dollars for each sector separately was calculated using the same method as the first scenario. Thus, the reduction in the CO₂ emission multiplier of all sectors and the energy sector separately was determined. Since a sector for renewable energy could not be added due to insufficient data, the number of people employed in the renewable energy sector cannot be calculated. Therefore, it is estimated that approximately 69.1% of the current people working in the energy sector will work in the renewable energy sector.

4. Result and Discussion

This study applied an environmentally expanded input-output analysis with a \$1 million demand scenario for each sector and expanded input-output analysis with employment data. The results shown in Table 3 are consistent with those in the literature. However, due to a lack of data, a new sector could not be added for renewable energy as in the literature, and an assumption was made with a different method. Specifically, the calculation assumed that the current energy sector will produce 69,1% renewable energy by 2053.

Table 3. Production, employment and CO₂ emission multiplier (Before COP29-After COP29) and C/I values for each sector

Codes-Sectors [‡]	Production Multiplier	Partial total backward linkage effect of the energy sector	Before COP29-CO ₂ Emission Multiplier	After COP29 - CO ₂ emission multiplier (2053)	Employment Multiplier
TTL_01T02: Agriculture, hunting, forestry*	2,08	0,03	419,3	129,6	8
TTL_03: Fishing and aquaculture*	1,86	0,02	533,0	164,7	12
TTL_05T06: Mining and quarrying, energy producing products**	2,08	0,06	1.471,6	454,7	17
TTL_07T08: Mining and quarrying, non-energy producing products**	1,73	0,02	593,4	183,4	16
TTL_09: Mining support service activities**	1,65	0,04	284,6	87,9	29
TTL_10T12: Food products, beverages and tobacco**	2,5	0,04	451,1	139,4	16
TTL_13T15: Textiles, textile products, leather and footwear**	2,28	0,05	363,2	112,2	27
TTL_16: Wood and products of wood and cork**	2,44	0,10	740,2	228,7	22
TTL_17T18: Paper products and printing**	2,27	0,06	462,7	143,0	19
TTL_19: Coke and refined petroleum products**	2,67	0,05	1.192,4	368,5	14
TTL_20: Chemical and chemical products**	2,14	0,05	612,3	189,2	13
TTL_21: Pharmaceuticals, medicinal chemical and botanical products**	2,15	0,05	591,3	182,7	18
TTL_22: Rubber and plastics products**	2,34	0,08	597,1	184,5	20
TTL_23: Other non-metallic mineral products**	2,32	0,16	2.106,3	650,8	19
TTL_24: Basic metals**	2,47	0,15	1.303,4	402,7	15
TTL_25: Fabricated metal products**	2,22	0,08	552,3	170,7	24
TTL_26: Computer, electronic and optical equipment**	1,79	0,03	180,6	55,8	15
TTL_27: Electrical equipment**	2,60	0,08	587,1	181,4	20
TTL_28: Machinery and equipment, nec**	2,29	0,07	489,1	151,1	20
TTL_29: Motor vehicles, trailers and semi-trailers**	2,35	0,06	425,1	131,4	18
TTL_30: Other transport equipment**	1,46	0,02	161,1	49,8	17
TTL_31T33: Manufacturing nec; repair and installation of machinery and equipment**	2,23	0,05	498,7	154,1	25
TTL_35: Electricity, gas, steam and air conditioning supply	3,37	2,33	5548,2	1714,4	14
TTL_36T39: Water supply; sewerage, waste management and remediation activities****	2,08	0,14	540,0	166,9	20
TTL_41T43: Construction	2,36	0,05	559,8	173,0	23
TTL_45T47: Wholesale and retail trade; repair of motor vehicles****	1,65	0,04	276,0	85,3	22
TTL_49: Land transport and transport via pipelines***	2,06	0,02	671,4	207,5	14
TTL_50: Water transport***	1,68	0,01	1.115,8	344,8	8

[‡] *Agriculture, ** Manufacturing industry, *** Transportation, **** are included in service sector

TTL_51: Air transport***	1,85	0,02	2.290,3	707,7	10
TTL_52: Warehousing and support activities for transportation****	1,43	0,02	214,5	66,3	18
TTL_53: Postal and courier activities****	1,91	0,03	393,2	121,5	21
TTL_55T56: Accommodation and food service activities****	1,88	0,05	282,2	87,2	28
TTL_58T60: Publishing, audiovisual and broadcasting activities****	2,07	0,04	250,7	77,5	18
TTL_61: Telecommunications****	2,00	0,06	276,0	85,3	12
TTL_62T63: IT and other information services****	1,17	0,01	67,2	20,8	15
TTL_64T66: Financial and insurance activities****	1,60	0,03	147,2	45,5	10
TTL_68: Real estate activities****	1,76	0,08	394,7	122,0	9
TTL_69T75: Professional, scientific and technical activities****	1,75	0,03	210,7	65,1	31
TTL_77T82: Administrative and support services****	1,59	0,02	182,7	56,4	54
TTL_84: Public administration and defence; compulsory social security****	1,65	0,05	305,6	94,4	11
TTL_85: Education****	1,24	0,03	152,5	47,1	19
TTL_86T88: Human health and social work activities****	1,86	0,06	286,6	88,6	27
TTL_90T93: Arts, entertainment and recreation****	1,77	0,05	237,0	73,2	16
TTL_94T96: Other service activities****	1,97	0,04	304,7	94,2	25

The findings shown in Table 3 are evaluated and discussed below within the framework of the column headings. These evaluations are made within TURKSTAT's sector consolidation [86].

4.1. Production Multiplier

When the production multiplier in Türkiye is evaluated in terms of each sector, "Electricity, gas, steam, and air conditioning supply," which is the basic input of all sectors, comes first. When the sectors are examined collectively, among all sectors, the share of the manufacturing industry, which is the leader in exports in Türkiye, is approximately 50%, the share of the service sector is approximately 33%, the portion of the land-air-water transportation sectors is approximately 6%, the share of the agricultural sector is approximately 4%, the share of the energy sector is approximately 4%, the share of the sector is approximately 4% and the share of the construction sector is approximately 3% (Table 3 - Column 1).

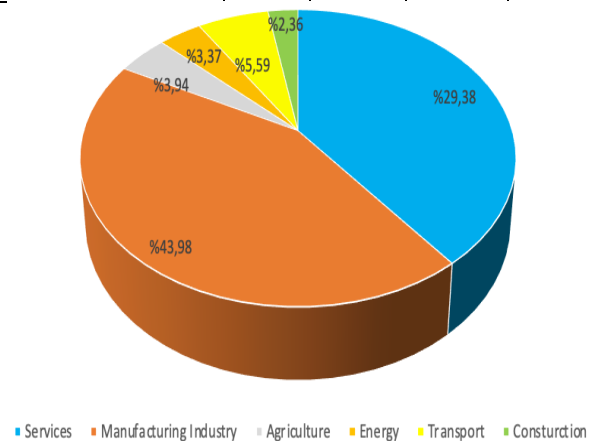


Fig. 3. Production multipliers of sectors (Prepared by the author using OECD [85] data.

The partial backward linkage impact of the energy sector needs to be examined to determine how much energy the sectors use. Furthermore, given that the production multiplier of the manufacturing industry sector has the highest share among all sectors, the dependence of this sector on energy is around 58% due to its production structure. The share of energy in the production multiplier coefficients of the service sector is approximately 43%. The portion of energy used by the transportation, agriculture, and construction sectors is .3%, 2.5%, and 2%, respectively. The energy sector's share of input from its own sector is 69% (Table 3 - Column 2). As can be seen from the findings, there is no linear relationship between the production multiplier of the sectors and the energy they use. Energy use is shaped depending on how much energy the relevant sector needs in production.

4.2. CO₂ Emission Multiplier

When the CO₂ emission multiplier in Türkiye is examined one by one in terms of sectors, "Electricity, gas, steam, and air conditioning supply" comes first, as in the production multiplier. Then comes the "air transport" sector due to the high CO₂ content of the fuel used in aircraft.

When CO₂ emission multipliers are examined as an aggregation of sectors (Table 3- Column 3), the highest share among all sectors belongs to the manufacturing industry sector. Then comes the service sector, which relies less on energy due to its production structure. The "Electricity, gas, steam, and air conditioning supply" sector, which ranks first when the sectors are evaluated one by one, ranks third as the sectors are aggregated. The transportation sector, including the "air transport" sector, is in fourth place, agriculture is in fifth place, and the construction sector is in last place.

The energy sector, which constitutes an important input for all sectors, is unsustainable because it causes CO₂ emissions in other sectors besides its CO₂ emissions. Therefore, urgent measures must be taken to diminish CO₂ emissions from the sector. For this reason, the conversion to 69,1% renewable energy by 2053, considered in the second scenario in the study, is of great importance. Figure 4 shows how much this transformation will reduce existing CO₂ emissions, (Before COP29, After COP29) (Table 3-Column4).

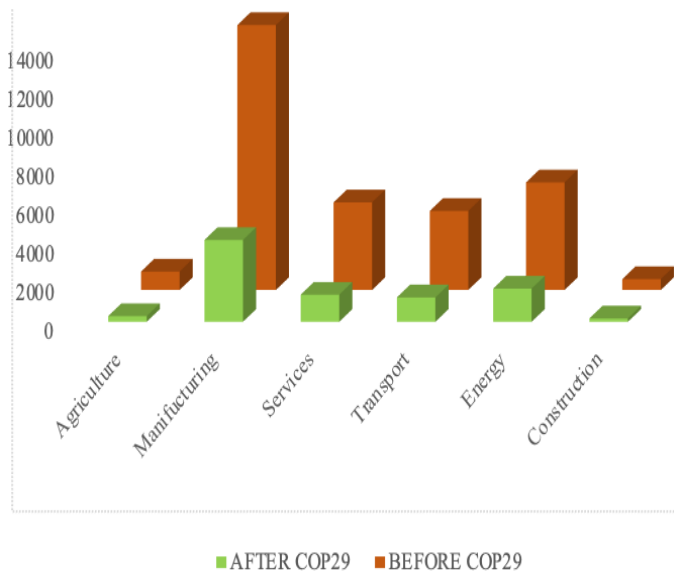


Fig. 4. CO₂ emission multipliers (Before COP29-After COP29).

Figure 4 shows that a demand of \$1 million for each sector reduces CO₂ emissions from fossil fuel production from 29323 (MtCO₂) to 9060,9 tons (MtCO₂) with renewable energy production.

4.3. Employment Multiplier

Within the production framework with existing energy resources, 828 new employment opportunities will arise in the economy due to a separate 1million dollar final demand for all sectors. While the highest employment occurs in the

service sector, it is followed by the manufacturing industry sectors. Afterward, employment increases are expected in the transportation, construction, agriculture, and energy sectors. The employment situation under the second scenario is shown in Figure 5.

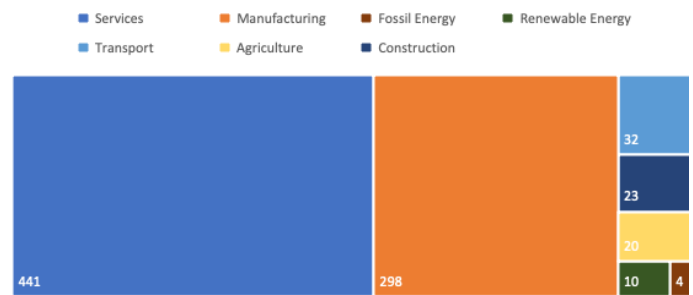


Fig. 5. Employment multipliers of the sectors and turning from brown to green in the energy sector employment.

Figure 5 shows that a \$1 million demand for the "energy" sector, which mainly uses fossil fuels, will generate approximately 14 additional jobs. Then, 69,1% of energy production's transition to renewable energy production itself will create employment for 10 people. While the green transformation affects employment only in the energy sector, it positively affects all other sectors by reducing CO₂ emissions.

As shown in the fifth column of Table 3, the service sector accounts for more than half of the total employment generated by all sectors but only one-fourth of the CO₂ emissions. In addition, the manufacturing industry, the leader in Türkiye's exports, accounts for around 40% of CO₂ emissions from all sectors. Considering that exports from manufacturing industry products are increasing daily in Türkiye, this will increase employment in the manufacturing industry sector and result in more CO₂ emissions (Table 3-Column 3). While all sectors continue to produce, converting to green energy is essential to ensuring the sustainability of the environment.

5. Conclusion

Since Türkiye's renewable energy potential is higher than many countries, it is in an advantageous position in terms of renewable energy production. In Türkiye, which has a young and educated population and workforce, the importance of renewable energy in creating new employment opportunities and reducing environmental pollution is increasing daily. In addition, Türkiye is a country dependent on energy imports. With renewable energy, Türkiye's energy needs can be provided through domestic production, and it also has the potential to become an exporting country. Therefore, energy supply security will be ensured. Considering these reasons, Türkiye's economic expectations from the advantages of green energy production are pretty high.

Besides, the study is motivated by policy actions, initiatives, and guidelines for COP conferences, especially the revised targets and pathways emphasized in the COP29 summit. Türkiye seems to be one of the most ambitious COP

members to achieve the targets of COP by enacting policies and joint actions in public-private partnerships; scientific evidence performs a vital function within this scope to attain environmental sustainability with robust economic performance. Therefore, the evidence obtained from the input-output analysis is pivotal. This study evaluated the employment and CO₂ emission multipliers caused by economic growth if there is a demand of \$1 million in each sector of the Turkish economy while transitioning to renewable energy. For this reason, extended input-output analysis with employment data and environmentally extended input-output analysis were used. Considering 44 eligible sectors, the aggregate demand of \$44 million for the Turkish economy will generate an employment multiplier of 828 people and a CO₂ multiplier of 29323 (MtCO₂) tons of CO₂ emissions.

As long as non-renewable energy is used in the "energy" sector, which meets the energy needs of all sectors, CO₂ emissions will increase. Green energy sources will provide a solution to this problem.

One of the most frequently asked questions is to what extent renewable energy production affects employment and CO₂ emissions. This question was answered by building on the first scenario and considering another scenario whereby Türkiye transitions toward a higher proportion of green energy in the energy sector by 2053. The results showed that 10 out of 14 people in the energy sector will work in renewable energy production, while CO₂ emissions will decrease to 9060,9 (MtCO₂) overall, particularly in the "energy" sector. Specifically, while using renewable energy affects employment only in the electricity, gas, steam, and air-conditioning supply sectors, it benefits all sectors by reducing CO₂ emissions.

When recent studies in the literature are examined, Tourkolias and Mirasgedis [77], Markaki et al. [19], Markaki and Papadakis [91], García Vaquero et al. [16], Gupta et al. [18], Caiafa et al. [14] calculate renewable energy employment. Li et al. [78], Liu et al. [79], Zhou et al. [56], Wimmer et al. [80], and Wen et al. [81] calculate how much renewable energy use will reduce CO₂ emissions. Studies that perform both calculations belong to Kolsuz and Yeldan [82], Hienuki [75], Bai et al. [83] and Dell'Anna [84]. However, in these studies, the effect of the renewable energy transformation adopted at the COP29 on green employment and CO₂ emission reduction was not investigated. In this research, it is anticipated that the gap identified in the literature will be filled within the framework of the findings.

As a result, it is important for every country that the production of sectors with high production multipliers, employment multipliers, and export rates continues to increase. However, as long as the energy used for production is fossil-based, CO₂ emissions will continue to be high, and the sustainable environment goal will not be achieved. Therefore, renewable energy conversion is requisite. As the findings show in the study, green energy ensures the continuity of the production multiplier and, on the other hand, creates green-collar employment opportunities and brings us step by step closer to achieving a green environment.

The results of this research supply reliable insights for policymakers and serve as a guide for developing countries that wish to undertake environmentally friendly and employment-enhancing green development. Future studies might consider designing projects to derive coefficients showing the relationship between the renewable energy sector and other sectors and add the renewable energy sector to the current input-output table. Thus, more comprehensive macroeconomic calculations can be performed without scenarios, such as green energy employment, income, renewable energy production, and renewable energy-based imported input multipliers. Overall, this study's method permits the evaluation of the impacts of a change in energy policies on cleaner production, employment, and the environment by using the input-output table of any country.

Within the framework of the findings obtained in the study, the following policies can be recommended:

- Customs reduction in the supply of intermediate goods to be used for renewable energy production,
- The state's commitment to purchase from the private sector that installs renewable energy within a period to be determined in return,
- Providing pieces of training for the use of green energy, primarily for those working in brown energy production and ensuring that they work primarily in green jobs
- Setting standards for renewable energy in investments for all sectors
- Providing accessible credit facilities, tax reductions/refunds/exemptions, and subsidies for entrepreneurs investing in renewable energy,
- Within the scope of the Carbon Border Adjustment Mechanism (CBAM), CO₂ emission measurement reports, which should be prepared quarterly in Türkiye as of October 2023, should be prepared more frequently, and the current situation should be checked more frequently.
- Government support for R&D efforts to create technologies to reduce the cost of green energy production,
- State institutions should organize these activities, provide training in schools, and provide information about the significance of using renewable energy through the media.
- The quality and security of electricity supply from renewable energy sources are still insufficient to meet today's needs. For this reason, it is necessary to establish and expand a smart grids system that can overcome problems that may arise in areas such as charging stations for electric vehicles, integration of renewable energy sources into the grid, and consumers' ability to generate their own electricity.
- Research and development studies and financial incentives should be provided to conduct cost-benefit analyses of the systems required for installing and using smart grids in residential facilities and to take advantage of these systems as needed.

➤ Existing diesel-fueled power grids should be integrated with renewable energy sources, and the power system should be made smarter to increase power generation efficiency.

➤ Smart meters should be widely deployed, and smart grid management should be introduced to eliminate power losses and distribution leakage.

➤ Smart transition scenarios for Türkiye should be defined, and strategies and roadmaps related to these scenarios should be developed.

With the renewable energy transition, some of those working in fossil energy production will be able to work in renewable energy production. Thus, the goal of decent work in the eighth sustainable development goal will be partially achieved. However, renewable energy transformation will not only lead to a transformation in the employment of the energy sector, but since the CO₂ emissions of the products produced in Türkiye will be low, the EU countries implementing CBAM will demand more exports from Türkiye. As exports increase, production will increase and thus employment will increase. Within the framework of the CBAM application to EU countries, countries using fossil energy have to pay carbon tax when exporting to EU countries. For Türkiye, 1 October 2023-31 December 2025 is the transition period, but the application will start as of 2026, so Türkiye's transition to renewable energy will prevent the carbon tax payment. Thus, new investments can be made through the funds to be gained, and employment will increase in this respect.

However, the study has some limitations, especially in terms of data availability, regarding the input-output analysis. Since the preparation of input-output tables by countries' statistical offices takes a long time, it is impossible to be up-to-date. For this reason, determining the current situation by using newly published data in future studies will enable the preparation of new road maps in terms of sustainable development.

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