January 2025

Integrated Policy Strategies and Regional Policy Coordination for Resilient, Green and Transformative Development: Supporting Selected Asian BRI Partner Countries to Achieve 2030 Sustainable Development Agenda

Project Paper No. 13

Kübra Atik Gözkün
Sabancı University
Istanbul, Türkiye
kubra.atik@sabanciuniv.edu

Özgür Orhangazi
Kadir Has University
Istanbul, Türkiye
ozgur.orhangazi@khas.edu.tr

Solar and wind power transition in Türkiye:

An input-output analysis of growth, employment, and current account effects

Abstract

Türkiye ratified the Paris Agreement in 2021 and declared its intention to achieve the "net zero" target by 2053. The government announced a target of an increase of 1 gigawatt in solar photovoltaic and wind onshore energy sources in the Green Reconciliation Action Plan. The Ministry of Energy and Natural Resources Strategy Plan for 2019- 2023 set wind and solar power investment targets.

Using targets declared by the government and country-specific parameters we identify through extensive research into government and private sector reports and analyses, we carry out an input-output analysis to estimate the potential consequences of alternative green transition investment programs in solar and wind power on emissions, economic growth, employment, and current account balance.

Contents

KEYWORDS: Green Transition, Renewable Energy, Green Investment, Türkiye

Acknowledgements

This paper has been prepared under the UNCTAD project "Integrated Policy Strategies and Regional Policy Coordination for Resilient, Green and Transformative Development: Supporting Selected Asian BRI Partner Countries to Achieve 2030 Sustainable Development Agenda", funded by the 2030 Agenda for Sustainable Development Sub-Fund of UN Peace and Development Trust Fund of DESA. The authors would like to thank UNCTAD staff for comments on earlier drafts. This paper represents the personal views of the authors only. The authors accept sole responsibility for any errors

Executive summary

In 2021, Türkiye ratified the Paris Agreement and declared its intention to achieve the "net zero" target by 2053. The government declared its intention to achieve an increase of 1 gigawatt (GW) in solar Photovoltaics (PV) and wind onshore energy sources in the Green Reconciliation Action Plan and the Ministry of Energy and Natural Resources Strategy Plan for 2019- 2023.

Most studies on green transition in Türkiye focused on the impact of adopting an environmental tax or the impact of coal subsidies. Studies focusing on employment effects overlooked the adverse employment effects from the contraction in coal mining and reported gross employment effects.

In this study, we estimate the potential benefits of adopting a green transition investment program in solar and wind power using the official targets declared by the government and country-specific parameters we identify through extensive research into government and private sector reports and analyses. We compare two alternative green transition investment scenarios with a "business as usual" scenario in which we extrapolate the current trends in energy production into the future. While we calculate the potential decline in emissions, our primary focus is on the macroeconomic consequences of such an investment program. We use input-output analysis to analyze the growth, employment, and current account balance consequences of different solar and wind investment scenarios from 2024 to 2040.

Under the "business as usual" scenario, domestic and imported coal use in power production grows annually at the rate of the last five years. Hence, new power plants are also built. In scenario 1, the electricity demand projections are based on the reference-demand scenario of production capacity projection published by the Ministry of Environmental and Natural Resources. Scenario 2 assumes a greener growth in electricity production. It takes 2028 official targets according to the government's 12th Development Plan (to reach 18 and 30 GW installed capacity for wind and solar energy) and the 2035 official targets (29,6 and 52.9 GW installed capacity by 2035) according to 2022 National Energy Plan of the Ministry of Energy and Natural Resources. We extend these official targets into 2040, assuming the installed capacity increase will remain unchanged after 2035. In our scenario, we make sure these targets are met by 2028 and 2035 respectively. As a result of this transition, both domestic and imported coal use falls, other renewables increase, and other fossil fuels decrease with their last five year's growth rate.

According to our "business as usual scenario," total foregone CO_2 emissions are calculated as 480.8 million tons of CO_2 eq. In contrast, the green development scenario decreases 824.8 million tons of CO_2 eq GHG from the atmosphere.

We estimate the net production and net value-added effects under all scenarios. The business-as-usual scenario increases production volume by 145.4 billion USD and value-added by 45 billion USD in 15 years. Our aggressive investment scenario generates a 123.4 billion USD increase in production volume and a 38 billion USD increase in value-added over 15 years. Our conservative investment scenario generates a 109.5 billion USD increase in production and a 33 billion increase in value added.

Given these, our findings indicate that a green transition under Scenarios 2.1 and 2.2 result in a net 17,417 to 94,424 less jobs, respectively, compared to the business-as-usual scenario due to the reduction in coal power plants under the green development scenarios. This corresponds to less than 0.02% of total employment in 2022.

The analysis forecasts a total decline of 197 million tons in imported coal (hard coke) under the green development scenarios. On the other hand, business-as-usual scenario implies a total increase of 156 million tons in imported coal. According to these figures, the net impact of the reduction in coal imports compared to the business-as-usual scenario on the current account balance is approximately 52.9 billion USD. On an annual basis, this corresponds to an improvement equivalent to 7.8% of the annual total current account deficit as of 2023.

Our findings show that all green investment scenarios would decrease greenhouse gas emissions and contribute to increased output and value-added, a modest amount of net new job generation, and when imported coal use in electricity production is decreased, a significant improvement in the current account balance. Therefore, in terms of macroeconomic consequences, there is no obstacle to an aggressive green energy investment program for policymakers.

Introduction

Türkiye exhibits complex climatic conditions, with a Mediterranean climate in the western and southern coastal areas and very hot southeastern regions in the summer, with varying temperatures according to the proximity to the sea. The adverse impacts of climate change on Türkiye mainly consist of more frequent heat waves, drought, soil loss, unproductive crop yields, extreme storms, and frequent floodings (Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC), 2021). The impact on coastal regions is expected to be exacerbated by rising sea levels, increasing waves, and storms changing direction. Moreover, the central and southeastern parts of Türkiye, where agriculture is the main economic activity, are subject to extreme draught risk due to higher evaporation and changed rainfall patterns. Türkiye is also expected to have water supply problems soon (Hockenos, 2021; World Bank, 2022). The draught, increased temperatures, and decreased rainfall will lead to soil degradation and a consequent reduction in crop yields, especially in the west, south, and southeast (CMCC, 2021). The increased temperatures and draught also bring frequent forest fires, contributing to increased emission levels.

These climatic conditions are also expected to impact the energy industry. The main concerns center around the decrease in hydropower output due to drought and increased energy consumption due to increased cooling demand (CMCC, 2021). Unfortunately, quantitative research focusing on the impact of climate change on the energy industry or mitigation practices is still lacking.

As of 2021, Türkiye's per capita emissions of carbon dioxide (CO2) and other greenhouse gasses (CO2 eq.) stood at 6.4 tonnes, while its total CO2 (eq.) emissions per $GDP (in constant USD) reached 0.530 kg. Although these figures are relatively low compared with the OECD average, their growth rate is relatively high. Türkiye's GHG emissions increased from 214 million tonnes (CO2-eq) in 1990 to 564.4 million tonnes in 2021, recording a cumulative increase of 156 percent. (Turkish Statistical Institute (Turkstat), 2023). Climate Equity Reference Project (CERP)[1] estimates that Türkiye's total CO2 (eq.) emissions will reach 680 million tons by 2030 if Türkiye's commitment to lowering its emissions remains low.

In 2021, Türkiye ratified the Paris Agreement and declared its intention to achieve the "net zero" target by 2053. The government declared a target of achieving an increase of 1 gigawatt (GW) in solar Photovoltaics (PV) and wind onshore energy sources in the Green Reconciliation Action Plan (Republic of Türkiye, 2021b) and the Strategy Plan of the Ministry of Energy and Natural Resources for 2019- 2023 (Republic of Türkiye 2019).

In this study, we estimate the potential benefits of adopting a green transition investment program in solar and wind power using the official targets as declared by the government and country-specific parameters we identify through extensive research into government and private sector reports and analyses. We compare two alternative green transition investment scenarios with a "business as usual" scenario in which the current trends in energy production are extrapolated into the future. While we calculate the potential decline in emissions, our primary focus is on the macroeconomic consequences of such an investment program. We use input-output analysis to analyze the growth,

[1] Climate Equity Reference Project, Calculator: https://calculator.climateequityreference.org

employment, and current account balance consequences of different solar and wind investment scenarios from 2024 to 2040.

Our analyses show that under the “business as usual” scenario, Türkiye’s emissions will decrease by 480.8 million tons of GHG. In contrast, under the scenarios of a green investment program, Türkiye’s emissions will decrease by 824.8 million tons of GHG. The difference is equal to %61 of 2021 total GHGs. Total employment generated in the green scenario is only 84,507 jobs less than the business-as-usual scenario, %0.02 of 2022 employment figures. The net impact of the green development path on the current account balance is 3.5 billion USD annually compared to the business-as-usual scenario, which is 7.8% of the 2023 current account balance of Türkiye. The improvements in the current account balance in the green development scenario are due to Türkiye continuing to import coal for electricity production in the business-as-usual scenario. The total output impact is 1.5 billion USD lower in the green development scenario, which is much lower than the annual improvement in the current account balance.

Most studies on green transition in Türkiye focused on the impact of adopting an environmental tax (Bouzaher, Şahin, and Yeldan 2015) or the effects of coal subsidies (Acar and Yeldan 2016). Studies focusing on employment effects overlooked the adverse employment effects from the contraction in coal mining and reported gross employment effects (Çetin and Eğrican 2011, Yılmaz 2014, ILO & UNDP 2022). More recently, Acar *et al.* (2023) employed a computable general equilibrium framework to analyze some of the employment and growth effects of a green transition. As such, our study contributes to these analyses.

Before going into the details of our analyses, we provide a brief overview of Türkiye’s latest energy outlook and its green transition targets in Section 1, and potential obstacles in front of green transition in Section 2. Then, in Section 3, we discuss both earlier works on green transition in the context of Türkiye and the works that undertake similar analyses for other countries. We present our methodology and data in Section 4 and our findings under different scenarios in Section 5. Finally, we conclude in Section 6 by discussing the implications of these findings, their limitations, and further research needs.

1. Overview of Türkiye’s energy outlook and green transition targets

While Türkiye has strong solar and wind power potential, coal-based power stations still occupy a large share of its electricity production. In 2023, wind and solar energy contributed significantly to Türkiye’s electricity production, generating 52.7 TWh, which accounted for 16.3% (solar PV: 5.8% and wind onshore: 10.5%) of the total electricity produced. Domestic coal energy accounted for %14.2 of total electricity produced, with 45.8 TWh, and imported coal accounted for %22.4, with 72.1 TWh (TETC, 2023b). Hydro energy resources account for %19.4, natural gas accounts for %20.9, and biomass and waste account for 6.1% of the total electricity production in Turkey as of 2023.

Electricity in Türkiye is supplied primarily by private production companies (%80.40), with %14.5 of the ownership belonging to the government under Electricity Generation Co., EÜAŞ, including plants with transferred operating rights (%1.3) (TETC, 2023b). Most of the company's holdings come from hydro, coal, and natural gas sources. Yet, there are two wind onshore power plants that started operating in 2024 with 17 MW total installed capacity (<%1) and none in solar energy plants (EÜAŞ, 2023).

In Türkiye, electricity generation power plants based on renewable energy sources that want to operate in the market and whose installed power exceeds 5 MW must obtain a production license from the Energy Market Regulatory Authority (EMRA) under the electricity market Law No. 6446. However, individuals and legal entities can engage in electricity production without a license or establishing a company under Unlicensed Electricity Production Regulation in the Electricity Market which helps promote and distribute electricity production (PwC, 2024). Moreover, the market is supported by YEKDEM, Renewable Energy Support Mechanism. YEKDEM has been designed to promote the development and use of renewable energy sources. YEKDEM provides financial incentives and guarantees for renewable energy producers, feed-in tariffs, and other supportive measures to encourage investment in renewable energy projects such as wind, solar, hydro, and biomass. In Türkiye, 62% of the total capacity in wind energy and %92.2 of the total capacity in solar energy is operated by procurement firms that benefit from the Renewable Energy Support Mechanism (YEKDEM). All wind energy procurement firms under YEKDEM are licensed producers, whereas most of the producers are unlicensed in solar energy (%88.5) (Energy Markets Operation Co. (EPİAŞ) - Transparency Platform, 2024).

1.1 Wind Potential

The Wind Energy Potential Atlas of Türkiye (REPA-V1) was prepared by the Ministry of Energy and Natural Resources in 2006 by using a medium-scale numerical weather prediction model and a micro-scale wind flow model. According to the REPA-V1 data, the total capacity of wind power plants that could be established in Türkiye was calculated to be 47,849.44 MW with an annual average wind speed of over 7.5 m/s (MENR, 2024a). However, the Wind Energy Potential Atlas of Türkiye has been updated recently with European Union funding and support from the European Bank for Reconstruction and Development. Recent reports from the ministry show that wind potential is approximately 100,000 MW under current technology and conditions, which can be increased to levels of up to 150,000 MW (MENR, 2024b). Figure 1 shows the annual average wind speed (m/s), and Figure 2 shows the average wind speed density in Türkiye.

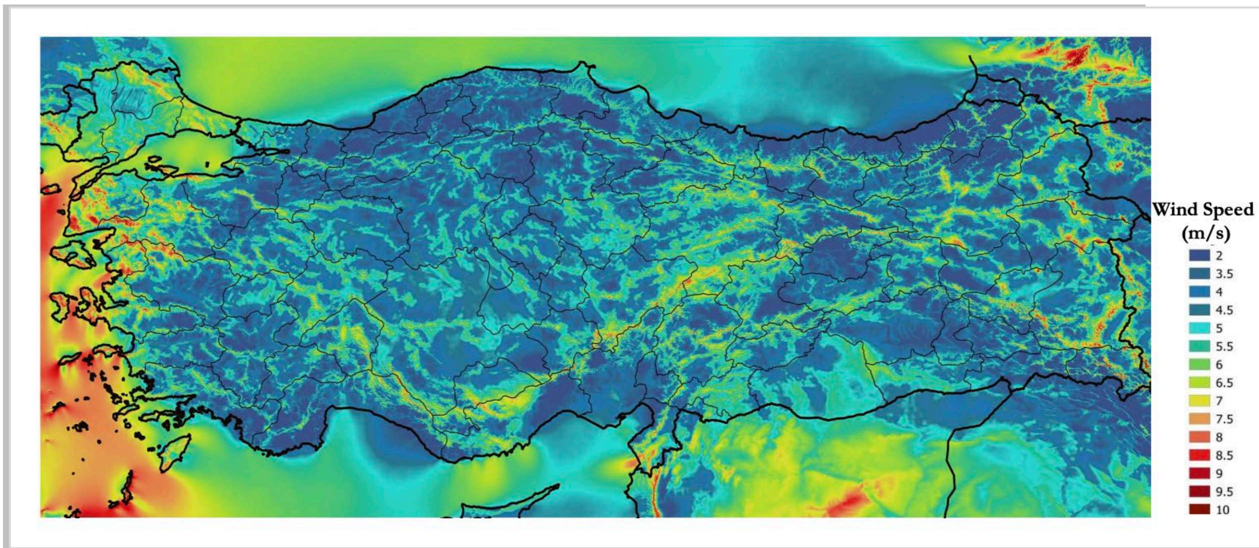

***Figure 1** Annual average wind speed (m/s) in Türkiye*

Source: Republic of Türkiye, Ministry of Energy and Natural Resources, Türkiye's Wind Power Potential, https://repa.enerji.gov.tr/REPA/, last accessed 15 July 2024.

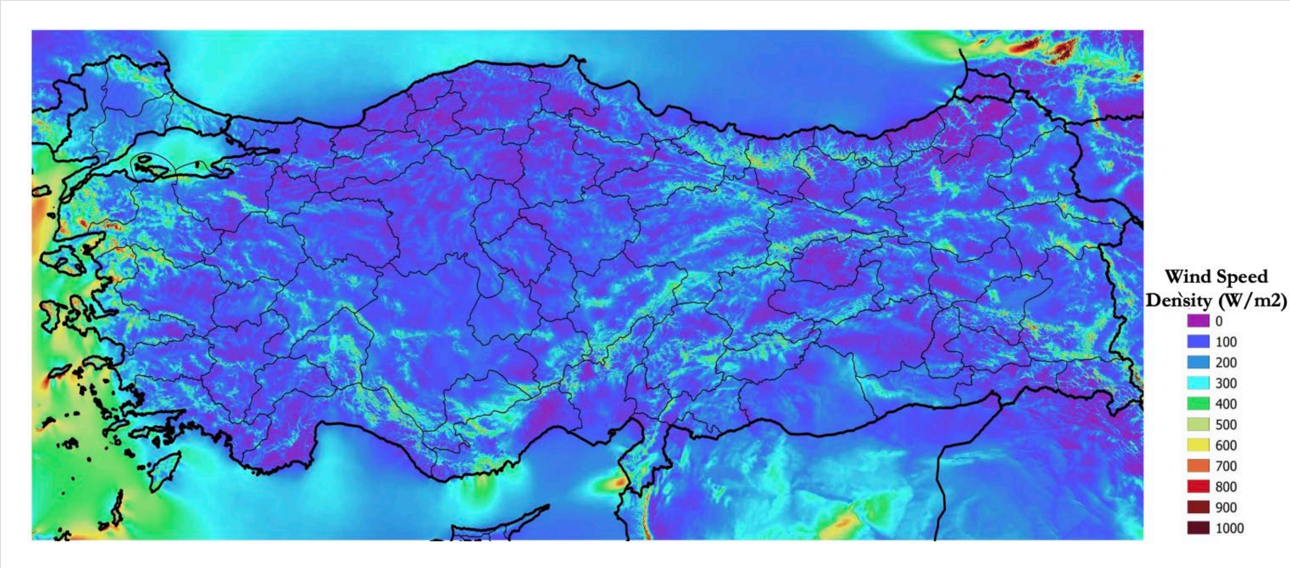

***Figure 2** Average wind speed density (W/m2) in Türkiye*

Source: Republic of Türkiye, Ministry of Energy and Natural Resources, Türkiye's Wind Power Potential, https://repa.enerji.gov.tr/REPA/, last accessed 15 July 2024.

1.2 Wind Energy Outlook

In the wind energy sector, the Marmara region takes the lead in wind energy production, having 44% of total production capacity, and the Aegean Region follows Marmara with %36.5. Izmir, Balıkesir, and Çanakkale are the leading cities in exporting the required manufacturing equipment and production capacity. Today, with 1,907 MW wind power plants installed, İzmir hosts the country's first wind measurement mast, wind turbine, and wind power plant. It also houses the first blade and tower factory, turbine maintenance and repair facilities, and an R&D center, contributing to a 1,907 MW installed capacity, creating 7,500 jobs and accounting for 85% of total wind exports (TUREB, 2022). According to the Ministry of Industry and Technology (2023), there are 25,000 jobs in wind industry equipment manufacturing. The top investors in Türkiye's wind energy sector include Polat Energy with 711.4 MW (6.11%), Borusan Energy with 5.63%, Güriş with 5.49%, Demirer Energy with 5% and Fiba Renewable Energy with 4.75% (Turkish Wind Energy Association (TUREB), 2022).

Wind turbines are critical to the renewable energy landscape, converting kinetic energy from wind into electrical energy. These intricate systems are composed of various parts, including the foundation, tower, rotor, hub, nacelle, and generator, each contributing to the overall efficiency and reliability of the turbines. In Türkiye, although the development and production of wind turbine equipment have gained considerable momentum, reflecting the country's strategic emphasis on renewable energy, the equipment used in utility-scale wind onshore power plants has generally been imported. The utility-scale power plants typically require larger rotor blades to capture more wind energy.

Most of the equipment used in large-scale onshore wind power plants in Türkiye is imported, with major suppliers including Siemens (%11.79), GE (%20.11), Nordex (%29.31), Vestas (%17.58), Enercon (%19.18) (TUREB, 2023). The only wind power plants with a utility-scale production capacity owned by EÜAŞ are launched in 2024 and they are equipped with around %65 domestic input use. Alaçatı wind power plant is equipped with the first locally produced wind turbines (produced by Aselsan) with a tower height of 100 meters and a rotor diameter of 136 meters. The power plant is also equipped with power converters and generators produced by Aselsan. The turbines produced by Aselsan show that the development of local wind turbine production is seen as a strategic priority. The Alaçatı RES project and several other initiatives aim to enhance local production capabilities, addressing supply challenges and increasing domestic content requirements to at least 65% (Aselsan, 2024).

Türkiye's wind energy sector has demonstrated significant export potential for smaller wind turbines, with wind energy equipment exports reaching $1.5 billion in 2023 (Ministry of Industry and Technology, 2023). According to the Turkstat data on harmonized systems, only wind turbines and related equipment exports increased to 297.2 million USD by 2023 from 0.6 million USD in 2014 (Turkstat, 2024). The top countries that Türkiye exports to are Denmark (%36 of the wind equipment exports in 2023), Finland (%24), and Germany (%15). Although imports show fluctuations throughout the years, the total amount of imports for the same equipment is around 403 million USD by 2023. The top countries Turkey imports from are Germany with %65, China with 17%, and Spain with %8. Figure 3 illustrates the trend of exports and imports in those industries.

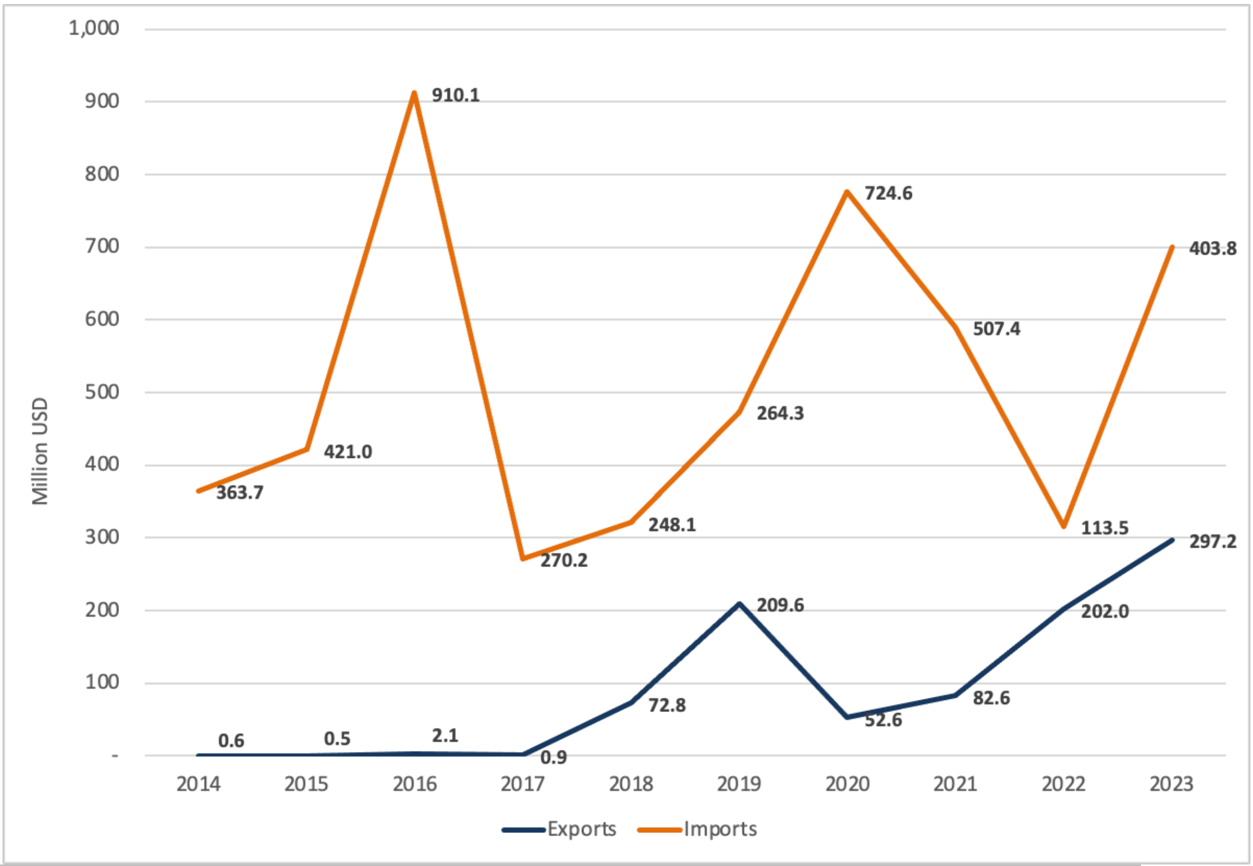

***Figure 3** Exports and Imports on wind turbine engines, generators, and parts, Türkiye*

Source: Republic of Türkiye, Turkish Statistical Institute, Special Trade System Database, Imports and Exports by Chapters and Countries.

Included GTIP Codes are 841280809011- Wind-powered engines and power-generating machines, 841290809012 - Components and parts of wind-powered engines and machines, 850231002100 - Electric power generation (electrogene) units operating with wind output power with output power < 100 kVA; excluding those for civil aircraft., 850231002200 - Electric power generation (electrogene) units operating with wind output power with output power = 100 kVA; excluding those for civil aviation, 850231002300 - Electric power generation (electrogene) units operating with wind output power with output power = 100 kVA; excluding those for civil aircraft

Wind Europe (2023) argues that Türkiye could play a significant role in the wider European wind energy supply chain due to the recent developments in the Turkish manufacturing industry and that Türkiye could reduce Europe’s dependence on China.

1.3 Solar Potential

The Solar Energy Potential Atlas (GEPA) is developed by the Ministry of Energy and Natural Resources to identify and promote the potential for solar energy production in Türkiye. This atlas provides the most suitable solar energy power plant locations using data on solar radiation, temperature, and other meteorological factors. The atlas is an important tool the ministry uses in planning and optimizing solar power plants (MENR, 2024d). Figures 4 and 5 demonstrate the solar radiation map and daily average sunshine duration of Türkiye, respectively. Both figures show that due to its advantageous geographical position, there is substantial capacity for solar energy production in Türkiye. According to the data provided by GEPA, the average annual total sunshine duration is 2,741 hours, and the yearly total radiation value is 1,527.46 kWh/m² (MENR, 2024e).

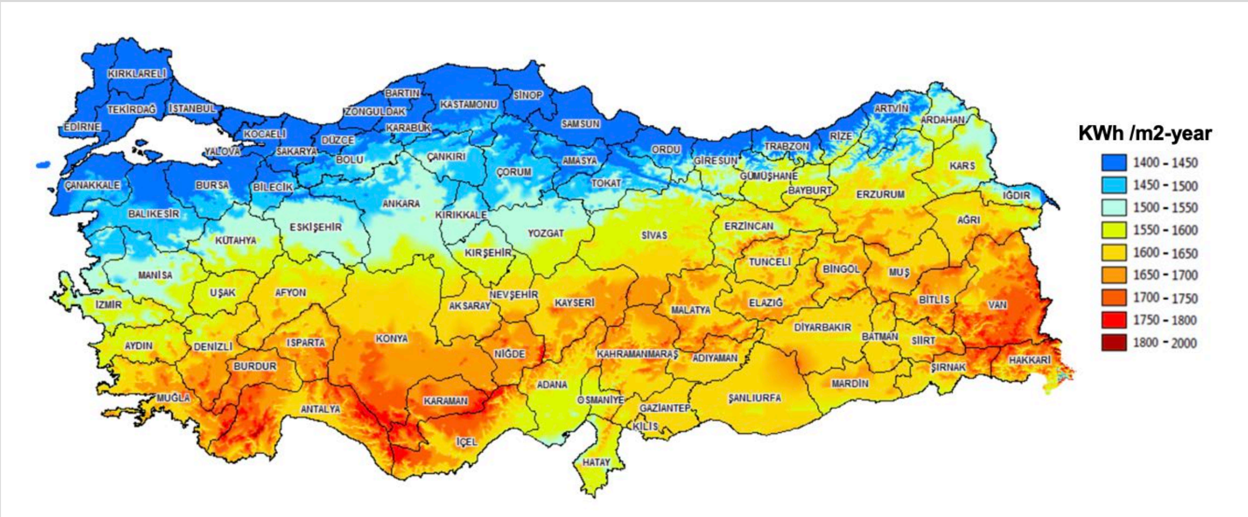

***Figure 4** Total Solar Radiation KWh/m2 in Türkiye*

Source: Republic of Türkiye, Ministry of Energy and Natural Resources, Solar Energy Potential Atlas, https://gepa.enerji.gov.tr/Default.aspx, last accessed 15 July 2024.

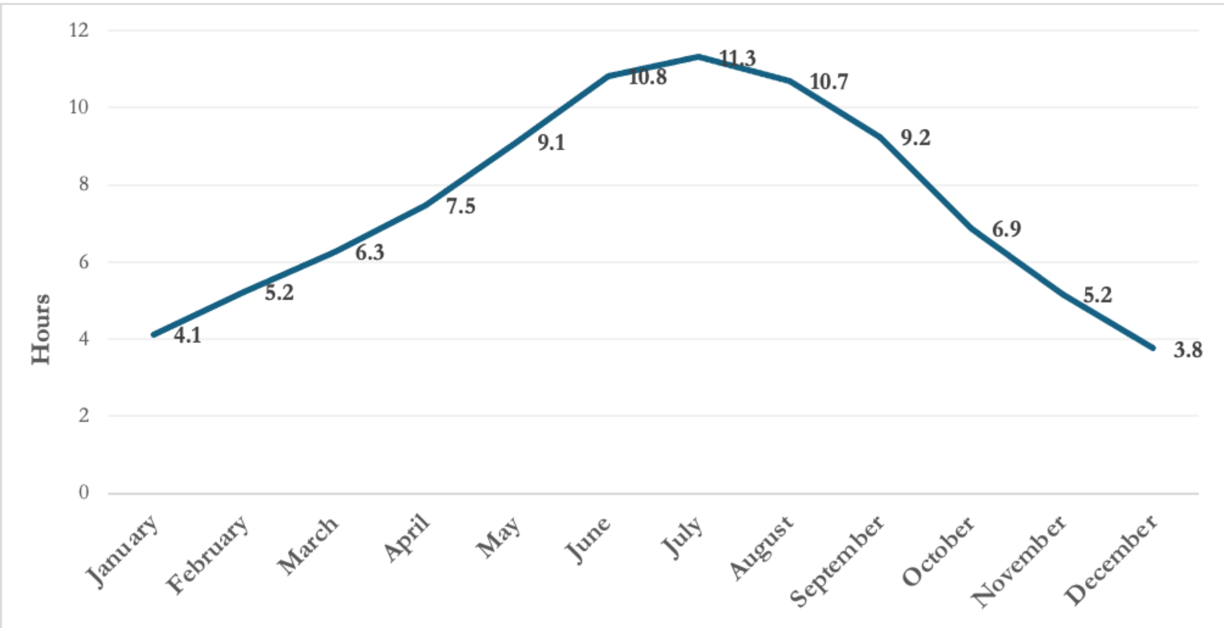

***Figure 5** Daily Average Solar Radiation KWh/m2 in Türkiye*

Source: Republic of Türkiye, Ministry of Energy and Natural Resources, Solar Energy Potential Atlas, https://gepa.enerji.gov.tr/Default.aspx, last accessed 15 July 2024.

1.4 Solar Energy Outlook

The solar PV power installation costs in Türkiye declined around %60 from 2016 to 2022 (IRENA, 2022), making solar energy an attractive option for various applications, particularly unlicensed power plants used for self-consumption. According to TETC electricity production reports, unlicensed solar power plants produce 4.2% of total electricity produced and 40% of total electricity produced by all unlicensed power plants, with 13.9 gigawatt-hours (GWh) of electricity production in 2022. According to recent reports, unlicensed solar power plants contribute between 7.7% and 10% to the country's total installed capacity as of 2022 (TETC, 2022b, PwC, 2024). The potential for upcoming years is expected to be at least 10 GW by industry stakeholders investing in unlicensed solar energy for self-consumption purposes for their businesses (Gifford, 2023).

In October 2023, the transitional period of the Carbon Border Adjustment Mechanism (CBAM), which aims to reduce carbon emissions from EU imports has begun. Under the CBAM electric energy has been classified among the sectors with high carbon emissions (Ministry of Trade, 2023). As a result, many companies with high electricity consumption have opted for unlicensed solar power plants to meet their businesses' electricity needs while negating carbon taxes under the CBAM (PwC, 2024).

The Energy Market Regulatory Authority (EMRA) has stated that by the end of 2023, applications for unlicensed solar power plants have reached 35 GW (PwC, 2024; Ata, 2023). However, the number of manufacturers with a production capacity higher than 1 GW is still only eight. These include by Kalyon PV with 2.0 GW panel production capacity and 1.2 GW cell production capacity, Smart Güneş with 2.9 GW panel production capacity and 2 GW cell production capacity, and Sirius and CM Energy with 3.5 GW panel production capacity (PwC, 2024).

Several factors contribute to the increase in unlicensed solar energy production. First, Türkiye's high solar radiation potential makes solar energy attractive (PwC, 2024). Furthermore, Türkiye has implemented tariffs and anti-dumping measures to limit imports for domestic panel production to boost domestic manufacturing (IRENA, 2023). Some Turkish textile manufacturers faced with declining profit margins also began to switch to solar panel parts production (Gifford, 2023).

There are now many facilities in Türkiye focusing on cell and panel production. Major firms focusing on cell and panel production are Kalyon and Smart Güneş, and battery investments are Pomega and Aspilsan (PwC, 2024). However, Kalyon Energy is the only firm with a fully integrated solar panel production facility. Other than the critical raw material polysilicon, which is generally imported from Chinese firms, Kalyon Energy is the first and only facility in Türkiye and Europe to integrate its upstream and downstream in solar panel production. On the other hand, in 2020, Aspilsan launched the first lithium-ion battery mass production facility in Türkiye and Europe, which is used to store solar energy (PwC, 2024).

Export data for solar PV panels and cells is only available from 2022 in Turkstat. With photovoltaic cells, panels, and panel parts, exports rose to 460 million USD and imports to 1.5 billion USD in 2023, showing a tremendous increase (Turkstat, 2024). The export surge is mainly due to Kalyon Energy (PwC, 2024) starting cell and panel exports to the

USA, constituting 90% of all exports (Turkstat, 2024). The manufacturing sector is now seen as a potential link in the global PV supply chain due to its high trade volume with China and proximity to Europe (Gifford, 2023). Imports were predominantly from China (82%), followed by Malaysia (%7) and Vietnam (%8) (Turkstat, 2024). The rise in imports indicates ample room for increasing domestic production capacity. Figure 6 illustrates the export and import of solar PV panels and parts over the past ten years.

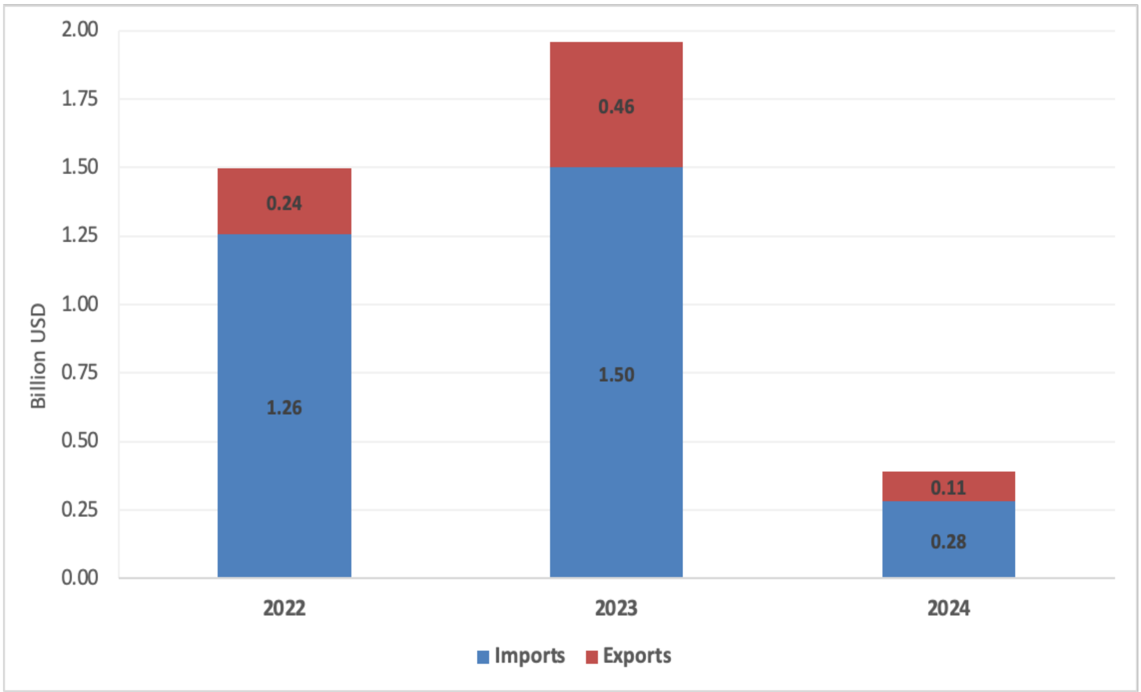

Figure 6 *Exports and Imports on Solar PV cells and panels, and parts, Türkiye*

Source: Republic of Türkiye, Turkish Statistical Institute, Special Trade System Database, Imports and Exports by Chapters and Countries.

Included HS codes are: 854190000011 - Aluminum frames for photovoltaic panels, 854149000019 - Other photosensitive semiconductor devices, 854142000000 - Photovoltaic cells not assembled in modules or made up into panels, 854143000000 - Photovoltaic cells assembled in modules or made up into panels.

According to Alparslan and Azem (2023), 36,925 people are employed in the sector. Solar Power Europe (2024) states that the Turkish solar energy sector employs over 50,000 people. The segment with the highest share among the total number of employees is the security segment, accounting for 32.5%, fixed per plant. The sector requires a high level of technical knowledge and the ability to adapt to new technologies. Approximately 51% of the sector's employment is of medium skill level, 36% of high skill level, and 13% of low skill level (Solar 3GW, 2024). Among the competencies that need to be developed in the solar energy sector in Türkiye are technical expertise and adaptation to innovative technologies. Specifically, integrating battery storage technologies into PV (Photovoltaic) systems will increase the need for detailed technical knowledge and practical skills in design, installation, maintenance, and repair (Solar 3GW, 2024).

1.5 Emissions Outlook

Figure 7 shows the distribution of GHG emissions across sectors. As of 2021, 70 percent of Türkiye's greenhouse gas (GHG) emissions and 85 percent of carbon dioxide (CO2) emissions come from energy production (UNCFCC, 2021). The UNFCCC Emissions Inventory (2023) highlights that, on average, public electricity and heat generation have contributed 36% to Türkiye's GHG emissions, a trend also evident in CO_2 emissions.

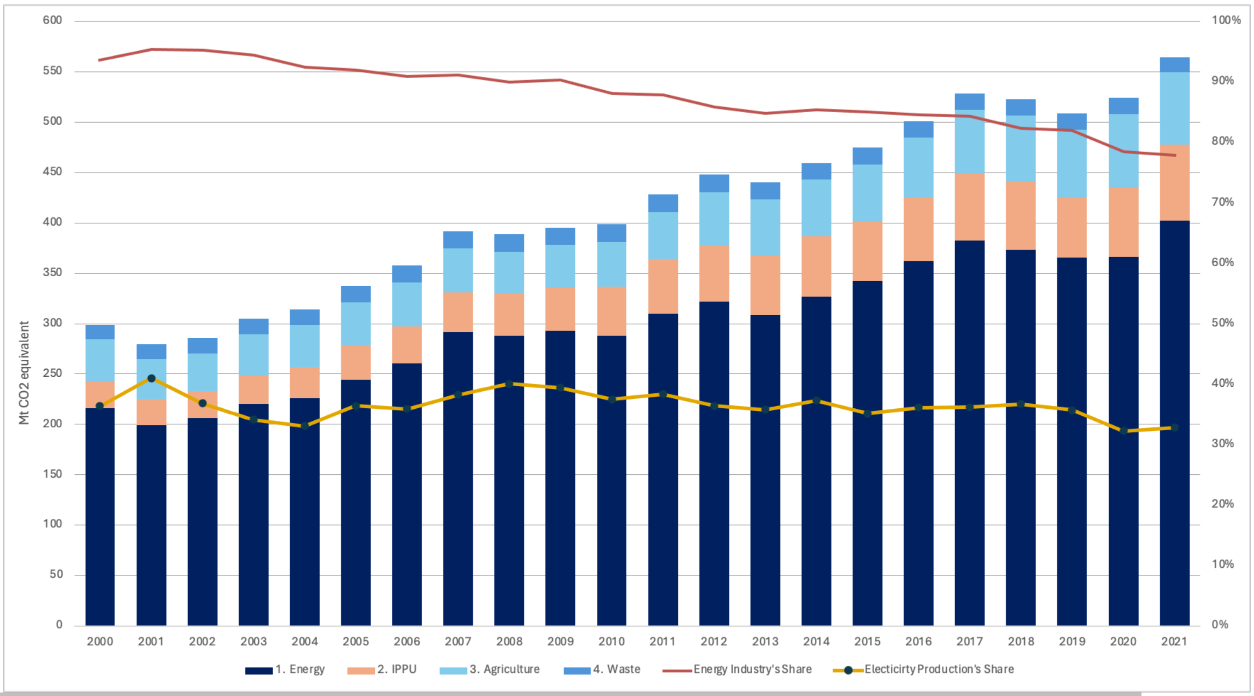

Figure 7 *Aggregate GHG emissions with LULUCF, Türkiye*

Source: United Nations Framework Convention on Climate Change, UNFCCC, https://di.unfccc.int/detailed_data_by_party, last accessed 08 June 2024.
Note: All numbers reported in million tons of CO2 equivalent.

Türkiye's primary energy supply heavily relies on imported energy, particularly coal, oil, and natural gas, as depicted in Figure 8. These imports are always susceptible to global market fluctuations and price changes, which warns us about the potential links between a green transition investment program and the current account balance. As shown in Figure 9, Türkiye's energy import costs often exceed its current account deficit, indicating a significant economic impact from energy imports on the country's financial health.

Transitioning to renewable energy could ease the financial strain from high import costs, improving national energy security, especially during global crises (Yalçın and Yalçın 2021; IMF 2022; Aslantürk 2020). In 2018, Türkiye spent $2.85 billion on coal imports for electricity generation, according to Ember (2021), highlighting the economic benefits of investing in renewable energy sources. Thus, a green investment project could be designed as a strategic energy policy that could reduce dependency on imports and enhance the resilience of its energy economy.

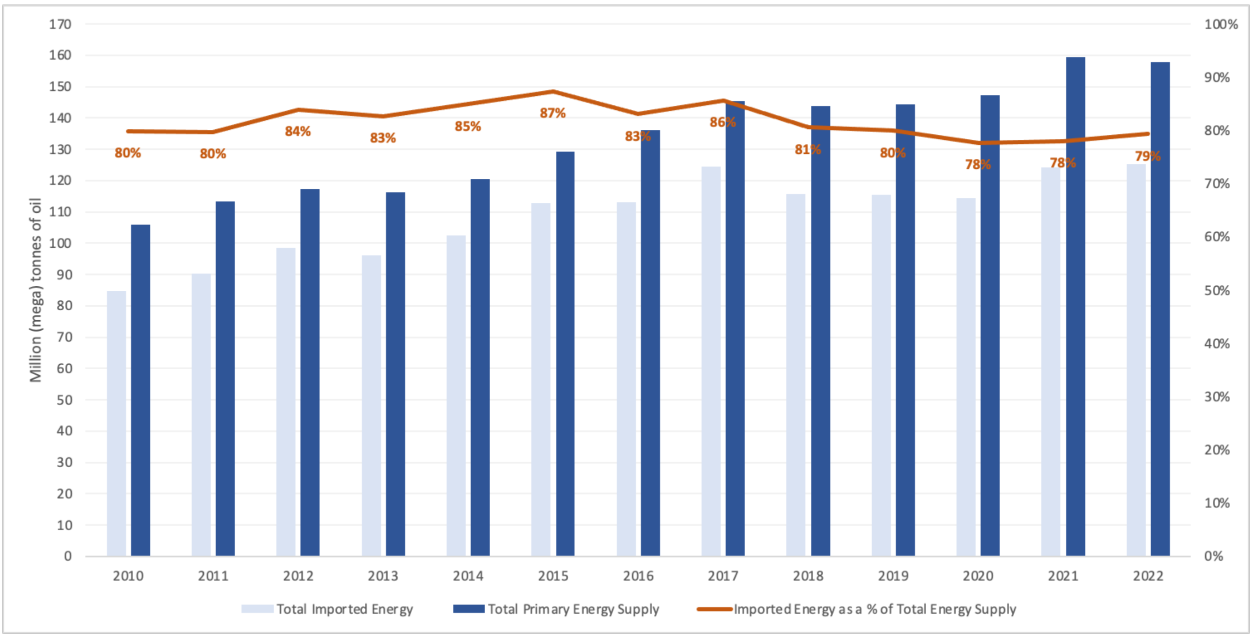

Figure 8 Total primary energy supply and imported energy of Türkiye

Source: Ministry of Energy and Natural Resources, National Energy Balance Sheets

Notes: Imported Energy as a % of Total Energy Supply = (Imported Energy in tonnes of oil eq.)/ (Total Supplied Energy in tonnes of oil eq). Total primary energy supply includes domestic production, net imports, and statistical discrepancy. Total imported energy includes coal, coke, coal tar, crude oil, petroleum products, natural gas, and a negligible amount of electricity (1%).

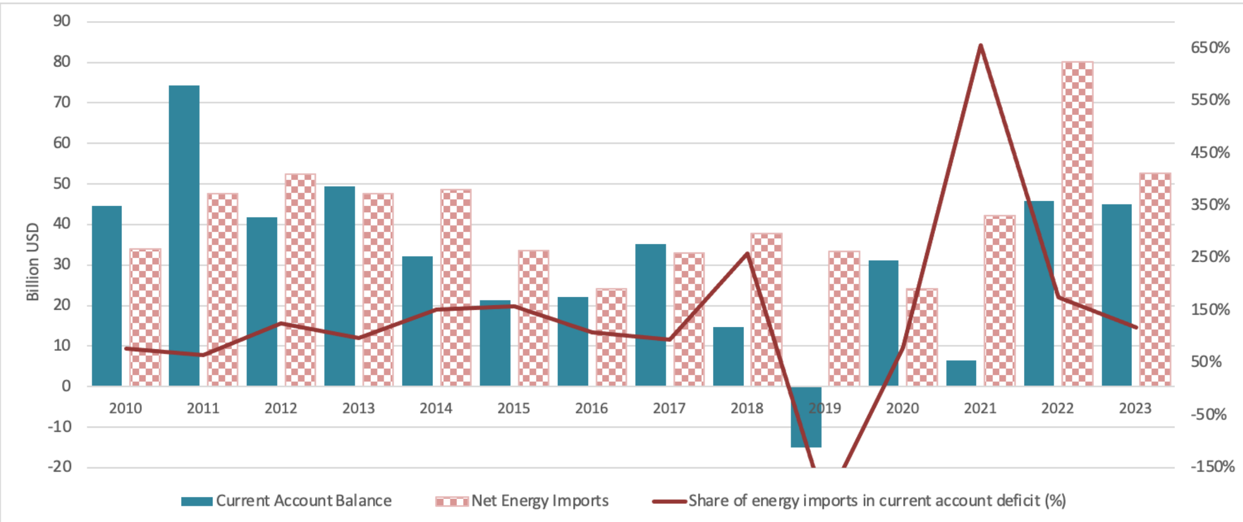

Figure 9 Energy import bill & current account deficit of Türkiye

Source: TCMB, EVDS, Current Account, Non-Monetary Gold, and Energy Foreign Trade (in billion USD)

Finally, Figure 10 presents the projections of the Ministry of Energy and Natural Resources (MENR, 2019) for the annual average electricity demand growth over the next twenty years. With an annual growth rate of 3.7%, electricity demand is expected to reach 415 terawatt-hours (TWh) by 2030 and 650 TWh by 2040 in the business-as-usual scenario. These projections are based on the electricity demand forecasts updated in the production capacity project report by the Turkish Electricity Transmission Company (TETC, 2021). The electricity demand forecasts of TETC have been based on the electricity demand projections of the Ministry of Energy and Natural Resources (MENR). The long-term energy planning and scenarios of low-demand, reference, and high-demand projections are analyzed through the Türkiye Energy Model (EST Energy

System for Türkiye) under the Instrument for Pre-Accession Assistance (IPA) Project, considering the balance between energy supply and demand while achieving the lowest cost (MENR, 2019).

Below, we use the low-demand scenario to assess the impact of increasing electricity demand on macroeconomic variables in the green growth case and reference demand for the business-as-usual case.

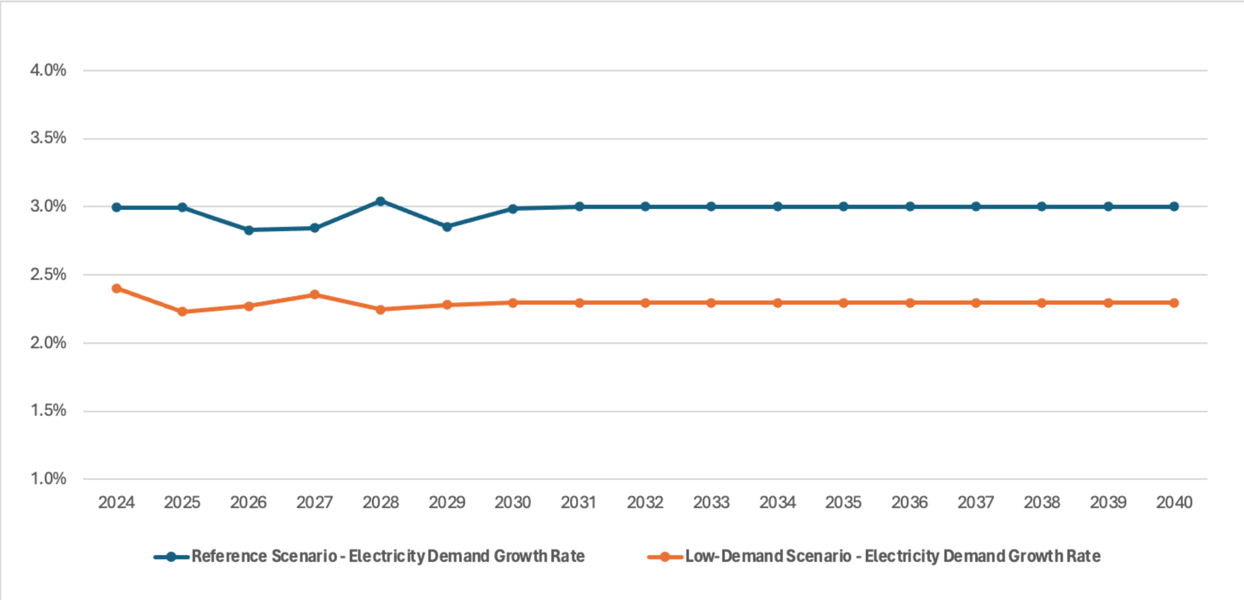

***Figure 10** Annual Average Electricity Demand Growth Rate - Türkiye*

Source: TETC, 2021.

Notes: The forecasts by TETC are only available until 2030. The growth rate for the subsequent years has been assumed to remain constant.

As part of the 12th Development Plan Green Reconciliation Action Plan (Republic of Türkiye, 2023) and the National Energy Plan of the Ministry of Energy and Natural Resources (MENA, 2022), Türkiye aims to increase solar PV and onshore wind energy capacity to 52.9 and 29.6 GW by 2035 according to MENA (2022) and to 30.0 and 18.0 GW by 2028 according to the 12th Development plan. These targets serve as the basis for the green growth scenario.

2. Potential obstacles and challenges

Obstacles and challenges in front of a green energy investment program in Türkiye have not been discussed much. Yet, the discussion above shows that despite the ambitious targets for domestic energy supply, recent capacity increases have been slower than anticipated in wind energy.

In terms of solar energy, despite improvements in domestic production of certain parts, there is still a high level of imported inputs. Given the recent turmoil in the Turkish economy with unstable exchange rates and high inflation, sudden input price movements are also a potential challenge for investors.

924 MW of wind power and 224 MW of biomass and waste heat plants in Türkiye are in the earthquake zone (total of 3.5 TWh per year - corresponding to 7.5% of the total solar, wind, biomass, and waste heat power generation in Türkiye (Solar Power Europe). This could be another potential challenge in the future.

3. Literature

Research on the employment impacts of green policies and the energy transition in developing countries, particularly Türkiye, is sparse (ILO & UNDP 2022; Bouzaher, Şahin, & Yeldan 2015). This scarcity is due to outdated input-output tables, insufficient reliable data, and the relatively recent development of the renewable energy sector (Acar et al., 2023). Despite these challenges, existing studies in Türkiye generally report net positive employment effects, though they often only consider gross impacts, i.e., excluding job losses arising from the contraction in the fossil fuel industry (Çetin and Eğrican 2011; Yılmaz 2014; Özenç & Özen 2020). Most research has focused on expanding renewable energy production capacity (Bölük 2013; ILO & UNDP 2022), with less emphasis on the impacts of a carbon tax (Bouzaher, Şahin, & Yeldan 2015). Some studies using applied computable general equilibrium (CGE) models suggest that carbon taxes can result in positive employment outcomes if revenues are reinvested in research and innovation (Bouzaher, Şahin, & Yeldan 2015). Other studies have assessed the employment effects of increasing wind and solar energy capacity without considering the decline of the fossil fuel industry (Özenç & Özen, 2020). Recent research using a macro-econometric input-output model indicates that transitioning from fossil fuels to renewable energy sources yields net positive employment impacts for Türkiye (ILO & UNDP 2022).

The input-output model is crucial for evaluating the employment impacts of green and brown energies, mainly through direct, indirect, and induced employment multipliers, which are the main outputs of the analysis. Employment multipliers show the employment impact in each industry upon a unit change in final demand spending. The employment multipliers are calculated by multiplying the Leontief inverse matrix, which shows the industrial output change upon a unit of expenditure in energy investments, i.e., output multipliers, with industry labor intensities (i.e., the labor required to produce one unit of output in that industry) to estimate labor needs. The labor needs arise from power plant construction, installation, and manufacturing of power plant equipment (direct employment), supplying inputs (indirect employment), and consumption increase triggered by income changes (induced employment) (Garrett-Peltier et al. 2015).

Renewable energy industries like solar PV and wind onshore technologies tend to have higher labor intensities, leading to greater direct and indirect employment multipliers than fossil fuel industries (Garrett-Peltier et al., 2015; Fankhauser, 2008).

Although the input-output model is increasingly used in developing countries, challenges remain due to immature renewable energy technologies and outdated input-output tables (Acar et al., 2023; UNDP & ILO, 2022). Techniques such as the Ratio-to-Average Sampling (RAS)[2] or cell-updating approach[3] can be employed using recent industry data

[2] The synthetic industry approach allows to treat renewable energy investments as the expenses of each industry involved during the construction, manufacturing, and installation process.

[3] Cell-updating approach, or augmentation method is more complex in the sense that it allows to adress technological advancements, such as the introduction of renewable industries, by adding these industries as new entries to the input-output tables, thereby updating all remaining technical coefficients to reflect these changes. (Malik et al. 2014). Both methodologies may change the underlying structure of the production technology.

to update the outdated tables (Miller and Blair 2009; Wang et al. 2015). However, renewable energy industries are not explicitly detailed in input-output tables. To address this issue, either renewable energy industries are integrated into the existing input-output table using a cell-updating approach, or renewable energy investments are introduced as a demand shock only, thereby leaving the underlying production technology unaffected by the synthetic industry or final demand approach (Garrett-Peltier 2017; O’Sullivan and Edler 2020). The synthetic industry approach allows us to consider renewable energy investments as the expenses of each industry involved during the construction, manufacturing, and installation. Since both approaches hold assumptions about the industrial structure of renewable sectors, they often require sensitivity analysis to check for the robustness of results under alternative industrial structures assigned to renewable energies (Silva, Oliveira, and Coelho, 2013; Dell’Anna, 2021).

The literature on employment impacts of renewable energy investments shows positive outcomes across various countries and scenarios. Studies like Dell’Anna (2021) and O’Sullivan and Edler (2020) demonstrate that increasing the share of renewables leads to significant job creation. In the United States, Garrett-Peltier (2017) found that renewable technologies generate 7.49 full-time equivalent (FTE) jobs per million dollars invested, compared to only 2.65 FTE in fossil fuel industries. Similar positive employment impacts are observed in developing countries, with studies like Pollin (2015) estimating a net employment increase of 0.5 to 1.5% of the labor force by investing an additional 1.0 to 1.5% of GDP in clean energy over 20 years. The literature consistently indicates that renewable energy investments create more jobs per unit of energy produced than fossil fuel counterparts, with a higher share of indirect effects in the total generated employment (Fankhauser 2008; Garrett-Peltier et al. 2015).

Study		Country	Findings
(Garrett-Peltier et al. 2015).	Investing 1.5 to 2% of GDP per year on renewable energy technologies and energy efficiency investments for 20 years, including bioenergy, solar PV, wind, geothermal, hydro, weatherization, grid upgrades, industrial energy efficiency, coal, oil	United States, S. Korea, Brazil, Indonesia, Germany, S. Africa	-The transition increases employment by 1 to 1.5% despite the reduction in the coal industry. -Higher indirect employment effects than direct employment effects. -Higher impact on employment in developing countries compared to developed countries.
UNDP and ILO 2022	Reference Scenario: Electricity demand is met by new coal power plants. Green Scenario: Electricity demand is met solely by new solar PV and wind power plants, in addition to energy efficiency investments	Türkiye	Annual 1.4% GDP spending on energy investments increases employment by 0.8% compared to the reference scenario.
O'Sullivan and Edler, 2020	Scenario: The gross employment figures from installed renewable investments are calculated using the Input-Output approach. Energy technologies included are: -Wind onshore & offshore, -Photovoltaic, -Hydropower, -Geothermal (deep & near surface) -Biomass (heating plants & power plants) -Solar thermal -Biogas	Germany	3.4 million jobs related to RES technologies were created from 2000 to 2018.
Garrett-Peltier 2017	Scenarios: Employment multipliers for RES technologies are calculated for wind, solar, bioenergy, geothermal, hydro, industrial energy, and energy efficiency.	U. S	7.49 FTE jobs were created for 1 million dollars for renewable technologies, and 7.72 FTE was generated for energy efficiency industries compared to 2.65 in fossil fuel industries.
Dell'Anna 2021	Scenario: Increasing renewables' share to 40% from 6.5% by 2040. Wind, Photovoltaic, hydroelectric, geothermal, and biomass are energy technologies included.	Italy	445.99 person-years per TWh for Wind, 423.81 person-years per TWh for PV

Table 1: Summary of the literature on renewable energy and energy-efficient investments based on input-output analysis.

4. Data and method

4.1 Data

Carrying out an input-output analysis of the potential consequences of a green investment program requires a wide range of data items. Some of these data items were obtained from official government statistics. However, as the necessary detailed sector-level data were not available in these statistics, we estimated specific parameters based on data provided in industry reports and policy documents. We present a comprehensive list of all the sources in Table A.1 in the Appendix.

4.2 Methodology

We use input-output methodology in this study. The input-output method is an analytical framework that can be used to assess sectoral interdependencies. The framework uses input-output tables, which assume a fixed relationship between the output and inputs of a given sector (Miller & Brail, 2009). It can be used to estimate the impact of final demand spending (i.e., consumption, government, investment, export spending) on the level of total output in each industry.

Moreover, the impact assessment is not limited to output but also can be extended to conduct a macroeconomic or environmental impact analysis. We use input-output analysis to assess the employment, output, and emission impacts of implementing renewable energy technologies and the corresponding decline in the coal industry. We choose this method instead of more complex macroeconomic models such as applied computable general equilibrium models (CGE) due to the complexity of the models and the variation in results based on different theoretical foundations adopted in the study (Breitschopf & Winkler, 2019).

The input-output analysis involves three steps:

1. Updating the 2012 Turkish Input-Output (I-O) Table to reflect 2022 conditions.

2. Calculating the employment, output, and emission multipliers, the unit outcome of the analysis shows the impact of a unit of renewable energy investment spending on sectoral output, employment, value-added, and emission levels.

3. Identifying components within total costs determines the final demand vector for each energy investment.

Investment costs and components for each energy source are sourced from IRENA, the Ministry of Industry and Technology, and Turkish sectoral reports like those from the Izmir Development Agency. These costs encompass all expenses until the plant becomes operational. Operation and maintenance costs include equipment, labor, and management expenses needed to maintain the plant's productivity. We also compare expenditure items with NACE Rev2 Industry codes to align them with current sectors in the input-output table.

4.2.1 Updating the input-output table

The RAS technique is used to update the input-output ratios in an input-output table based on recent economic data, preserving fixed relationships between sectoral transactions and value-added (Wang et al. 2015). The RAS technique relies on the update of the technical coefficients, the coefficients of a matrix that show the interindustry relation (A Matrix), based on the target year's gross output, total inter-industry sales, and total interindustry purchases (Wang et al. 2015).

Following Acar *et al.* (2022), we employ a modified RAS technique to adjust the technical coefficients of the A matrix according to 2022 sectoral gross value added and total inter-industry transactions. First, the gross value-added part of the 2012 I-O table has been restructured where total value-added equals the sum of employee compensation, net taxes, and net payments to capital for each sector, and total production equals the sum of total intermediate production and total value added. The sum of the total output and imports gives the total supply. Second, we derive the technical coefficients of the 2012 input-output table by dividing each sector's total value-added by each sector's total sales. The technical coefficients reflect the fixed relation between a sector's output and its inputs (Miller and Blair 2009). Assuming this fixed relation within a sector will be sustained, we estimate the interindustry transactions, factor payments, and expenditures of 2020. Adjustments on gross payments to capital have eliminated the discrepancy between the total use and supply. 2022 and 2012 input-output tables exhibit identical input structures within each sector; however, each sector's share in total value-added changes between these two tables.

In updating the input-output table, the intersectoral matrix was revised from a 64x64 matrix to a 62x62 sector matrix. In terms of sector classification, the services provided by households as employers of domestic staff (represented by sector T) and other personal services (represented by S96) were merged into a single sector under S96+T. The sectors for owner-occupied housing receiving imputed rent (L68A) and real estate services (L68B) were consolidated under sector L68.

4.2.2 Measuring the employment, output, and emission multipliers

The second step in the analysis consists of calculating output multipliers and then converting these multipliers to employment, GDP, and emission multipliers using the Leontief Inverse Matrix and requirement matrices. The methodology pursued in this step forms the basis of the input-output analysis and is further detailed in Appendix A.2.

4.2.3 Determining the sectoral composition of energy investments

In the final demand approach, the investment expenditures for each energy source are allocated to specific sectors, determining their share within the total expenditures and creating a final demand vector for the related sectors. Revealing the cost structure of energy investments provides valuable insights about the industries involved in the production process. For example, investments in wind and solar energy will facilitate the production of electrical and mechanical equipment, increase construction activities, or alter the demand for land use and engineering services. The unit investment cost for each technology and cost composition data for each power plant investment are provided in Table 2.

Technology	Installed Costs $/KW	O&M Cost $/KW-year
Solar PV	690.0	14.5
Wind Onshore	1,589.3	36.3
Coal Domestic/Imported	2,916.1	40.0 – 42.5

Table 2 Investment costs of energy technologies

Source: Solar PV installation costs: IRENA, 2022 – for Türkiye; Wind Onshore power plant installation costs: the average of costs in IRENA (2022), Izmir Development Agency (IDA) (2021) and EMRA (2022)

Cost Category	Nace Rev.2 Code	Sector Detail	IRENA (2022)	Pollin et al. (2014)
Investment Cost	C28	Manufacture of machinery and equipment not elsewhere classified	44.00%	17.50%
	F	Construction works and construction activities	6.00%	30.00%
	C25	Manufacture of fabricated metal products (excluding machinery and equipment)	0.00%	17.50%
	C27	Manufacture of electrical equipment	17.00%	0.00%
	C26	Manufacture of computers, electronic and optical products	4.00%	17.50%
	J62-J63	Computer programming, consultancy, and related activities & Information service activities	1.00%	0.00%
	C24	Basic metals industry	7.00%	0.00%
	M71	Architectural and engineering activities; technical testing and analysis activities	0.00%	17.50%
	M74-M75	Other professional, scientific, and technical activities	17.00%	0.00%
	K66	Auxiliary activities for financial services and insurance activities	4.00%	0.00%
Cost Category	**Nace Rev.2 Code**	**Sector Detail**	**Tourkalias et al. 2011**	**Pollin et al. (2014)**
Operations and Maintenance Costs	C27	Manufacture of electrical equipment	15.00%	-
	C28	Manufacture of machinery and equipment not elsewhere classified	15.00%	-
	C33	Installation and repair of machinery and equipment	-	25.00%
	F	Construction	20.00%	25.00%
	K66	Auxiliary activities for financial services and insurance activities	-	-
	L68B	Real estate services	50.00%	-
	N80-N82	Security and investigation services; landscape services; office management, office support, and other business support services	-	50.00%

Table 3 Investment and maintenance cost components for solar power plants

Cost Category	Nace Rev.2 Code	Sector Detail	IDA (2016)	EIA (2020)	İzmir Development Agency (2021)
Investment Cost	C25	Manufacture of fabricated metal products (excluding machinery and equipment)			15.00%
	C26	Manufacture of computers, electronic and optical products	0.33%		6.82%
	C27	Manufacture of electrical equipment		7.27%	11.60%
	C28	Manufacture of machinery and equipment not elsewhere classified	75.63%	64.29%	35.66%
	D35	Electricity, gas, steam, and air conditioning supply	8.88%		
	F	Construction	8.81%	15.49%	20.35%
	K66	Services of insurance, reinsurance, and pension funding, except compulsory social security	1.22%		8.22%
	L68	Real estate services	3.90%		
	M69-M70	Legal and accounting services; head office services; management consulting services		6.29%	
	M71	Architectural and engineering services; technical testing and analysis services	1.22%	6.66%	1.25%
	M72	Scientific research and development services			1.10%
Cost Category	**Nace Rev.2 Code**	**Sector Detail**	**Pollin et al. (2014)**	**EIA (2020)**	**Tourkalias et al. (2011)**
Operations and Maintenance Costs	C22	Rubber and plastic products			5.00%
	C33	Installation and repair of machinery and equipment	25.00%	84.70%	45.00%
	F	Accommodation and food services	25.00%	15.30%	
	I	Telecommunication services			2.00%
	J61	Auxiliary activities for financial and insurance services			1.00%
	K66	Security and investigation services; landscaping services; office management, office support, and other business support services			17.00%
	L68	Rubber and plastic products			30.00%
	N80-82	Installation and repair of machinery and equipment	50.00%		

Table 4 Investment and maintenance cost components for wind onshore power plant

Cost Category	Nace Rev.2 Code	Sector Detail	İzmir Development Agency (2016)	EIA (2020)	İzmir Development Agency (2021)
Investment Cost	C25	Manufacture of fabricated metal products (excluding machinery and equipment)			15.00%
	C26	Manufacture of computers, electronic and optical products	0.33%		6.82%
	C27	Manufacture of electrical equipment		7.27%	11.60%
	C28	Manufacture of machinery and equipment not elsewhere classified	75.63%	64.29%	35.66%
	D35	Electricity, gas, steam, and air conditioning supply	8.88%		
	F	Construction	8.81%	15.49%	20.35%
	K66	Services of insurance, reinsurance, and pension funding, except compulsory social security	1.22%		8.22%
	L68	Real estate services	3.90%		
	M69-M70	Legal and accounting services; management consultancy services		6.29%	
	M71	Architectural and engineering services; technical testing and analysis services	1.22%	6.66%	1.25%
	M72	Scientific research and development services			1.10%
Cost Category	**Nace Rev.2 Code**	**Sector Detail**	**Pollin et al. (2014)**	**EIA (2020)**	**Tourkalias et al. (2011)**
Operations and Maintenance Costs	C22	Rubber and plastic products			5.00%
	C33	Installation and repair of machinery and equipment	25.00%	84.70%	45.00%
	F	Construction	25.00%	15.30%	
	I	Accommodation and food services			2.00%
	J61	Telecommunication services			1.00%
	K66	Auxiliary services for financial and insurance services			17.00%
	L68	Real estate services			30.00%
	N80-82	Security and investigation services; landscaping services; office management, office support, and other business support services	50.00%		

Table 5 Investment and maintenance cost components for coal power plants

5. Empirical findings

5.1 Scenarios

We undertake analysis under two main scenarios. Scenario 1 assumes "business as usual" and takes the growth rate of all types of energy production over the last five years and extrapolates into the future with the exceptions of solar power, wind onshore, and biomass capacity investments, for which we take the average capacity increase (in MW) in the last five years. Under the "business as usual" scenario, domestic and imported coal use in power production grows annually at the rate of the previous five years, which leads to the installation of new power plants. In scenario 1, the electricity demand projections are based on the reference-demand scenario of production capacity projection published by the Ministry of Environmental and Natural Resources (2021).

Both scenarios 2.1 and 2.2 assume a greener growth in electricity production, but they differ based on the industry policy adopted. They take 2028 official targets, according to the government's 12th Development Plan (to reach 18 and 30 GW installed capacity for wind and solar energy), and the 2035 official targets (29,6 and 52.9 GW installed capacity by 2035) (MENA, 2022). We extend these official targets into 2040, assuming the installed capacity increase will remain the same after 2035.

In scenario 2.1 and 2.2, we make sure these targets are met by 2028 and 2035, respectively. As a result of this transition, both domestic and imported coal use falls, other renewables increase, and other fossil fuels stay constant throughout the project. Electricity demand is projected to be 520 TWh by 2040, which are based on the low-demand scenario of production capacity projection published by the Ministry of Environmental and Natural Resources (2021). The official targets are summarized in Table 6 and the assumptions and targeted capacity changes for each energy source in all scenarios are presented in Table 7.

Targets	Sources	Reference
Solar PV/Wind Onshore Installed Capacity (2028)	12th Development Plan	Republic of Türkiye, 2022
Solar PV/Wind Onshore Installed Capacity (2035)	National Energy Plan	Ministry of Energy and Natural Resources of the Republic of Türkiye, 2022
Electricity Demand Projections (2020-2040)	Production Capacity Report	Ministry of Energy and Natural Resources of the Republic of Türkiye, 2019

Table 6 Official Targets

Scenarios	Demand Projections	Energy Source	Annual Capacity Change (%)	2040 Installed Capacity (GW)
Scenario 1 - Business-as-usual	Reference Demand (3%)	Solar PV	7.2%	39.4
		Wind Onshore	5.7%	29.7
		Imported Coal	4.0%	19.3
		Domestic Coal	0.3%	12.0
Scenario 2.1 - Green Development with Aggressive Industrial Policy	Low - Demand (2.3%)	Solar PV	10.8%	65.0
		Wind Onshore	6.7%	34.7
		Imported Coal	-18.0%	0.0
		Domestic Coal	-18.0%	0.0
Scenario 2.2 - Green Development with Conservative Industrial Policy	Low - Demand (2.3%)	Solar PV	10.8%	65.0
		Wind Onshore	6.7%	34.7
		Imported Coal	-18.0%	0.0
		Domestic Coal	-18.0%	0.0

Table 7 Scenarios

Scenario 2 – Green development is analyzed under an expansionary and conservative industry scenario. The industry dimension analyzes whether the investments will generate a domestic production scale-up in various industries or keep the reliance on imports constant. Scaling up domestic production corresponds to an aggressive industrial policy, which seeks to expand the domestic capacity of the industry. The aggressive industrial policy is studied under scenario 2.1 – Green Development with Aggressive Industrial Policy. The alternative is the conservative industrial policy (Scenario 2.2), which relies on imports to meet the increased demand. In the literature, industries with 90% or higher domestic content have been treated as nontradeable (Lombardo and Ravenna 2012; Garrett-Peltier et al. 2015). The nontradeable industry products are assumed to be produced and consumed in the domestic market and cannot be easily traded. In contrast, tradeable industry products can be easily exported or imported. We assume a 20% reduction in the domestic content of the tradeable industries, consistent with the previous literature (Garrett-Peltier et al. 2015; Pollin, Heintz, and Garrett-Peltier 2009). This reduction in the domestic content of these industries is reflected under the conservative industrial policy, under scenario 2.2 – Green Development with Conservative Industrial Policy.

5.2 Emissions

The main aim of the transition to renewable energy is to reduce carbon dioxide emissions. Yet, green investment generates some greenhouse gas emissions through activities such as equipment manufacturing, construction works, landscaping services, etc. Therefore, although the electricity generated by renewable energy power plants reduces total emissions, a significant portion is also generated with the investments. We use the marginal emissions factor published by the Ministry of Energy and Natural Resources in 2023 to measure the total foregone CO_2 emissions by renewable energy investments.

In the “business as usual” scenario, total foregone CO_2 emissions are calculated as 480.8 million tons. In scenario 2.1 – Green Development under aggressive industry policy, total foregone CO_2 emissions amount to 824.8 million tons, whereas scenario 2.2. Green Development under conservative industry policy decreases total GHGs by 826.6 million tons (CO_2-eq). The difference between the green development and business-as-usual scenario (344.0 mt CO2 -eq) represents 61% of Türkiye's total GHG emissions in 2021, highlighting a significant impact on the country's overall emissions.

5.3 Economic growth

Using the input-output methodology, we estimate the net production and net value-added effects under three scenarios. Whereas net value added refers to the country’s GDP (the sum of compensation of employees, payments to capital and net taxes), total production includes intermediate production expenditures in addition to the value added.

In the “business as usual” scenario, the impact of fossil fuel investments on total production is estimated to be 145.4 billion USD and 45 billion USD on value-added. In scenario 2.1 – Green Development under aggressive industry policy, total impact on output is estimated to be 123.4 billion USD and on value-added is 38 billion USD. Similar to scenario 2.1, scenario 2.2. Green Development under conservative industry policy increases total output by 109.5 billion USD and total value added by 33 billion USD.

5.4 Employment

Our findings show that investment in energy production through coal generates higher employment opportunities than renewable energy. However, renewable energy investments generate more employment throughout their lifetime through more maintenance jobs than coal. This is not surprising given that construction jobs are short-lived, whereas operations and maintenance jobs continue through the power plant’s lifetime.

Given these, our findings indicate that a green transition under Scenarios 2.1 and 2.2 result in a net 17,417 to 94,424 fewer jobs, respectively, compared to the business-as-usual scenario due to the reduction in coal power plants under the green development scenarios. In the “business as usual” scenario, the impact of fossil fuel investments on employment is estimated to be 1.31 million jobs. In scenario 2.1 – Green Development under aggressive industry policy, total impact on employment is estimated to be 1.30 million jobs, and 1.2 million jobs in scenario 2.2. Green Development under conservative industry policy.

5.5 Current account

The impact of investments on the current account balance have been calculated by considering the expected decrease in the electricity production capacity of thermal power plants reliant on imported coal and, consequently, a reduction in these plants’ coal imports. The analysis forecasts a total decline of 197 million tons in imported coal (hard coke) under the green development scenarios, equal in scenario 2.1 and scenario 2.2. On the other hand, business-as-usual scenario implies a total increase of 156 million tons in imported coal. The total difference between green development scenario with aggressive industrial policy and business-as-usual scenario equals 353 million tons of coal.

In the “business as usual” scenario, the impact of increase in coal imports on the current account balance is estimated to be 23.4 billion USD. On the contrary, both scenario 2.1 – Green Development under aggressive industry policy and scenario 2.2. Green Development under conservative industry policy reduces the current account deficit by 29.5 billion USD. Therefore, the net impact of the reduction in coal imports compared to the business-as-usual scenario on the current account balance is approximately 52.9 billion USD over the course of our scenario. On an annual basis, this corresponds to an improvement equivalent to 7.8% of the annual total current account deficit as of 2023.

6. Conclusion

Türkiye has ratified the Paris Agreement in 2021 and has submitted the 1st Intended Nationally Determined Contribution (NDC) to the UNFCCC in 2021. In this study, we carried out an input-output analysis to project the emissions, growth, employment, and current account consequences of green transition under different scenarios. Our findings indicate that under the “business as usual” scenario net emission would decrease by 20.1 mtCO_2 eq. whereas under green development scenarios this decline would be somewhere between 81.6 and 83.6 mtCO_2 eq. Table 9 summarizes our findings.

Scenarios	Net Emissions (mtCO2 equivalent)	Net Output (Billion USD)	Net Employment (Thousand people)	Net Current Account Effect (Billion USD)
Scenario 1: Business-as-usual	(480.8)	145.4	1,317	23.4
Scenario 2.1: Green Development (Aggressive Industrial Policy)	(824.8)	123.4	1,300	(29.5)
Scenario 2.2: Green Development (Conservative Industrial Policy)	(826.6)	109.5	1,174	(29.5)
NET DIFFERENCE (S1-S2.1)	(344.0)	(22.4)	17,4	(52.9)

Table 9 Summary of projection results under different scenarios

The critical point is that this transition could also increase output and employment. While the net output effect would be larger under the “business as usual scenario” the difference over time between this scenarios and the green investment scenarios would only be around 20-40 billion USD. Similarly, net employment effects would still be positive under all scenarios. While in macroeconomic terms there will be a net positive job creation, in specific sectors there will be job losses and policies to address these losses need to be designed.

Furthermore, given that Türkiye now uses imported coal to produce electricity, a green transition program could reduce the need for these imports, further contributing to economic growth and positively impacting the current account balance.

In addition to investing in renewable energy, examining the economic impacts of energy efficiency is essential. Research indicates that the expected rise in electricity demand has negative implications for employment, production, value-added, and emissions. Addressing this growing demand through enhanced building insulation, energy-efficient lighting, and the development and implementation of advanced technologies to reduce industrial electricity consumption mitigates greenhouse gas emissions and optimizes these investments' benefits. Furthermore, socioeconomic research that explores the financing mechanisms for these investments and investigates the transition strategies to offset losses in fossil fuel sectors is critical for achieving an equitable green transformation in Türkiye.

References

Acar, Sevil A., Aşıcı, Ahmet. A., and A. Erinç Yeldan. 2022. "Potential effects of the EU's carbon border adjustment mechanism on the Turkish economy." Environment, Development, and Sustainability 24: 8162–8194. https://doi.org/10.1007/s10668-021-01779-1.

Acar, Sevil and Erinc Yeldan. 2016. "Environmental impacts of coal subsidies in Turkey: A general equilibrium analysis." Energy Policy 90 ©: 1-15.

Acar, Sevil, Bora Kat, Mathis Rogner, Deger Saygin, Yael Taranto, A. Erinc Yeldan. 2023. "Transforming Türkiye's power system: An assessment of economic, social, and external impacts of an energy transition by 2030." Cleaner Energy Systems Volume 4, 2023.

Alparslan Ufuk, Yıldırım Azem. 2023. There is more than 120 GW of potential available on rooftops. Ember Report. https://ember-climate.org/insights/research/turkiye-can-expand-solar-by-120-gw-through-rooftops/

Ari, Anil, Nicolas Arregui, Simon Black, Oya Celasun, Dora M. Iakova, Aiko Mineshima, Victor Mylonas, Ian H.V. Parry, Iulia Teodoru, and Karlygash Zhunussova. 2022. "Surging Energy Prices in Europe in the Aftermath of the War: How to Support the Vulnerable and Speed up the Transition Away from Fossil Fuels." International Monetary Fund (IMF) Working Papers 2022/152.

Aslantürk, Oğuzhan. 2020. "The role of renewable energy in ensuring energy security of supply and reducing energy-related import." International Journal of Energy Economics and Policy 10 (2): 354–359.

Aselsan. 2022. Sustainability Report. https://www.aselsan.com/tr/surdurulebilirlik/raporlarimiz?s=2022

Aselsan. 2023. Wind Turbine ART4.X. https://wwwcdn.aselsan.com/api/file/ART4.X-RUZGAR_TURBINI_TR.pdf

Böhringer, Christoph, Andreas Keller, and Edwin van der Werf. 2013. "Are Green Hopes Too Rosy? Employment and Welfare Impacts of Renewable Energy Promotion." *Energy Economics* 36 (03): 277–285.

Böhringer, Christoph, Nicholas J. Rivers, Thomas F. Rutherford, and Randall Wigle. 2012. “Green Jobs and Renewable Electricity Policies: Employment Impacts of Ontario’s Feed-in Tariff.” *BE Journal of Economic Analysis and Policy* 12 (1). https://doi.org/10.1515/1935-1682.3217.

Bouzaher, Aziz, Şebnem Şahin, and A. Erinç Yeldan. 2015. “How to go green: a general equilibrium investigation of environmental policies for sustained growth with an application to Turkey’s economy.” *Letters in Spatial and Resource Sciences* 8 (1): 49–76. Doi:10.1007/s12076-014-0124-0.

Bowen, Alex. 2012 “‘Green’ Growth, ‘Green’ Jobs and Labor Markets.” *World Bank Policy Research Working Paper No. 5990.*

Breitschopf, Barbara, and Jenny Winkler. 2019. “The EU 2030 Renewable Energy Vision – Can it be more Ambitious?” *Advances in Environmental Studies* 3 (1): 164–178. https://doi.org/10.36959/742/214.

Chatri, Fatemeh, Masoud Yahoo, and Jamal Othman. 2018. “The economic effects of renewable energy expansion in the electricity sector: A CGE analysis for Malaysia.” *Renewable and Sustainable Energy Reviews* 95: 203–216.

Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC). 2021. G20 Climate Risk Atlas: Impacts, policy, economics – TURKEY

Çetin, Müjgan, and Nilüfer Eğrican. 2011. “Employment impacts of solar energy in Turkey.” *Energy Policy* 39 (11): 7184–7190.

Dell’Anna, Federico. 2021. “Green Jobs and Energy Efficiency as Strategies for Economic Growth and the Reduction of Environmental Impacts.” *Energy Policy* 149: 112031. https://doi.org/10.1016/j.enpol.2020.112031.

Ember. 2021. “G20 Profile, Turkey”. Ember Global Electricity Review 2021. Accessed 22 June 2023. https://ember-climate.org/app/uploads/2022/02/Global-Electricity-Review-2021-Turkey.pdf.

Energy Market Regulative Authority (EMRA), Unit Investment Amounts by Source in the Electricity Market, Energy Market Regulatory Board Decision No:11328

Eurostat, 2023, Turkey Air Emissions Accounts by NACE Rev. 2 Activity. https://ec.europa.eu/eurostat/databrowser/view/ENV_AC_AINAH_R2__custom_9516514/default/table?lang=en

European Investment Bank. 2023. “EIB Project Carbon Footprint Methodologies: Methodologies for the Assessment of Project GHG Emissions and Emission Variations,” Version 11.3, https://enerji.gov.tr//Media/Dizin/EVCED/tr/%C3%87evreVe%C4%B0klim/%C4%B0klimDe%C4%9Fi%C5%9Fikli%C4%9Fi/%C4%B0klimDe%C4%9Fi%C5%9Fikli%C4%9FiHakk%C4%B1nda/Belgeler/EK-2.pdf

Electricity Generation Co. 2023. EÜAŞ At A Glance. Strategy Development Department, Strategic Planning Directorate. https://www.euas.gov.tr/hakkimizda

Fankhauser, Samuel, Friedel Sehlleier, Nicholas Stern. 2008. “Climate change, innovation, and jobs.” *Climate Policy* 8: 421–429. https://doi.org/10.3763/cpol.2008.0513.

Garrett-Peltier, Heidi. 2017. “Green versus Brown: Comparing the Employment Impacts of Energy Efficiency, Renewable Energy, and Fossil Fuels Using an Input-Output Model.” *Economic Modelling* 61 (February): 439–447. https://doi.org/10.1016/j.econmod.2016.11.012.

Garrett-Peltier, Heidi, Pollin, Robert, Heintz, James and Chakraborty, Shouvik. 2015 “Global Green Growth: Clean Energy Industrial Investments and Expanding Job Opportunities” *United Nations Industrial Development Organization and Global Green Growth Institute.*

Global Climate Network (GCN). 2009. “Low-Carbon Jobs in an Inter-Connected World.” *Global Climate Network Discussion Paper No.3.*

Gifford, J. 2023. “Weekend read: A manufacturing bridge between Europe and Asia,” PV Magazine, 13 May, www.pv-magazine.com/2023/05/13/weekend-read-a-manufacturing-bridge-between-europe-and-asia/

Hockenos, Paul. 2021. As the Climate Bakes, Turkey Faces a Future Without Water. https://e360.yale.edu/features/as-the-climate-bakes-turkey-faces-a-future-without-water

International Labour Organization (ILO), and United Nations Development Program (UNDP). 2022. *Social and Employment Impacts of Climate Change and Green Economy Policies in Türkiye: Application of the Green Jobs Assessment Model for Türkiye.* Geneva: International Labour Office.

International Energy Agency (IEA). 2021b. *Financing clean energy transitions in emerging and developing economies.* Paris: OECD Publishing.

International Renewable Energy Agency (IRENA). Perspectives for the Energy Transformation: Investment Needs for a Low-Carbon Energy System. 2017. www.irena.org.

International Renewable Energy Agency (IRENA). 2020. Renewable Power Generation Costs. Abu Dhabi, UAE: IRENA.

International Renewable Energy Agency (IRENA). 2022. Renewable Power Generation Costs. Abu Dhabi, UAE: IRENA.

International Renewable Energy Agency (IRENA). 2023. Renewable Energy and Jobs – Annual Review 2023

Kammen, Daniel M., Kamal Kapadia, and Matthias Fripp. 2004. "Putting Renewables to Work: How Many Jobs Can the Clean Energy Industry Generate?" *University of California Berkeley Report of the Renewable and Appropriate Energy Laboratory*.

Lombardo, Giovanni, and Federico Ravenna. 2012. "The Size of Tradable and Non-Tradable Sectors: Evidence from Input-Output Tables for 25 Countries." *Economic Letters* 16 (3): 558-561.

Maia, Jorge, Thierry Giordano, Nico Kelder, Ganief Bardien, Moleboge Bodibe, Peet du Plooy, Xoliswa Jafta, et al. 2011. "Green Jobs: An estimate of the direct employment potential of a greening South African Economy." *Industrial Development Corporation, Development Bank of Southern Africa, Trade and Industrial Policy Strategies*.

Malik, Arunima, Manfred Lenzen, Rômulo Ely, Erik Dietzenbacher. 2014. "Simulating the impact of new industries on the economy: The case of biorefining in Australia." *Ecology Economics* 107: 84–93.

Malik, Aman, Christoph Bertram, Elmar Kriegler, Gunar Luderer. 2021. "Climate policy accelerates structural changes in energy employment." *Energy Policy* 159: 112642.

Miller, Ronald E., and Peter D. Blair. 2009. *Input–Output Analysis: Foundations and Extensions*. New York, NY: Cambridge University Press, 2nd Edition.

Ministry of Energy and Natural Resources of the Republic of Türkiye (MENR). 2019. *“Turkey Electricity Demand Projection Report (2020-2040 Period)*. Ministry of Energy and Natural Resources.

Ministry of Energy and Natural Resources of the Republic of Türkiye (MENR). 2010-2021. National Energy Balance Tables: 2010-2021. Ministry of Energy and Natural Resources

Ministry of Energy and Natural Resources of the Republic of Türkiye (MENR). 2023a. “2022 Hard Coal Sector Report”. Ministry of Energy and Natural Resources.

Ministry of Energy and Natural Resources of the Republic of Türkiye (MENR). 2022. “Türkiye Ulusal Elektrik Şebekesi Emisyon Faktörü Bilgi Formu”. https://enerji.gov.tr/evced-cevre-ve-iklim-turkiye-ulusal-elektrik-sebekesi-emisyon-faktoru

Ministry of Energy and Natural Resources of the Republic of Türkiye (MENR). 2022b. Bilgi Merkezi – İklim Değişikliği ve Uluslararası Müzakereler. https://enerji.gov.tr/bilgi-merkezi-iklim-degisikligi-ve-uluslararasi-muzakereler

Ministry of Energy and Natural Resources of the Republic of Türkiye (MENR). 2024a. Wind Energy Potential Atlas. https://enerji.gov.tr/bilgi-merkezi-enerji-ruzgar

Ministry of Energy and Natural Resources of the Republic of Türkiye (MENR). 2024b. Türkiye’nin Rüzgar Potansiyeli 150 Bin MW. https://enerji.gov.tr/haber-detay?id=21198

Ministry of Energy and Natural Resources of the Republic of Türkiye (MENR). 2024c. Türkiye Rüzgar Enerjisi Potansiyeli. https://repa.enerji.gov.tr/REPA/

Ministry of Energy and Natural Resources of the Republic of Türkiye (MENR). 2024d. Solar Energy Potential Atlas, https://gepa.enerji.gov.tr/Default.aspx

Ministry of Energy and Natural Resources of the Republic of Türkiye (MENR). 2024e solar. https://enerji.gov.tr/bilgi-merkezi-enerji-gunes

Ministry of Industry and Technology of the Republic of Türkiye. 2023 https://www.sanayi.gov.tr/medya/haber/ruzgar-sektoru-turek-2023te-bulustu

Ministry of Trade, Harmonized System Tariff Search Engine, Customs Tariff Statistical Position. https://uygulama.gtb.gov.tr/Tara/#

Ministry of Trade, 2023. EU Border Carbon Adjustment Mechanism Transition Period Implementation.

Mu, Yaqian, Wenjia Cai, Samuel Evans, Can Wang, and David Roland-Holst. 2018. "Employment impacts of renewable energy policies in China: A decomposition analysis based on a CGE modeling framework." *Applied Energy* 210: 256-267.

Organization for Economic Co-operation and Development (OECD). 2021. "Long-term baseline projections, No. 109 (Edition 2021)", OECD Economic Outlook: Statistics and Projections (database), https://doi.org/10.1787/cbdb49e6-en (accessed on 15 April 2024).

Organization for Economic Co-operation and Development (OECD). Factbook: 2015-2016 Statistics.

O'Sullivan, Marlene, and Dietmar Edler. 2020. "Gross Employment Effects in the Renewable Energy Industry in Germany: An Input-Output Analysis from 2000 to 2018." *Sustainability* 12: 6163. https://doi.org/10.3390/su12156163.

Omoju, Oluwasola Emmanuel, Lulit Mitik Beyene, Emily E. Ikhide, Stephen K. Dimwobi, and Augustina Ehimare. 2020. "Assessing the macroeconomic impacts of financing options for renewable-energy policy in Nigeria: Insights from a CGE model." *Working Papers MPIA No. 2020-01.*

Özcan, Mustafa. 2022. "Increasing voluntary carbon credits potential via renewable energy projects in Turkey." Pamukkale University Journal of Engineering Sciences 28(5): 710-719.

Özenç, Bengisu, and Efşan N. Özen. 2020. "Türkiye'de Yebilenebilir Enerjiyle Beceri ve İstihdam Gelişimi Elektrik Sektörünü Karbonsuzlaştırmanın Yan Faydalarının Analizi." *Istanbul Policy Center, Sabancı University.*

Pollin, Robert, James Heintz, Heide Garrett-Peltier. 2009. "The Economic Benefits of Investing in Clean Energy. How the Economic Stimulus Program and New Legislation Can Boost US Economic Growth and Employment." *Political Economy Research Institute, University of Massachusetts at Amherst.*

Pollin, Robert, Heidi Garrett-Peltier, James Heintz, and Bracken Hendricks. 2014. “Green Growth: A US Program for Controlling Climate Change and Expanding Job Opportunities.” *Political Economy Research Institute, University of Massachusetts at Amherst*.

Pollin, Robert. 2015. *Greening the Global Economy*. Cambridge, MA: MIT Press.

PricewaterhouseCoopers (PwC). 2024. Dünyada ve Türkiye’de Güneş Enerjisi Sektörü. https://www.pwc.com.tr/tr/sektorler/enerji/yayinlar/2024/pdf/dunyada-ve-turkiyede-gunes-enerjisi-sektoru.pdf

Republic of Türkiye. 2019. “2019-2023 Strategic Plan.” *Republic of Türkiye, Ministry of Energy, and Natural Resources.*

Republic of Türkiye. 2021b. “Green Deal Action Plan of Turkey.” *Republic of Türkiye, Ministry of Trade.*

Rivers, Nicholas. 2013. “Renewable energy and unemployment: a general equilibrium analysis.” *Resource and Energy Economics* 35: 467–485.

Rutovitz, Jay. 2010. “South African energy sector jobs to 2030: How the Energy [R]evolution will create sustainable green job.” *Institute for Sustainable Futures.*

Rutovitz, Jay, Elsa Dominish, and Jenni Downes. 2015. “Calculating Global Energy Sector Jobs: 2015 Methodology.” *Institute for Sustainable Futures.*

Shura Energy Transition Center. 2018. “Türkiye’nin Enerji Sisteminde Yenilenebilir Kaynakların Artan Payı: İletimde Genișleme ve Esneklik Seçenekleri.” *Sabanci University.*

Silva, P. Pereira Da, Carla Oliveira, and Dulce Coelho. 2013. “Employment Effects and Renewable Energy Policies: Applying Input-Output Methodology to Portugal.” *International Journal of Public Policy* 9 (3): 147-166.

Sinner, John. 2020. “Carbon Footprint Methodology Energy, European Investment Bank”. https://ec.europa.eu/regional_policy/sources/policy/evaluations/guidance/2021/ghg-methodologies/renewable-cogeneration.pdf.

Solar Power Europe. 2023. Global Market Outlook For Solar Power 2023 – 2027.

Solar 3GW. 2024. Türkiye güneş enerjisi sektöründe istihdam.

Turkish Electricity Transmission Corporation, TETC. 2023b. Load Dispatch Information Center https://ytbsbilgi.teias.gov.tr/ytbsbilgi/frm_istatistikler.jsf

Turkish Electricity Transmission Corporation, TETC. Production Capacity Report 2021-2025. 2021

Turkish Electricity Transmission Corporation, TETC. Electricity Production-Consumption Reports. 2022. https://www.teias.gov.tr/aylik-elektrik-uretim-tuketim-raporlari

Turkish Electricity Transmission Corporation, TETC. 2022a. The Distribution Of Gross Electricity Generation By Primary Energy Resources And The Electric Utilities In Turkey. https://www.teias.gov.tr/turkiye-elektrik-uretim-iletim-istatistikleri

Turkish Electricity Transmission Corporation, TETC. 2022b. The Distribution Of Installed Capacities By Primary Energy Resources And The Electric Utilities In Turkey. https://www.teias.gov.tr/turkiye-elektrik-uretim-iletim-istatistikleri

Turkish Statistical Institute, Special Trade System Database. 2024. Imports and Exports by Chapters and Countries

Turkish Statistical Institute, 2023, Solid fuels quantity of production, export, import, deliveries and stock changes. 2020-2022. 2023

Turkish Statistical Institute (Turkstat). (2021). “Turkish Greenhouse Gas Inventory 1990-2019” Turkish Statistical Institute National Inventory Report for submission under the United Nations Framework Convention on Climate Change.

Turkish Statistical Institute, 2003-2022, Imports by Chapters, Chapter 27: Mineral fuels, mineral oils, distillation products, bituminous substances, and mineral waxes under HS2 Classification.

Turkish Statistical Institute, Annual Industry and Service Statistics. Value added at factor costs by economic activities, Except financial and insurance activities. 2009-2020. 2020.

Turkish Statistical Institute. Employment and basic indicators in financial sectors, 2002-2020

Turkish Statistical Institute. National Accounts. Gross domestic product at current prices by kind of economic activity (A21) (value, share, percentage change), at current prices, 1998-2020.

Turkish Statistical Institute. National Accounts. Domestic Input-Output Table. 2012.

Turkish Statistical Institute. National Accounts. Input-Output Table. 2012.

Turkish Statistical Institute. National Accounts. Import Input-Output Table. 2012.

Turkish Statistical Institute. National Accounts. Seasonally adjusted at current prices gross domestic product value and percentage change. 2020.

Turkish Wind Energy Association (TUREB), 2022. Turkish Wind Energy Statistic Report. July, 2022.

Turkish Wind Energy Association (TUREB), 2023. Turkish Wind Energy Statistic Report. January, 2023.

Tourkolias, Christos, and Sebastian Mirasgedis. 2011. “Quantification and monetization of employment benefits associated with renewable energy technologies in Greece.” *Renewable Sustainable Energy Review* 15 (6): 2876–2886.

United Nations Framework Convention on Climate Change (UNFCCC). 2021. GHG data 1990-2021”. Accessed 22 April 2024. https://unfccc.int/topics/mitigation/resources/registry-and-data/ghg-data-from-unfccc.

United Nations Framework on Climate Change (UNFCCC). 2018. “Methodological tool: Tool to calculate the emission factor for an electricity system.” Clean Development Mechanism, UNFCC.

United Nations Framework on Climate Change (UNFCCC). 2019. Large-scale Consolidated Methodology: Grid-connected electricity generation from renewable sources”. Clean Development Mechanism, UNFCC.

Wang, Huiwen, Cheng Wang, Haitao Zheng, Haoyun Feng, Rong Guan, and Wen Long. 2015. “Updating Input-Output Tables with Benchmark Table Series.” *Economic Systems Research* 27 (3): 287-305.

Wie, Max, Shana Patadia, and Daniel M. Kammen. 2010. “Putting Renewables and Energy Efficiency to Work: How Many Jobs Can the Clean Energy Industry Generate in the US?.” *Energy Policy* 38 (2): 919–31.

World Bank. National Accounts Data. Manufacturing industry share in total GDP (%) & Industry (including construction) share in total GDP (%). 2010 – 2020.

Wind Europe. 2023. The Turkish wind supply chain keeps getting stronger. https://windeurope.org/newsroom/news/the-turkish-wind-supply-chain-keeps-getting-stronger/

World Wide Fund for Nature (WWF) & Sürdürülebilir Ekonomi ve Finans Araştırmaları Derneği (SEFIA). Enilenebilir Enerji Çağında Kömürün Fizibilitesi: Hunutlu Termik Santrali Örneği. 2020. https://wwftr.awsassets.panda.org/downloads/hunutlufinansal_analiz_tr.pdf?10440/Yenilenebilir-Enerji-Caginda-Komurun-Fizibilitesi-Hunutlu-Termik–Santrali-Ornegi

Yalçın, H. Emre, and Cihan Yalçın. 2021. “Energy Efficiency, Renewable Energy and Current Account Balance: Econometric Findings and Scenario Analysis for Turkey.” *Republic of Türkiye, Central Bank Working Paper No. 21/29.*

Ata, Baha. 2023. 35 bin megavatlık lisanssız güneş enerjisi proje başvurusu. https://yesilhaber.net/35-bin-megavatlik-lisanssiz-gunes-enerjisi-proje-basvurusu/

Yılmaz, Selen Arlı. (2014). “Yeşil İşler ve Türkiye’de Yenilenebilir Enerji Alanındaki Potansiyeli.” Republic of Türkiye, Ministry of Development, General Directorate of Social Sectors and Coordination No: 2887.

Appendix

Data Sources

Data Sets	Data	Source	Objective
Data Set 1	2012 Input-Output Table: Technical Coefficients of inter-sectoral relationship	Turkstat	To analyze the effect of demand changes according to inter-sectoral input-output relationships and to examine their overall economic impact. To ensure the consistency of results with two different input-output tables
Data Set 3	2022 Input-Output Table (Calculated): Sectoral Value Added Sectoral GDP Sectoral Value Added Central Government Budget Revenues (VAT and Excise Tax) Sectoral Value Added	Turkstat, Ministry of Treasury and Finance	To update the 2012 Input-output table to 2022 values.
Data Set 3	2022 Sector-Based (Nace Rev2-2 digit) Employment Data: Employment/Production Coefficient	Eurostat	To convert the input-output table into an employment requirement table
Data Set 4	2022 Sector-Based (Nace Rev2-2 digit) Value-Added Data: Value-Added/Production Coefficient	Turkstat	To convert the input-output table into a value-added requirement table
Data Set 5	2021 Sector-Based (Nace Rev2) Emission Data Emission/Production Coefficient	Eurostat, Turkstat	To convert the input-output table into an emission requirement table.
Data Set 6	2022 – Production, import, export, delivery, and stock change quantities of solid fuels	Turkstat	To estimate the reduction in imported coal usage.
Data Set 7	2021 Marginal Emission Factors	Ministry of Energy and Natural Resources	To calculate the emission reduction effect of electricity production from renewable energy sources.
Data Set 8	Employment Factors: Employment coefficients for Manufacturing/Construction/Operation and Maintenance Sectors (Solar/Wind/Coal/Natural Gas)	Literature	To calculate employment factors that will be used to estimate potential direct jobs resulting from increasing installed capacity in solar and wind energy and the shrinkage in fossil energy sectors.
Data Set 9	2040 Gross Electricity Demand Projection: 2040 electricity demand (TWh) Annual increase rate of electricity demand for 2020-2040 (%)	Ministry of Energy and Natural Resources – Türkiye Electricity Energy Demand Projection Report, 2020-2040	Calculate the increase in installed capacity for solar and wind energy alongside the decrease in installed capacity for fossil sectors and meet the estimated electricity demand for the year 2040.
Data Set 10	Installed Capacity Report by Primary Sources: Installed capacity information by source for the year 2022 (MW)	Turkish Electricity Transmission Company	Calculate the increase in installed capacity for solar and wind energy alongside the decrease in installed capacity for fossil sectors and meet the estimated electricity demand for 2030.
Data Set 11	2020-2022 National Energy Balance Table: Imported energy by source for the year 2020-2022 (Thousand TOE)	Ministry of Energy and Natural Resources	Calculate the increase in installed capacity for solar and wind energy alongside the decrease in installed capacity for fossil sectors and meet the estimated electricity demand for 2030.
Data Set 12	2022 Electricity Production Consumption Report: Electricity production information by source for the year 2020/2021 (TWh)	Turkish Electricity Transmission Company	Calculate the increase in installed capacity for solar and wind energy alongside the decrease in installed capacity for fossil sectors and meet the estimated electricity demand for 2030.
Data Set 13	2022 National Energy Balance Table: Imported energy by source for the year 2020/2022 (Thousand TOE	Ministry of Energy and Natural Resources	Calculate the changes in imported energy quantity and amount according to capacity increase and domestic/imported input usage scenarios.
Data Set 14	2000-2023 Imports by Chapters: Chapter 27: Mineral fuels, mineral oils and products of their distillation, bituminous substances, mineral waxes	TCMB – EVDS	Calculate the changes in imported energy quantity and amount according to capacity increase and domestic/imported input usage scenarios.
Data Set 15	Energy Technologies Investment Cost Vectors: Cost Components of Solar, Wind, and Coal Technologies	Literature, Sectoral Reports	To generate demand vectors for the input-output methodology.

Leontieff inverse matrix and derivation of requirement matrices

In the I-O tables, the total production in sector i, denoted by Xi, is the sum of intermediate input production (Zij) and total final demand (including consumption, investment, government spending, and net exports, denoted by fi). This setup illustrates a linear production function technology. According to Leontieff's analysis, the total production function for sector i is expressed using the following equations (Miller and Blair 2009):

X1= z11 + z12 +… + z1j + … + z1n + f1

X2= z21 + z22 +… + z2j + … + z2n + f2

Xi= zi1 + zi2 +… + zij + … + zin + fi

Xn= zn1 + zn2 +… + zni + … + znn + fn **(1.1)**

The matrix form of the above equations can be written as:

X= Zi + f, and Z is denoted by Z= $\begin{bmatrix} z_{11} & \cdots & z_{1n} \\ \vdots & \ddots & \vdots \\ z_{n1} & \cdots & z_{nn} \end{bmatrix}$ (n x n) matrix, f is denoted by $\begin{bmatrix} f_1 \\ f_2 \\ . \\ f_n \end{bmatrix}$ (n x 1) matrix and X is denoted by $\begin{bmatrix} x_1 \\ x_2 \\ . \\ x_n \end{bmatrix}$ (1 x n) matrix, where Z reflect all the inter-industry input-output relations**(1.2)**

between the sectors, f is the final demand for all sectors, i.e., the investment amount for each sector, and X is the total output of each sector. The input-output methodology enables the assessment of the impact of the final demand (f) deviations on inter-industry production decisions using the Leontief Inverse Matrix. To obtain the Leontief Inverse Matrix, Equation (1.1) should be converted into a matrix, where each item of the matrix refers to a technical coefficient a_ij, computed according to the following equation:

a_ijj = z_ij/Xj. **(1.3)**

The technical coefficient is calculated by dividing the inputs produced by sector i and purchased by sector j by the total output of sector j, representing a fixed relationship.

In equation (1.2), the value zij is replaced with ($aij*xj$), updating equation 1.1 as follows (Equation 1.4), and can then be written in matrix form (Equation 1.5):

X1= (a_11 * x_1) + (a_12 * x_2) +… + (a_1n * x_n) + f1

X2= (a_21 * x_1) + (a_22 * x_2) +… + (a_2n * x_n) + f2

..

Xn= (a_n1 * x_1) + (a_n2 * x_2) +… + (a_nn * x_n) + fn **(1.4)**

(1.5) X= AX + f where A represents $\begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix}$ (n x n) matrix, f; $\begin{bmatrix} f_1 \\ f_2 \\ . \\ f_n \end{bmatrix}$ (n x 1) matrix

and X; $\begin{bmatrix} x_1 \\ x_2 \\ . \\ x_n \end{bmatrix}$ (1 x n) matrix (Miller and Blair, 2009).

Equation 1.5 can be defined as (1.6a) by using simple algebraic operations:

X-AX= f ➔ X = $(I-A)^{-1}$ where $\mathbf{(I-A)^{-1}}$ is the Leontieff inverse matrix and denoted by L from now on. **(1.6a)**

In the literature, there are two typical applications for assessing the impacts of renewable energy industry investments through input-output analysis: integrating new sectors with all their input-output relationships into the existing table or adding renewable energy investments as a demand shock to the analysis (Miller and Blair 2009; Garrett-Peltier et al. 2015). The first approach integrates renewable energy sectors as new industries into the existing input-output table by proportionally updating the shares of existing industries. However, this approach is complex and time-consuming, producing unsatisfactory results, and is deemed suitable for economies where the structure of the renewable energy industry significantly differs from that of the manufacturing industry (O'Sullivan and Edler, 2020). The second approach partially integrates renewable energy sectors into the existing industrial structure; it assumes that the renewable energy industry uses outputs from existing industries in its production process but does not sell its output to the existing sectors (Miller and Blair, 2009). This study employs the second approach, the synthetic industry or final demand approach (Garrett-Peltier, 2017).

Therefore, we can calculate the impact of investments on each sector's total output by using

$\Delta X = L*\Delta f$ **(1.7)**

Leontieff Inverse Matrices can also be used to examine the effects of changes in final demand on employment or emissions in the economy. The Leontieff Inverse Matrix transforms into the employment/emission requirements matrix ERM (equation 1.8) by multiplying the matrix with the employment/emission to output ratio of each sector available in the I-O table.

$$ERM = (E/O) \times L \quad \textbf{(1.8)}$$

Total changes can be represented by

$$\Delta E = ERM \ \mathbf{x} \ \Delta f \quad \textbf{(1.9)}$$

where ΔE represents the total change in employment/emission levels in each sector, resulting from changes in final demand, (Δf). The final demand vector is the sectoral cost composition of each energy investment.