Resilient, Green and Transformative Development in Asian Belt and Road Countries

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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.

Overview

Main Goals:

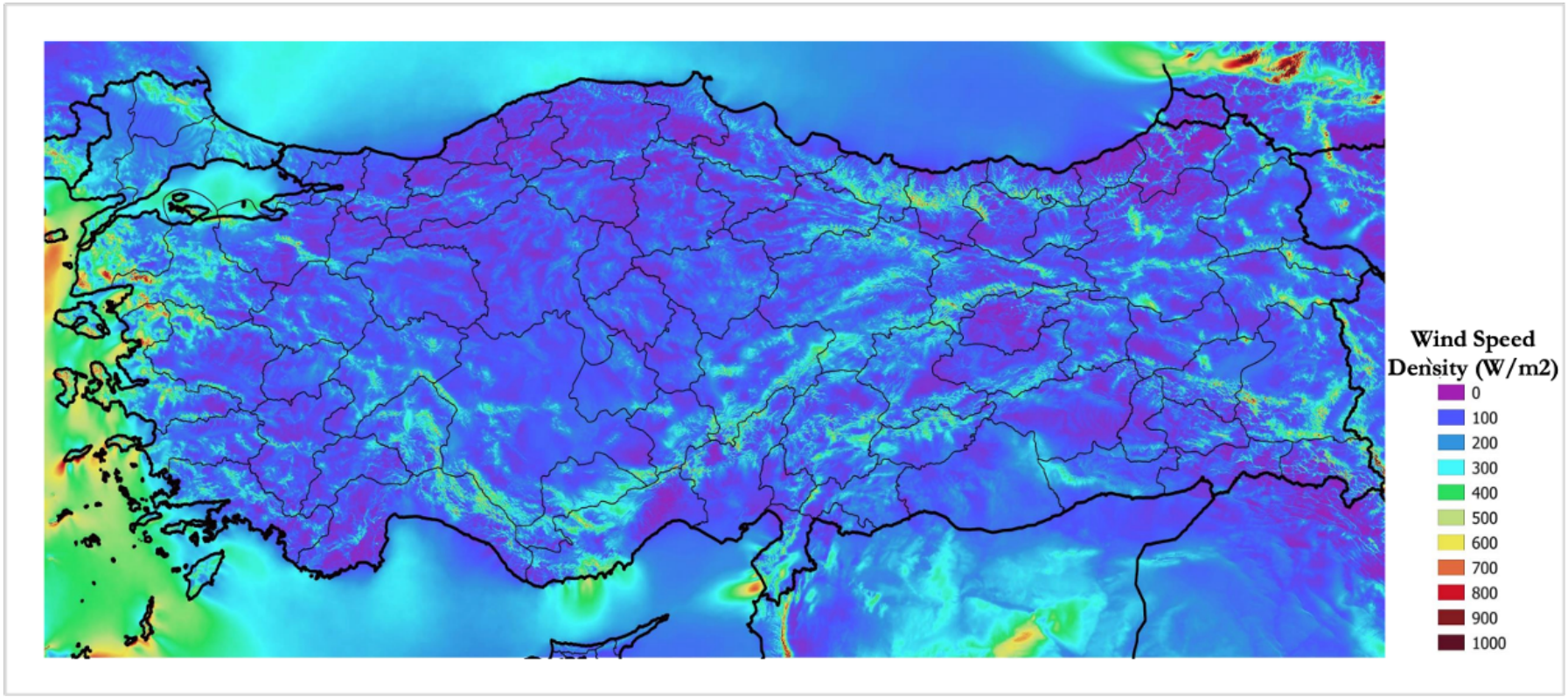
- Analyze potential macroeconomic impacts of renewable energy investments.
- Compare scenarios: **“Business as usual”** vs. **“Green development.”**
- Focus areas: Growth, employment, emissions, and current account balance.

Electricity Outlook

	Wind Onshore	Solar PV	Domestic Coal	Imported Coal
Installed capacity 2024 (MW)	12,864	19,882	11,475	10,456
Electricity production 2024 (TWh)	33.1	23.6	41.2	68.1
Share in total production (%)	10.6	7.6	13.2	21.8
Licensed production[1] (%)	99.4	17.7	93.7	100.0
Unlicensed production (%)	0.5	82.2	0.0	0.0
Owned by EÜAŞ[2] (%)	0.1	0.0	6.3	0.0

[1] Includes private electricity generation companies and built-operate-transfer power plants.
[2] The Electricity Generation Company, The Ministry of Energy and Natural Resources, Republic of Türkiye.

Average Wind Speed Density (W/m^2)



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

Wind Energy in Türkiye: Key Insights

Regional Distribution:

- Marmara Region leads with 44% of total production capacity and Aegean Region follows with 36.5%.
- İzmir, Balıkesir, and Çanakkale together host 4.5 GW wind power plants and are the top cities exporting wind manufacturing equipment.
- The region also hosts the first wind measurement mast, turbine, and power plant, facilities like blade and tower factories, turbine maintenance, repair centers, and R&D.

Economic Impact[1]:

- İzmir alone contributes to 85% of total wind exports and supports 7,500 jobs.
- 25,000 jobs in wind industry equipment manufacturing nationwide.

Top Investors:

- Polat Energy with 6.11% (711.4 MW), Borusan Energy with 5.63%, Güriş A.Ş. with 5.49%, Demirer Energy with 5% and Fiba Renewable Energy with 4.75%.

[1] Data source: Turkish Wind Energy Association, TUREB, 2024.

Wind Turbine Systems and Domestic Production

Türkiye's Current Status:

- Momentum gained in equipment development and production.
- Equipment for utility-scale onshore power plants predominantly imported.

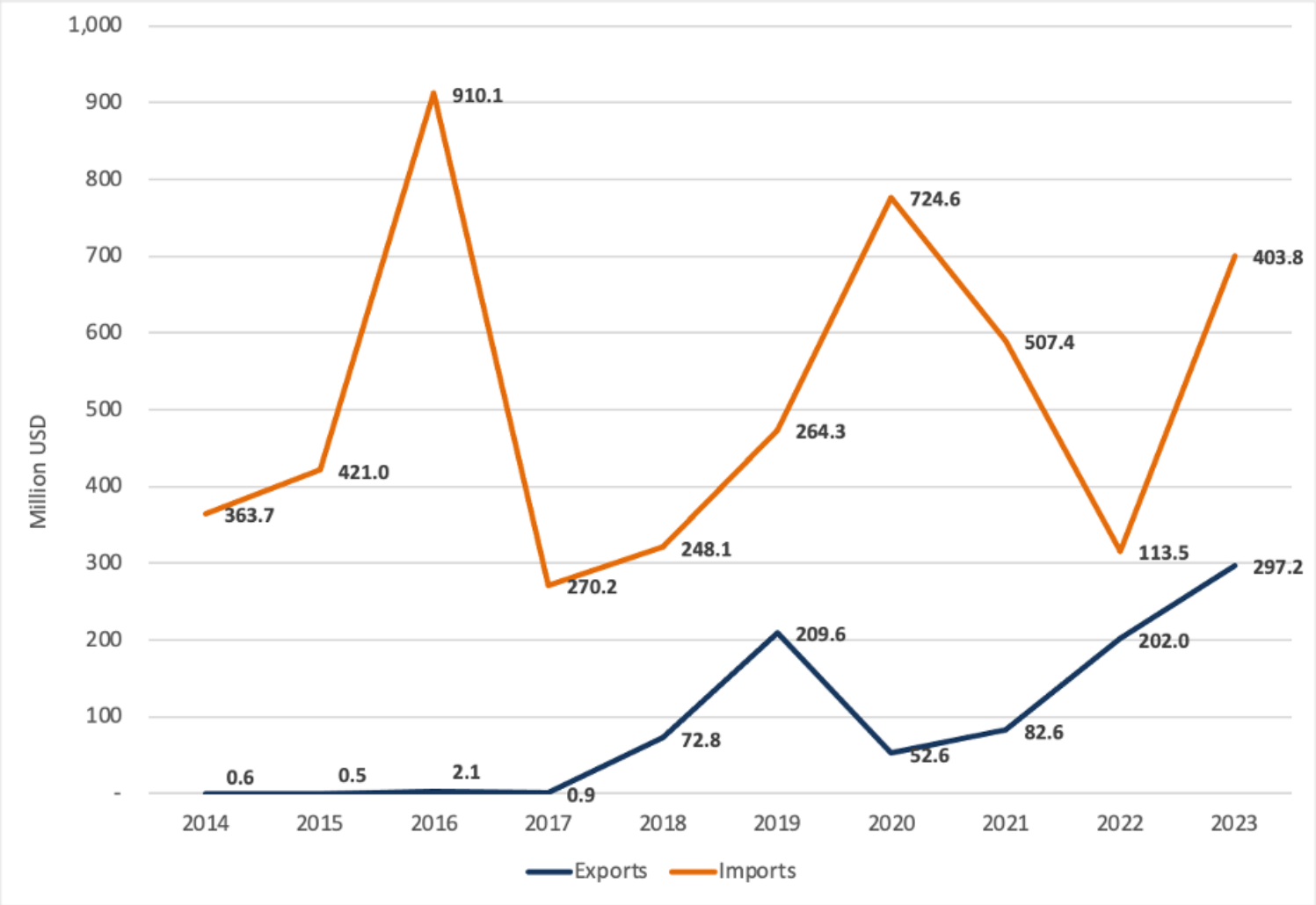
Key Manufacturers:

- Nordex 29.3%, GE 20.1%, Enercon 19.2%, Vestas 17.6%, Siemens 11.8.

Local Production, Alaçatı Wind Power Plant (2024):

- 65% domestic content achieved.
- Locally produced turbines by Aselsan with 100 m. of tower height 100 and 136 m. of rotor diameter.
- Equipped with Aselsan-produced power converters and generators.
- Strategic priority to enhance domestic production capabilities.

Wind Energy - Exports and Imports



Notes:
Included units are Wind-powered engines and power-generating machines, components and parts of wind-powered engines and machines, electric power generation units operating with wind output power

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

Export Potential and Trade Dynamics

Wind Energy Equipment Exports[2]

- Exports rise to $297.2 million in 2023, up from $0.6 million in 2014.
- Top Export Destinations are Denmark 36%, Finland 24%, Germany 15%.

Wind Energy Equipment Imports:

- Exhibits significant volatility over the years, fluctuating between $113 million and $910 million between 2014 and 2023.
- Total imports is $403 million in 2023.
- Major suppliers are Germany 65%, China 17%, Spain 8%.

Comparative Insights:

- The exports-to-imports ratio is improving, but imports remain substantial and highly sensitive to exchange rate fluctuations.
- Domestic production can be prioritized to address trade imbalances.

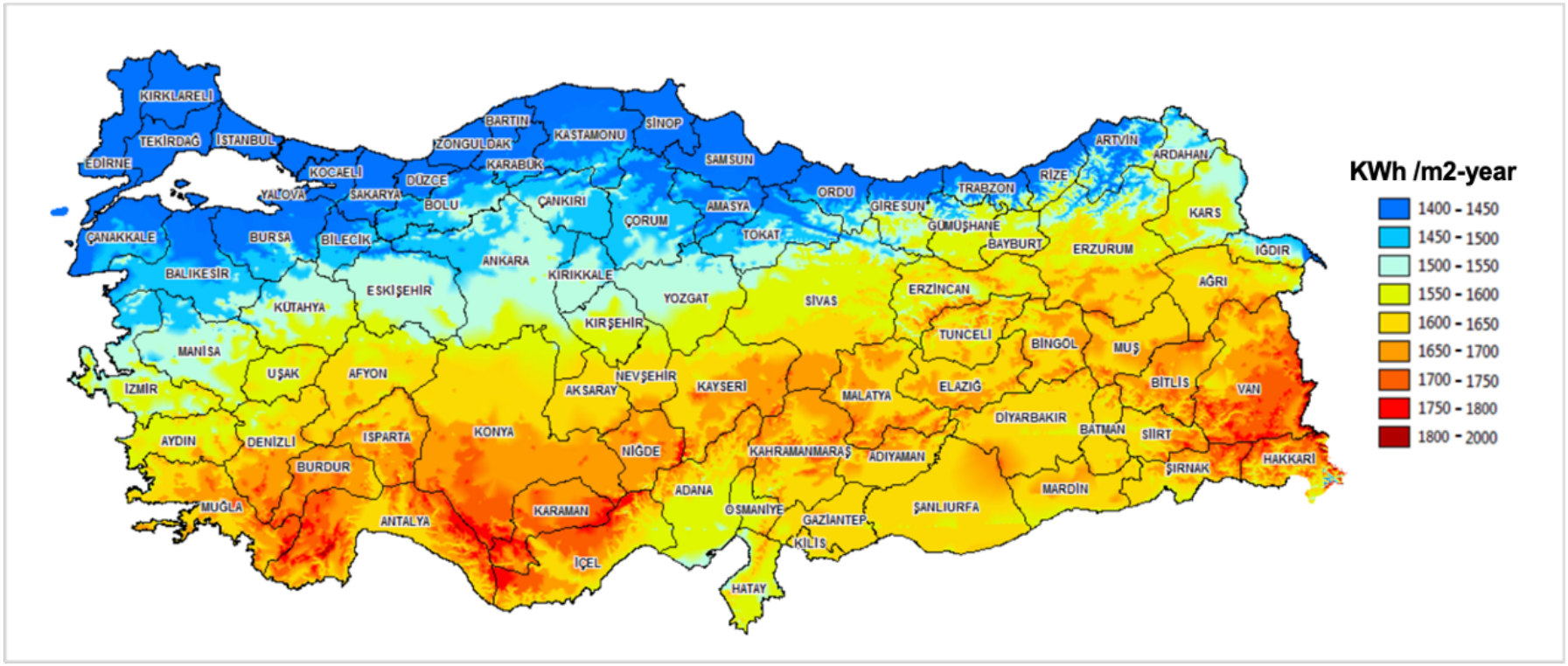
[2] Wind-powered engines and power-generating machines, their components and parts, and electric power generation units

Wind Energy Outlook

Category	Details
Electricity Production (2023)	33.9 TWh, 10.5% of total electricity produced
Potential	Over 100,000 MW
Regional Production Leaders	Marmara (44%), Aegean (36.5%)
Imports (2023)	403 million USD
Exports (2023)	297 million USD
Top Export Destinations	Denmark (36%), Finland (24%), Germany (15%)
Top Import Destinations	Germany (65%), China (17%), Spain (9%)
Key Challenges	High reliance on imported equipment

Notes:
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 ¡ 100 kVA; excluding those for civil aircraft, 850231002200 - Electric power generation (electrogene) units operating with wind output power = 100 kVA; excluding those for civil aviation, 850231002300 - Electric power generation (electrogene) units operating with wind output power = 100 kVA; excluding those for civil aircraft.
Source:
Republic of Türkiye, Turkish Statistical Institute, Special Trade System Database, Imports and Exports by Chapters and Countries.

Photovoltaic Power Potential



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

Solar Energy in Turkey: Key Insights

Production Capacity:

- Applications for Unlicensed Solar Power Plants reached 35 GW by the end of 2023 (PwC, 2024; Ata, 2023).
- 8.6 GW of installed capacity increase in 2023.

Major Manufacturers (Panel & Cell Production Capacity):

- Kalyon PV with 2.0 GW panel capacity. and 1.2 GW cell capacity.
- Smart Güneş with 2.9 GW panel capacity and 2.0 GW cell capacity.
- Sirius & CM Energy with 3.5 GW panel capacity.

Factors Driving Growth:

- High solar radiation potential.
- Implementation of tariffs and anti-dumping measures for domestic production.
- Diversification by Turkish manufacturers into solar panel parts.

Solar Energy Systems and Production

Cell Production:

- Kalyon Energy owns the fully integrated solar panel production facility.
- First in Türkiye and Europe to integrate upstream and downstream production.
- Relies on imported polysilicon (mainly from China).
- Higher than 80% domestic input ratio.

Battery Investments:

- Aspilsan launched the first lithium-ion battery mass production facility (2020).
- Supports solar energy storage.
- Pomega starts an ongoing battery investment project, with 3GW storage capacity.

Challenges and Opportunities:

- Heavy reliance on imported polysilicon.
- Growing domestic manufacturing facilities seen as a strategic priority.

Export Potential and Trade Dynamics

Solar panel and cell exports:

- Photovoltaic panel and cell exports reached $460 million in 2023, mainly driven by Kalyon Energy.
- 90% of exports are directed to the USA.

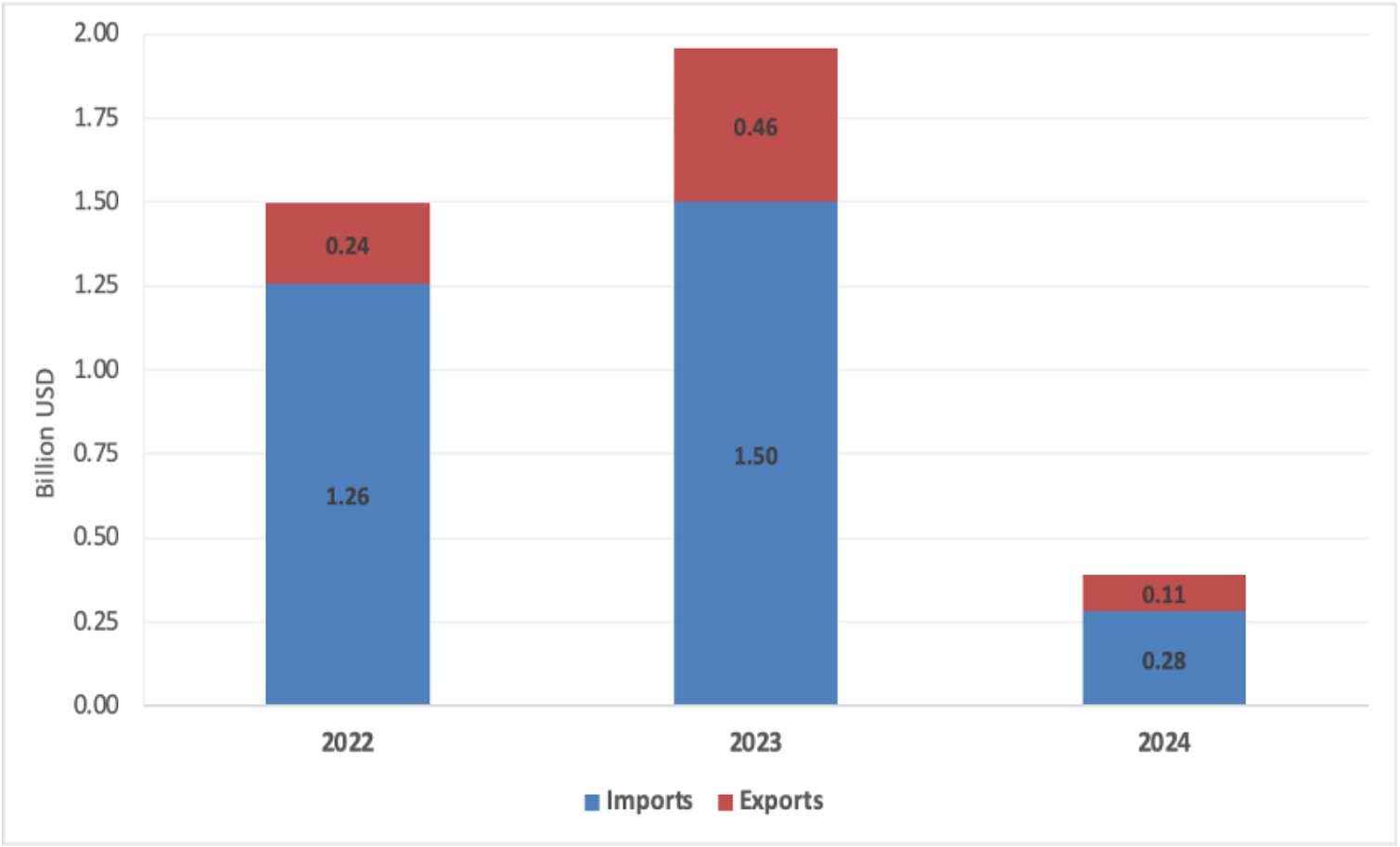
Solar panel and cell imports:

- Total PV panel and cell imports reached $1.5 billion in 2023.
- Major suppliers are China 82%, Malaysia 7%, Vietnam 8%.

Comparative Insights:

- Türkiye's manufacturing sector positioned as a link in the global PV supply chain.
- High trade volume with China; proximity to Europe offers strategic advantages.
- Significant potential to reduce import dependency by boosting domestic capacity.

Solar Energy - Exports and Imports



Notes:
Included units are Photovoltaic cells assembled in modules or made up into panels, photovoltaic cells not assembled in modules or made up into panels, and aluminium frames for photovoltaic panels
Source:
Republic of Türkiye, Turkish Statistical Institute, Special Trade System Database, Imports and Exports.

Solar Energy Outlook

Category	Details
Electricity Production (2023)	13.9 TWh, 5.8% of total electricity produced
Potential	Annual sunshine of 2,741 hours and 1,527.46 kWh/m2 radiation value
Regional Production Leaders	Central and Southern Türkiye (Konya, Sanliurfa, Kayseri)
Imports (2023)	1.5 billion USD
Exports (2023)	460 million USD
Top Export Destinations	USA (90%), Europe
Top Import Destinations	China (82%), Vietnam (8%), Malaysia (7%)
Key Challenges	High dependency on imported polysilicon and other components from China.

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

Employment and Sectoral Insights

Employment Contributions:

- Solar Energy:
  - Over 50,000 jobs in solar energy (Solar Power Europe, 2024).
  - Largest segment: Security roles (32.5%) fixed per plant.
  - Skill levels are high with 36%, medium with 51%, and low with 13%.
- Wind Energy employs 25,000 people (TUREB, 2024).

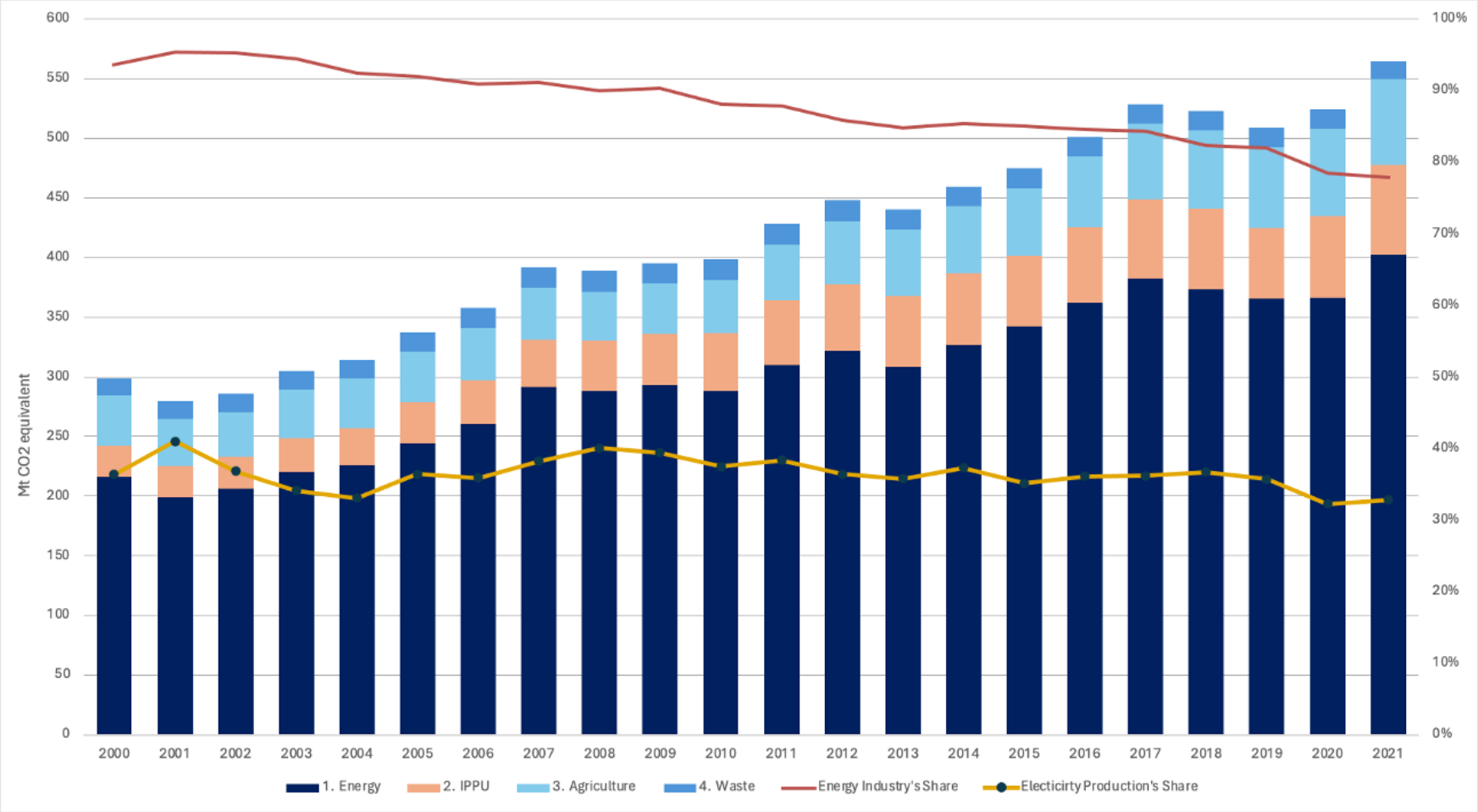
Competency Needs and Growth Potential:

- Need of technical expertise in battery storage integration with PV systems.
- Proficiency in design, installation, maintenance, and repair of innovative systems.
- Significant room for domestic manufacturing expansion.

Challanges:

- High dependency on imports.
- Exchange rate volatility.
- Earthquake zones.

Emissions Outlook



Note:
Aggregate GHG emissions with LULUCF, Türkiye
Source:
United Nations Framework Convention on Climate Change, UNFCCC. `https://di.unfccc.int/detailed_data_by_party`.

Current Account Balance and Energy Imports

Year	Exports	Imports	Goods Balance	Goods & Services Balance	Goods Balance Excl. Energy Imports	Energy Imports	Energy Exports	Energy Trade Balance
2014	173.3	239.9	-66.6	-25.4	-10.4	56.2	7.5	-48.7
2015	154.9	203.9	-49.0	-13.1	-10.4	38.7	5.1	-33.5
2016	152.6	192.6	-39.9	-14.5	-12.5	27.5	3.4	-24.1
2017	169.2	227.8	-58.6	-26.9	-20.9	37.7	4.8	-32.9
2018	178.9	219.6	-40.7	-4.3	2.9	43.6	5.8	-37.8
2019	182.2	199.0	-16.8	26.0	25.0	41.7	8.4	-33.3
2020	168.4	206.3	-37.9	-22.7	-8.9	28.9	4.7	-24.2
2021	224.7	254.0	-29.3	3.3	21.4	50.7	8.5	-42.2
2022	253.4	342.9	-89.6	-37.5	7.0	96.5	16.4	-80.1
2023	251.0	337.3	-86.3	-29.6	-17.2	69.1	16.4	-52.7
2014-23 Avg.	190.9	242.3	-51.5	-14.5	-2.4	49.1	8.1	-40.9

Note: Data represents trade metrics (in billion USD) from 2014 to 2023.

Literature Review - Employment Impacts

Methodology	Policy Instruments	Country	Results	Studies
The EFA	Renewable Energy and Energy Efficiency Investments	United States, Europe, Organization for Economic Co-operation and Development (OECD), South Africa	Lower employment multipliers in developed countries	Wei et al. 2010; Rutovitz 2010; Maia et al. 2011; Ortega et al. 2015; Malik et al. 2021
The I-O Method	Renewable Energy, Energy Efficiency Investments	Portugal, Greece, United States, Australia, S. Korea, Brazil, Indonesia, Germany, Italy, South Africa, Turkey	- Investing 1 to 1.5% of GDP annually generates 0.5 to 1.5% increase in employment despite the retrenchment in coal industry (Garrett-Peltier et al. 2015). - Higher indirect employment effects than direct employment. - Higher employment impact in developing countries than in developed ones.	Malik et al. 2014; Garrett-Peltier et al. 2015; Garrett-Peltier 2017; O'Sullivan and Edler 2020; Dell'Anna 2021; ILO & UNDP 2022
Complex Macroeconomic Models	Taxing pollution, lump-sum tax, consumption tax, caps & dividends, feed-in-tariff policy with consumer tax, and subsidies for	Canada, Turkey, Malaysia, Nigeria, China	Results depend on assumptions in models or specific parameter values, such as tax revenue recycling (both positive and negative).	Bouzaher, Şahin, and Yeldan 2015; Chatri et al. 2018; Mu et al. 2018; Omoju et al. 2020

Methodology Overview

- Input-Output Analysis Framework
  - Updating I-O Tables using naive RAS Technique
- Measurement of employment, value-added, and output and emission multipliers
- Determining the final demand, i.e., sectoral composition of energy investments

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

Note: Installed costs and operation & maintenance costs for various energy technologies.

National Targets

- Under the 12th Development Plan and the National Energy Plan (Ministry of Energy and Natural Resources, 2022), Türkiye has set ambitious goals for expanding renewable energy capacity:
  - **By 2035 (National Energy Plan, 2022):**
    - Solar PV capacity: 52.9 GW.
    - Onshore wind capacity: 29.6 GW.
  - **By 2028 (12th Development Plan):**
    - Solar PV capacity: 30.0 GW.
    - Onshore wind capacity: 18.0 GW.
- These targets form the foundation of Türkiye's green growth scenario, emphasizing sustainable energy development.

Scenarios

Scenario	Description	Installed Capacity (2040)	Key Details
Scenario 1: Business as Usual	Continuation of recent trends in fossil fuel use	Solar: 39.4 GW, Wind: 29.7 GW	Heavy reliance on fossil fuels, slower renewable energy adoption.
Scenario 2.1: Green Development (Aggressive Policy)	Reduction on fossil fuel, increase on solar and wind production	Solar: 65 GW, Wind: 34.7 GW	Focus on boosting local manufacturing and minimizing import reliance.
Scenario 2.2: Green Development (Conservative Policy)	Reduction on fossil fuel, increase on solar and wind production	Solar: 65 GW, Wind: 34.7 GW	Greater dependency on imported components for scaling renewable capacity.

Results

Metrics	Scenario 1	Scenario 2.1	Scenario 2.2	Difference
Total Production (Billion USD)	145.4	123.4	109.5	(22.0)
Net Value-Added (Billion USD)	45	38	33	(7)
Net Employment (Million Jobs)	1.3	1.3	1.2	(0.01)
Net Foregone CO2 Emissions (Million Tons CO2-eq)	(480.8)	(824.8)	(826.6)	(344.0)
Net Coal Imports (Million Tons)	156	(197)	(197)	(353)
Current Account Impact (Billion USD)	23.4	(29.5)	(29.5)	(52.9)
Import Impact (Billion USD)	23.3	22.7	22.7	(0.6)
Net CA Impact (Billion USD)	46.7	(6.8)	(6.8)	(53.5)

Conclusion

- Green transition scenarios reduce emissions and improve the current account balance.
- Net employment impact is manageable with targeted policies.
- Scaling up domestic production (Scenario 2.1) offers better long-term benefits.

Thank You

Appendix

Data Sets	Data	Objective
Data Set 1	2012 Input-Output Table - Technical Coefficients of inter-sectoral relationship	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 2	2020 Input-Output Table (Calculated) - Sectoral Value Added - Sectoral GDP - Central Government Budget Revenues (Value-added Tax and Excise Tax) - Sectoral Value Added	To update the 2012 Input-output table to 2020 values.
Data Set 3	2020 Sector-Based (Nace Rev2-2 digit) Employment Data - Employment/Production Coefficient	To convert the input-output table into an employment requirement table.

Data Sources (continued)

Data Sets	Data	Objective
Data Set 4	2020 Sector-Based (Nace Rev2-2 digit) Value-Added Data - Value-Added/Production Coefficient	To convert the input-output table into a value-added requirement table.
Data Set 5	2020 Sector-Based (Nace Rev2) Emission Data - Emission/Production Coefficient	To convert the input-output table into an emission requirement table.
Data Set 6	2020 - Production, import, export, delivery, and stock change quantities of solid fuels	To estimate the reduction in imported coal usage.
Data Set 7	2020 Marginal Emission Factors	To calculate the emission reduction effect of electricity production from renewable energy sources.
Data Set 8	2032 Gross Electricity Demand Projection - 2032 electricity demand (TWh) - Annual increase rate of electricity demand for 2020-2040 (%)	To calculate the increase in installed capacity for solar and wind energy alongside the decrease in installed capacity for fossil sectors and to meet the estimated electricity demand for 2030.

Data Sources (continued)

Data Sets	Data	Objective
Data Set 9	2010-2022 National Energy Balance Table - Imported energy by source for the year 2010/2022 (Thousand tonnes-of-oil equivalent - TOE)	To calculate the increase in installed capacity for solar and wind energy alongside the decrease in installed capacity for fossil sectors and to meet the estimated electricity demand for 2030.
Data Set 10	2020 National Energy Balance Table - Imported energy by source for the year 2020/2022 (Thousand TOE)	To calculate the changes in imported energy quantity and amount according to capacity increase and domestic/imported input usage scenarios.
Data Set 11	Current Account, Non-Monetary Gold, and Energy Foreign Trade	To calculate the changes in imported energy quantity and amount according to capacity increase and domestic/imported input usage scenarios.
Data Set 12	Import according to the International Standard Industrial Classification (SITC, Rev.4) - Mineral fuels, oils, and alkaline products	To calculate the changes in imported energy quantity and amount according to capacity increase and domestic/imported input usage scenarios.