SHURA
ENERGY TRANSITION CENTER

NET ZERO 2053: THE SOCIOECONOMIC IMPACT OF TRANSITIONING TO CARBON-FREE ENERGY IN TÜRKİYE

About SHURA Energy Transition Center

SHURA Energy Transition Center, founded by the European Climate Foundation (ECF), Agora Energiewende, and Istanbul Policy Center (IPC) at Sabancı University, contributes to the decarbonisation of the energy sector via an innovative energy transition platform. It caters to the need for a sustainable and broadly recognized platform for discussions on technological, economic, and policy aspects of Türkiye's energy sector. SHURA supports the debate on the transition to a low-carbon energy system through energy efficiency and renewable energy by using fact-based analysis and the best available data. Taking into account all relevant perspectives by a multitude of stakeholders, it contributes to an enhanced understanding of the economic potential, technical feasibility, and the relevant policy tools for this transition.

Authors: Iannis Charalampidis (E3M Modelling) and Yael Taranto (SHURA)

Acknowledgments

Leonidas Paroussos (E3M Modeling) provided consultancy and support in the preparation of the report, modeling and results assessment. Prof. Dr. Erinç Yeldan (Kadir Has University), Gülay Dinçel (Economist/ Senior Consultant), Karin Kritzinger (Agora Energiewende) and Prof. Dr. Sevil Acar (Boğaziçi University) reviewed draft texts at various stages of the study and provided feedback. Alkım Bağ Güllü (SHURA), Hasan Aksoy (SHURA) and Selahattin Hakman (Head of SHURA Steering Committee) reviewed the report and provided guidance and feedback. We are grateful for all the reviews, opinions and feedback provided.

SHURA Energy Transition Center is grateful to the generous funding provided by the ECF.
This report can be downloaded from www.shura.org.tr

For further information or to provide feedback, please contact the SHURA team at info@shura.org.tr

Design

Tasarımhane Tanıtım Ltd. Şti.

Disclaimer

This report and the assumptions made within the scope of the study have been drafted based on different scenarios and market conditions as of end 2023. Since these assumptions, scenarios, and the market conditions are subject to change, it is not warranted that the forecasts in this report will be the same as the actual figures. The institutions and the persons who have contributed to the preparation of this report cannot be held responsible for any commercial gains or losses that may arise from the divergence between the forecasts in the report and the actual values.

NET ZERO 2053: THE SOCIOECONOMIC IMPACT OF TRANSITIONING TO CARBON-FREE ENERGY IN TÜRKİYE

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

BAU	Business as Usual
BEV	Battery Electric Vehicles
CAPEX	Capital Expenditure
CBAM	Carbon Border Adjustment Mechanism
CCS	Carbon Capture and Storage
CGE	Computable General Equilibrium
CH_4	Methane
CO_2	Carbon Dioxide
EU	European Union
EUR	Euro
GDP	Gross Domestic Product
GW	Gigawatt
ICE	Internal Combustion Engine
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
MWh	Megawatt-hour
N_2O	Nitrous Oxide
NGO	Non-Governmental Organization
NZ2053	Net Zero 2053
OPEX	Operational Expenditure
PHV	Plug-in Hybrid Vehicle
PPP	Purchasing Power Parity
PV	Photovoltaic
R&D	Research and Development
RES	Renewable Energy Sources
SAM	Social Accounting Matrix
TWh	Terawatt-hour
USD	United States Dollar

Key Messages

- The net-zero pathway foreseen for Türkiye implies a major transformation not just of the energy system but also of industrial composition and modes of transportation. The impact of the energy transition aspect on GDP and overall employment is calculated to be mostly positive, in the range of –0.2% to 2.1% of baseline GDP, and in the range of 1.6% to 6.2% of baseline employment.

- The use of revolving medium- and long-term financing for energy transition investments will enhance the positive impacts on GDP and employment by preventing energy transition investments from crowding out investments in other sectors. Access to financing will be a key element in maximizing the benefits of the energy transition. GDP will be 1.6% higher with external financing compared to a self-financing scenario.

- Sticky wages—in other words, adjustments related only to skill levels and productivity rather than supply-demand or distributional policies—are found to have an additional positive impact of 0.6% on GDP. While employment is 2.9% to 4.6% higher with sticky wages, the desirability of lower wages in exchange for higher employment is questionable from a social perspective. Carefully designed just transition policies for employment and wage protection need to be an integral part of the transition.

- Production gains in manufacturing related to clean energy will compensate in large part for losses in traditional and fossil fuel-related manufacturing, resulting in a relatively small overall impact in the range of –2.2% to –0.1%. Access to finance, contributing 1.6 percentage points, will be key to minimizing negative impacts. A balanced industrial policy with due attention to strategic manufacturing areas and just transition principles will be key to transitioning toward a viable zero-carbon economy.

- Reduced import dependency in energy will be one of the most visible impacts of the energy transition. The significant decrease in energy imports is expected to exceed increased equipment imports related to the transition process, generating a cumulative positive trade balance impact equivalent to 1.8% of GDP. While the overall trade balance will be unimpacted, significant upside potential in exports of clean energy equipment and downside potential in imports exist with the implementation of strategic trade and industrial policies.

- The overall cumulative benefits of the transition will be around twice as much as the costs. Total average annual benefits over 2020–2055 are estimated at around USD 51.4 billion against an estimated cost of USD 26 billion. Over 55% the total benefits stem from social welfare impacts (health, environment, and climate change) related to avoided air pollution and carbon emissions.

Executive Summary

In November 2021, Türkiye declared a net-zero emissions target for 2053. Achievement of the target requires a major realignment of not only the energy system but also major demand sectors such as industry, transport, and buildings. In February 2023, the SHURA Energy Transition Center published a roadmap for the decarbonization of Türkiye's power sector entitled Net Zero 2053: A Roadmap for Türkiye's Power Sector. The roadmap included the decarbonization of end-use sectors as well as their electrification, which is an essential component of achieving the net-zero target and is closely related to the planning of the power sector (SHURA, 2023).

It is important to assess the socioeconomic impact of such a major shift in the energy system not only to compensate for any possible negative impacts but also to be able to implement the right policies to make the transition possible. While a previous SHURA study on the socioeconomic impact of a partial transition vision for Türkiye by 2030 and numerous international studies find that the overall impact of a low-carbon energy transition on gross domestic product (GDP) and total employment is generally small and positive (SHURA, 2021), it has been necessary to perform a more comprehensive analysis in light of the net-zero emissions target by mid-century. This study aims to quantify the impact of the net-zero power system transition on national income, employment, and industrial sectors in order to guide the necessary policy actions to maximize the benefits of the transition while minimizing or eliminating potential risks. It is intended as a tool for a more in-depth policy discussion of the relevant socioeconomic issues in order to enable a just transition.

Scenarios

The Net Zero 2053 (NZ2053) Scenario, which encompasses the actions, investments, and main assumptions related to the achievement of Türkiye's net-zero emissions target by 2053, has been taken from SHURA's *Net Zero 2053: A Roadmap for Türkiye's Power Sector* study (SHURA, 2023). The current study on the socioeconomic impact of the net-zero transition aims to measure the impacts of the transition described in the NZ2053 scenario. For this purpose, the following net-zero (NETZERO) scenario variants involving a central scenario, and sensitivity analyses were designed to be compared with a baseline scenario.

Baseline scenario: Türkiye's real GDP grows with an average annual rate of 3.3% between 2020 and 2050. Population is expected to grow by 15%, reaching almost 100 million people in 2055. For the purpose of the net-zero study, the reference (baseline) scenario was constructed in a way that would facilitate the dual goals of higher value-added and lower energy/carbon intensity. Similarly, transport modes in the Baseline scenario emphasize less carbon-intensive rail and sea transport over land and air transport where possible.[1]

[1] For more detail on the Baseline Scenario, see https://shura.org.tr/en/net-zero-2053-a-roadmap-for-the-turkish-electricity-sector/

Net-Zero scenario: The goal to reach net-zero carbon emissions by 2053 is made possible for Türkiye through the displacement of fossil fuels by renewable energy, improved energy efficiency, and increased electrification in end-use sectors. Under the Net Zero 2053 (NZ2053) scenario, total carbon emissions peak in 2025, and in 2035 they reduce to 62.8% of 2025 levels. Final energy consumption reverts back to 2020 levels after peaking in 2030; power generation more than triples.

As the Baseline scenario includes adjustments in the composition of the current industrial and transport sectors to support decarbonization, the Net-Zero Scenario focuses exclusively on measuring the impacts of the energy transition.

Carbon pricing, at the same level in both the Baseline and the Net-Zero scenarios, is assumed to have a neutral effect on public financing in all scenarios. No additional enabling conditions (such as circular economy, major behavioural changes, etc.) are assumed in any of the scenarios.

Both the Baseline and the central Net-Zero scenario, denoted NETZERO, assume that investments are financed by loans, which are fully repaid after ten years with an interest rate of 5%. In both the Baseline and NETZERO, labour markets are assumed to be flexible, adjusting to demand and supply.

Several sensitivity scenarios in the Net-Zero case are assumed, as summarized in Table ES1:

Table ES1. Summary of baseline and net-zero scenario variants

	Baseline	NETZERO	NETZERO_FI	NETZERO_CO	NETZERO_TT	NETZERO_TT_FI	NETZERO_TT_CO
Financing	Financing with repayment	Financing with repayment	Revolving financing	Self-financing	Financing with repayment	Revolving Financing	Self-financing
Labour Market	Flexible	Flexible	Flexible	Flexible	Sticky Wages	Sticky Wages	Sticky Wages

- **NETZERO (the central scenario):** Investments in power generation and the grid are financed through loans that are repaid in subsequent periods at a given interest rate.
- **NETZERO_FI:** Loan-based, revolving financing scenario—increasing debt with no repayment within the simulation period.
- **NETZERO_CO:** self-financing scenario; no loans assumed, investments in other sectors are crowded out.
- **NETZERO_TT:** financing with repayment and sticky wages.
- **NETZERO_TT_FI:** loan-based, revolving financing scenario with sticky wages.
- **NETZERO_TT_CO:** self-financing scenario with sticky wages.

Impact Summary

Between 2020 and 2055, GDP, wages, and total employment are projected to increase in real terms under both the baseline and net-zero scenarios. Specifically, GDP is expected to grow 2.7-fold, with employment rising by 6.4 million people in the Baseline scenario and 6.8 million in the central net-zero scenario. This indicates no absolute losses in either scenario. The impact of the transition is assessed by comparing the differences between the baseline and net-zero scenarios.

Table ES2. Impact summary table NETZERO (central case) in comparison to the baseline scenario

As Percentage of Baseline GDP*	Cumulative (2021-2055)	2030	2040	2055
National Income Impact (GDP)	**1.4%**	**0.5%**	**0.8%**	**3.0%**
Manufacturing Impact	**-0.6%**	**-0.3%**	**-0.3%**	**-0.8%**
Overall International Trade Balance Impact	**0.0%**	**-0.1%**	**-0.1%**	**-0.3%**
Total Energy Security Impact	**1.8%**	**0.6%**	**1.9%**	**2.4%**
Socioeconomic Welfare Impact	**2.4%**	**0.7%**	**2.5%**	**3.3%**
Wage Income	0.6%	0.0%	0.4%	1.1%
Health & Environmental Impact	0.7%	0.1%	0.9%	0.7%
Climate Change Impact	1.1%	0.5%	1.2%	1.4%
As Percentage of Baseline Total Employment**				
Net Additional Employment	1.6%	-0.2%	0.1%	1.4%

** The first column shows the difference between the cumulative indicator in the NETZERO and Baseline scenario as a percentage of the total cumulative baseline GDP. The next three columns show the difference between the net-zero and Baseline scenarios as a percentage of the baseline GDP in the specified year.*

***Each column shows the difference between the net-zero and the Baseline scenario in the increase in the number of people employed between the base and target year as a percentage of employment in the base year. The base year for the cumulative and 2030 columns is 2020, whereas it is 2030 for the 2040 column and 2040 for the 2055 column.*

National income impact: Measured by the change in GDP. The impact on GDP is positive and increases with time.

Manufacturing impact: Measured by the change in manufacturing value added. The cumulative impact is small, negative, and increases in magnitude after 2040. Nevertheless, it should be stressed that the Baseline scenario already involves a shift in both industrial composition and transport modes toward more value-added and less energy/carbon-intensives sectors, which facilitates the net-zero transition.

Overall international trade balance impact: The international trade balance is defined as exports minus imports. The overall international trade balance impact is close to zero.

Total energy security impact: For the purposes of this report, energy security is defined as lower reliance on imports for energy and energy generation goods and equipment as a result of the energy transition. The indicator used to measure the energy security impact is the trade balance (exports minus imports) of energy (mostly fossil fuels) and equipment used for clean energy generation and consumption (batteries, advanced electrical appliances, advanced heating and cooking appliances, equipment for wind energy, photovoltaic (PV) panels, hydrogen, and carbon capture and storage (CCS)). The cumulative energy security impact is relatively high and increases overtime.

Socioeconomic welfare impact: For the purposes of this report, the socioeconomic welfare impact is defined as the increase in total wage income and the avoidance of health and climate change risks associated with the use of fossil fuels. The cumulative impact on total wage income is small but increases overtime. The health and environmental impacts stemming from air pollution are remunerated based on SHURA's externality study released in 2020 (SHURA, 2020). For the climate change impact, a carbon value of 70 EUR/ton adjusted by the purchasing power parity GDP per capita (PPP GDP/capita) differential between Türkiye and a reference EU country was used.[2] Despite this rather modest estimate of external costs, the impact is significant and increases overtime.

Employment impact: The cumulative impact on employment creation, measured by the difference in net additional employment, is positive. Nevertheless, the 20-year period until 2040 needs particular attention as the net impact during this period is close to zero.

Table ES3. Cumulative Impact Range in Comparison to the Baseline Scenario (2020–2055)

As Percentage of Baseline GDP	Minimum	Central	Maximum	Sc. Min.	Sc. Max
National Income Impact	-0.2%	1.4%	2.1%	NZ_CO	NZ_TT_FI
Manufacturing Impact	-2.2%	-0.6%	-0.1%	NZ_CO	NZ_TT
Overall International Trade Balance Impact	-0.5%	0.0%	0.0%	NZ_CO	NZ_TT_FI
Total Energy Security Impact	1.8%	1.8%	1.8%	-	-
Socioeconomic Welfare Impact	2.2%	2.3%	2.4%	NZ_CO	NZ_TT_FI
As Percentage of Baseline Total Employment					
Cumulative Net Additional Employment	0.2%	1.6%	6.2%	NZ_CO	NZ_TT

[2] As in the externality study, the reference country used was Germany, and PPP GDP/capita was assumed to gradually converge to that of Germany starting from 59% in 2022, reaching 85% in 2055. The resulting carbon value was 35 EUR/ton in 2022, gradually going up to 49 EUR/ton by 2055.

Table ES3 shows the range of cumulative impacts and the scenario conditions under which minimum and maximum values occur in relation to the central NETZERO scenario. In nearly all cases, maximum positive impact is achieved in the loan-based scenario combined with sticky wages, and the minimum impact occurs in the self-financing case with flexible wages. However, the net impact of financing (1.6%) on GDP is higher than that of sticky wages (0.7%).[3] On the other hand, the sticky wages scenario incorporating financing with loan repayment creates the maximum number of jobs by a wide margin.

Cost-benefit analysis

Table ES2 summarizes the magnitude of the impacts of the transition on the main socioeconomic areas likely to be impacted by the transition. While the table provides a perspective on the net socioeconomic benefits of the transition after accounting for the socioeconomic costs, it does not include the net financial cost. The figures in the table do not account for the additional costs of setting up and running the new energy system, stemming mainly from investments in renewable energy facilities, power grid improvements, batteries, digitalization, etc., which are reflected in the system costs. The benefits of the transition have to be weighed against the financial costs to be incurred. Table ES4 shows the balance of annual benefits and costs of the transition.

The net benefits of the transition that are part of national accounting can be captured by the difference in GDP. Total benefits also include the benefits not captured in GDP, social welfare impacts related to avoided air pollution and carbon emissions. The costs are represented by the system costs.

Table ES4. Cost-benefit table for NETZERO in comparison to the baseline scenario (2014 USD billion)

	Annual Average (2020-2055)	2030	2035	2040	2045	2050	2055
Benefits	**51.4**	**13.8**	**26.5**	**46.9**	**67.2**	**90.4**	**114.5**
Difference in National Income	22.5	6.0	9.8	13.0	33.4	54.1	70.8
Health, Environment & Climate Change Impact	28.9	7.8	16.7	33.9	33.8	36.3	43.8
Costs	**26.0**	**8.9**	**15.9**	**43.5**	**56.0**	**45.1**	**36.0**
System Costs	26.0	8.9	15.9	43.5	56.0	45.1	36.0
Net Benefit	**25.4**	**4.9**	**10.6**	**3.4**	**11.2**	**45.3**	**78.5**
Benefit/Cost	**2.0**	**1.5**	**1.7**	**1.1**	**1.2**	**2.0**	**3.2**

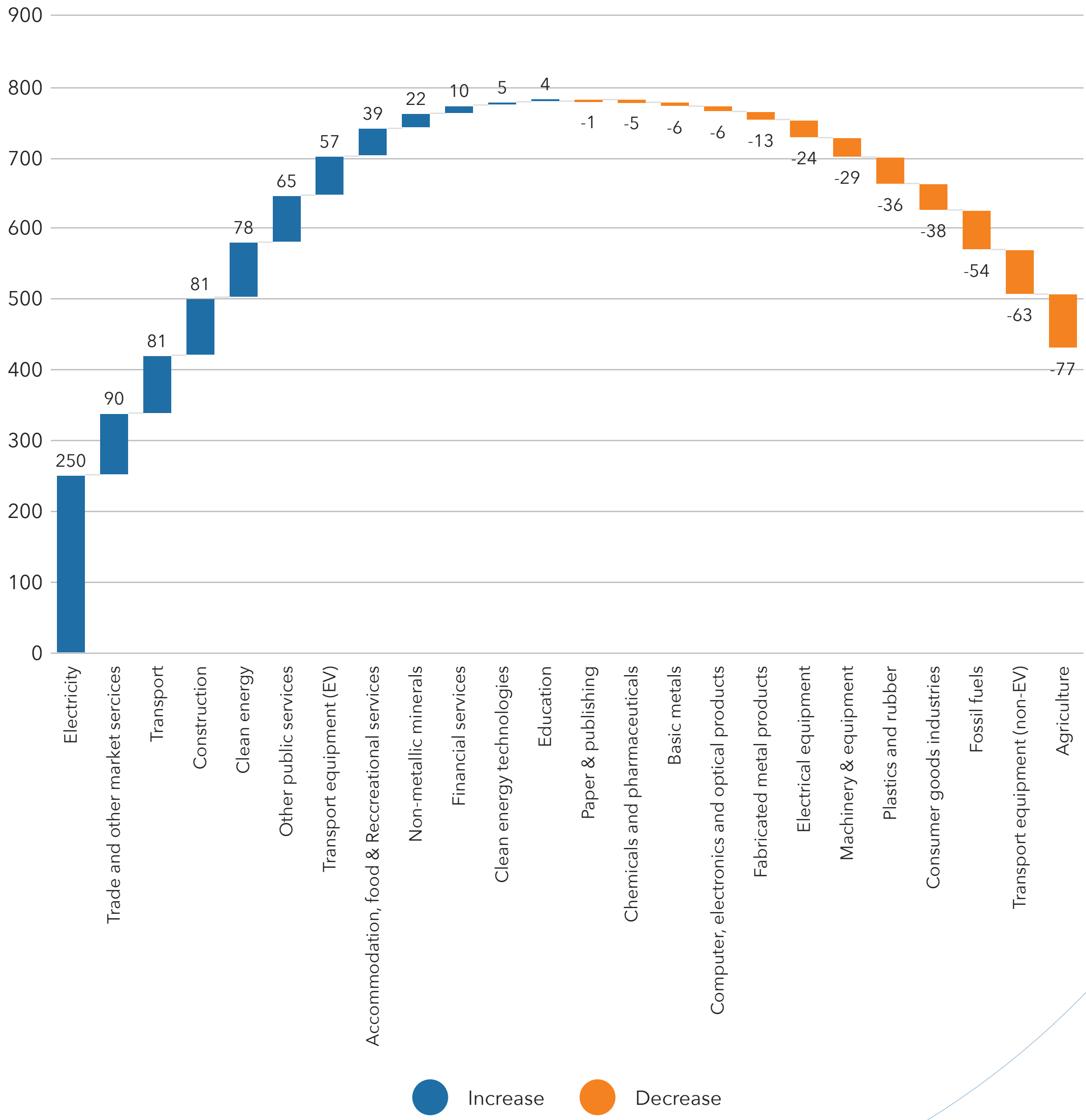
[3] The impact of financing is calculated by subtracting the impact of the self-financing scenario from that of the NETZERO (central) scenario. The impact of sticky wages is calculated by subtracting the impact of the central scenario from the loan-based sticky wages scenario.

On average, the benefits of the transition will be around twice as high its costs. Following investment peaks during 2036–2045, system costs will rise rapidly and temporarily approach the level of net benefits around 2040. Particular attention will be needed around this period to develop appropriate industrial and just transition policies to increase positive impacts on GDP.

Sectoral employment impacts

While total employment will be positively impacted by the transition in all net-zero scenarios (a total of 432,000 more jobs are created in the central NETZERO scenario than in the baseline), there will be negative impacts on individual sectors, particularly in fossil fuel production and distribution and related sectors as in the production of non-electric vehicles. The fact that the Baseline scenario already favours manufacturing areas with high value-added and low carbon intensity, the small negative impacts on sectors such as machinery and equipment and electrical equipment do not need to raise concern. They result from some cost increases particular in the net-zero scenarios; nevertheless, around 600,000 new jobs are created in these sectors in both the baseline and net-zero scenarios. It will be important to develop just transition policies to compensate for employment losses in fossil fuel related sectors, which span a wide range of trade and transport services in addition to the production of equipment and vehicles that use fossil fuels, such as non-EV vehicle manufacturing. New employment areas present major alternative employment opportunities; however, it will be crucial to provide appropriate training and compensation schemes for the employees at risk of losing their jobs.

Figure ES1. Additional employment created in the NETZERO scenario in comparison to the baseline scenario (cumulative 2020–2055; thousand people employed)



Conclusions

This study, which examines the implications of a defined net-zero carbon energy transition pathway on socioeconomic indicators and which is essentially a quantitative modelling exercise, should be considered as a starting point for policy guidance rather than a definitive outcome. Supporting this study with qualitative research and discussions that address the national economy and sustainable development as a whole, centred around just transition principles, will contribute to the planning of a healthy transition process. In this context, it is of critical importance to continue studies and to maintain dialogues on all technical, economic, and social aspects of the transition, involving the public and private sectors, professional associations, non-governmental organisations (NGOs), labour and employers' organisations, universities, and other research institutions. The main policy areas that can be addressed in the short term to respond to the impacts discussed in this report are energy and climate policies, economic policies, industrial policy, employment policy, and financing policies. The transition requires substantial investment and a rigorous planning process, especially with regard to financing and labour markets, but promises benefits far beyond its costs. Provided that Türkiye strikes a strategic balance between industrial policy, access to finance, and just transition measures, it can amplify the positive effects of this transition and ensure that the transition to a decarbonized economy is both sustainable and equitable for all stakeholders.

SECTION 1
Introduction

In November 2021, Türkiye declared a net-zero emissions target for 2053. Achievement of the target requires a major realignment of not only of the energy system but also of major demand sectors, such as industry, transport, and buildings. In February 2023, SHURA Energy Transition Center published a roadmap for the decarbonization of Türkiye's power sector titled Net Zero 2053: A Roadmap for Türkiye's Power Sector. The roadmap included plans for the decarbonization of end-use sectors as well as their electrification, which is an essential component of achieving the net-zero target and is closely related to the planning of the power sector (SHURA, 2023).

It is essential to assess the socioeconomic impact of such a major shift in the energy system, not only to compensate for and reduce any possible negative impacts but also to be able to implement effective policies to make the transition a successful one. While a previous SHURA study on the socioeconomic impact of a partial transition for Türkiye by 2030 and numerous international studies find that the overall impact of a low-carbon energy transition on gross domestic product (GDP) and total employment is generally small and positive (SHURA, 2021), it has been necessary to perform a more comprehensive analysis in light of Türkiye's net-zero emissions target by mid-century. This study aims to quantify the impact of the net-zero power system transition on national income, employment, and industrial sectors in order to guide the necessary policy actions to maximize the benefits of the transition while minimizing or eliminating potential risks. It is intended as a tool for a more in-depth policy discussion in regard to the relevant socioeconomic issues in order to enable a just transition.

The objective of this study is to evaluate the socio-economic impacts of decarbonizing Türkiye's energy system. The decarbonization of the energy system is a capital-intensive process where high value-added products such as wind turbines, PV panels, energy efficient appliances/machines, synthetic fuels, energy storage options, and batteries replace low value-added products such as fossil fuels.

Decarbonizing the energy system leads to a decline in fossil fuel demand and the shrinking of fuel imports while domestic investment expenditures in renewables, energy efficiency improvements, and electrification increase. This transition occurs within a dynamic framework where prices, technology costs, production structures, consumer preferences and habits are continually evolving, necessitating new types of labour skills, infrastructure, and materials.

In the early stages of the transition to a low-carbon energy system, financing needs are expected to be high,[4] and the essential technologies and skills may not have reached full learning potential. Consequently, energy costs could rise initially due to skill mismatches and high capital requirements, potentially increasing production costs and leading to a temporary deceleration in GDP growth. However, our study suggests that a well-structured transition plan, incorporating timely policies and measures to address potential financial and labour shortages, can accelerate GDP growth over time."

[4] The transition to a low-carbon energy system implies changing the consumption and production patterns from low CAPEX/high OPEX to a high CAPEX/low OPEX. This requires significant upfront investments/expenditures that pay off in the long term through low operating and maintenance costs. Hence, capital/financing requirements at the early stages of implementation are expected to be high, and the respective resources and instruments must be in place.

Policies and measures can generate positive externalities that reduce costs and promote the cost-efficient adoption of technologies. Competitiveness impacts are dynamic: industries will evolve to produce new value-added products and materials, first-mover advantages may enhance competitiveness, and the economy could benefit from export-driven growth and increased domestic value added. However, effective coordination of all system changes is crucial, including the mobilization of sufficient financing to support the large-scale deployment of new technologies.

This study consists of five sections following the introduction. The second section provides a review of the literature and proceeds to describe the methodology and model used in the study. The third section, in turn, describes in detail the scenarios used in the study. The fourth section presents the results of the scenarios, and the fifth section offers a summary of the overall impact analysis and cost-benefit analysis. The sixth and the final section, the conclusion, discusses the general outcomes pointed out in the study.

SECTION 2
Approach
and Methodology

Quantifying and assessing the socio-economic implications of the decarbonization of the energy system is a complex task as it requires considering uncertainties regarding producer/consumer choices, technological dynamics, and the interdependencies of multiple systems all at the same time. Computable General Equilibrium (CGE) models have been extensively used to evaluate climate and energy policies and are particularly effective in capturing these system interdependencies.

In this study GEM-E3, a large-scale applied CGE model, is used in order to calculate the economic and employment impacts of power sector decarbonization in Türkiye. The model allows users to understand the key mechanisms driving the model results, thanks to its rigorous microeconomic theory foundations and model tractability. For this reason, this study employs the internationally renowned GEM-E3 model.

The model's focus is on the socio-economic assessment of energy and climate policies, and particularly on the impacts related to GDP, sectoral production, welfare, employment, and fiscal revenues. The model represents Türkiye as an individual country, features a detailed representation of the interactions between its economy and energy system, and represents its (bilateral) flows with all main trading partners in an endogenous manner. The model has a distinct representation of power generation technologies, the sectors providing/manufacturing the clean energy technologies, and detailed representation of employment by economic activity and occupation. Finally, the model allows for equilibrium unemployment and alternative financing schemes for investments associated with the NETZERO transition.

2.1. GHG emissions reduction and economic activity: A review of the literature

A substantial body of literature has explored the economic impacts of various clean energy pathways at both national and global levels. However, the effects of transitioning to a net-zero economy can vary significantly across countries, sectors, and over time. Studies yield mixed results regarding the economic impacts of clean energy transitions. Some estimate positive GDP impacts compared to Baseline scenarios, while others suggest relatively small GDP losses. These discrepancies are attributed to various factors, including the design of the scenarios, the types of models employed (e.g., static vs. dynamic, CGE vs. macro-econometric), the inclusion of externalities (such as health impacts and other avoided costs), resource constraints (including investment financing schemes), the choice of recycling and subsidy schemes, and assumptions about the future costs of clean energy technologies and goods associated with the transition. Additionally, the timeline of emissions reductions plays a role in these varying outcomes.

Table 1 provides a summary of major studies in this area.[5] The differences in results across studies are also attributed to the time period and the pathway of investments undertaken. As indicated, decarbonization is a highly capital- and resource-intensive process, especially in the short to medium term. The increased penetration of renewables, renovation of buildings,

[5] The table complements the literature review included in the previous SHURA report (Socioeconomic Impact of the Power System Transition in Turkey, published in 2021)

purchase of energy efficient equipment, and electrification of transport will require a significant amount of money upfront. However, energy savings yield longer term benefits. Hence, the impacts should be considered on a cumulative basis, factoring in that the positive effects of the energy transition are larger in the longer run.

Table 1. Climate and energy policies' impacts on GDP—review of relevant studies

Study	Authors	Model	Country targets	Emissions	Impact on GDP	Notes
A comprehensive socio-economic assessment of EU climate policy pathways	Weitzel et al. (2023)	JRC-GEM-E3 (CGE)	EU	-55%	GDP: -0.28% to -0.48%	The results are influenced by assumptions of the labour market (perfect vs. imperfect), recycling of carbon revenues (lump-sum vs. labour tax), firms' behaviour (market share maximization vs. profit maximization), and emissions allocation schemes (auctioning vs. free allowances)
The Macroeconomic Implications of a Transition to Zero Net Emissions	Hallegatte et al. (2023)	Multi-model	Türkiye		GDP (NETZERO): 1.46% in 2030, 1.15% in 2040 GDP (no labour market frictions): 1.66% in 2030, 2.23% in 240 GDP (crowding out): 0.97% in 2030, -0.33% in 2040	Three alternative cases were examined: the main scenario, a scenario with fully flexible wages, and a scenario with full crowding out effects
Socioeconomic impact of the power system transition in Turkey	SHURA (2021)	CGE	Türkiye		GDP: 1.0% in 2030, 3.4% in 2040	
Energy system transition and macroeconomic impacts of a European decarbonization action towards a below 2°C climate stabilization	Vrontisi Z., Fragkiadakis K., Kannavou M., Capros P. (2020)	GEM-E3 (CGE)	EU28	EU-WB2°C: -80% GHG emissions from 1990 Global mitigation: 675Gt CO_2 2015-2050	GDP (2030): -0.15% to -0.17% GDP (2050): +0.20% to +0.80%	Different scenario setups: no global action (extra-EU countries' NDC targets) and global mitigation actions. Recycling of carbon revenues through indirect taxes

What are the impacts of climate policies on trade? A quantified assessment of the Paris agreement for the G20 economies	Vrontisi Z., Charalampidis I. Paroussos L. (2020)	GEM-E3 (CGE)	Global	NDC WB2C: 675 Gt CO_2 2015–2050	GDP-Word (2030): –0.26% up to –1.13% GDP-World (2050): –1.13% up to –2.09% GDP-TUR (2030): up to –0.6% GDP-TUR (2050): approximately –0.15% to –0.9%	Recycling of carbon revenues through general taxation
Turkish energy sector development and the Paris Agreement goals: A CGE model assessment	Kat B., Paltsev S. and Yan M. (2018)	TR-EDGE (CGE)	Türkiye	–21% from BAU in 2030	GDP BAU+TreM (2030): –0.82% GDP NoN+TrEm (2030): –1.1%	
The possible macroeconomic and sectoral impacts of carbon taxation on Turkey's economy: A computable general equilibrium analyses	Aydin L. (2018)	CGE model	Türkiye	3 alternative values for Carbon tax: 7 USD/ton, 20 USD/ton, 35 USD/ton	GDP: –0.061%, –0.181%, –0.328%	
Energy efficiency in residential and non-residential buildings: Short-term macroeconomic implications	Slabe-Erker et al. (2022)	CGE model	Slovenia	Additional investments in buildings (EUR 1.7 billion)	Positive GDP impacts throughout the projection period (ranging between +1.81% and +2.25%)	
Measuring the socio-economic footprint of the energy transition	Garcia-Casals X., Ferroukhi R. and Parajuli B. (2019)	E3M (macro-econometric)	World	760 Gt CO_2 2015–2050	GDP: +1.5% in 2031 and +1% in 2050 Mixed effects at the regional level. Losers include energy producing countries, Argentina, South-East Asia, Canada, India, among others	Recycling option income taxes
Environmental impact assessment for climate change policy with the simulation-based integrated assessment model E3ME-FTT-GENIE	Mercure et al. (2018)	E3M-FTT-GENIE (macro-econometric)	World	Set of policies that achieve >70% chance of not surpassing 2°C	The assessment identifies both winners and losers (OPEC and North America). Slightly negative impact in global GDP	

**GSYİH üzerindeki etki sütununda artış yönündeki etkiler %, azalış yönündeki etkiler %- olarak gösterilmiştir.*

The impacts of climate and energy policies on GDP depend on the economic structure, energy system, renewables potential, and extent of emissions reduction in the geographical area under consideration, for example: (i) the capacity of the local economy to produce the equipment and services necessary for energy system decarbonization, (ii) the financial resources available to support investment, and (iii) the availability of skilled labour and employment dependency on fossil fuel-producing sectors.

In 2021, production of renewable energy generation equipment (solar PV panels, wind turbines) was concentrated in a few countries. According to the International Energy Agency, China produced more than 74% of solar PV panels (IEA, 2022). In wind turbines production, there is greater regional diversification, with Europe holding a market share of 42% (Wind Europe, 2020). This concentration implies that the transformation of the electricity system can be import-intensive for other countries, potentially worsening their current account balances. Energy saving and efficient equipment is more costly than conventional equipment but has lower operating and maintenance costs over time.[6] Without appropriate financing instruments, the initial purchase of these devices may reduce disposable income in the short term, even though they lead to cost savings in the long run. Among the different studies, two factors are common in increasing income and employment: i) increased investments (e.g., in power generation technologies) that provide a demand boost in the economy, especially for construction and services, which are labour intensive; ii) lower fossil fuel consumption, which decreases imports (in the case of non-energy-producing countries) and frees up resources to be directed to the consumption of non-energy goods.

Another factor influencing the magnitude of GDP impacts is the choice of how carbon revenues are recycled, with particularly positive effects observed when they are used to reduce labour costs. Financing constraints and availability also play a crucial role, as assumptions about the cost of financial resources affect the economy through changes in interest rates and capital returns. Conversely, assumptions involving idle capital or financing schemes, such as loan-based approaches, can alleviate stress in capital markets and potentially yield positive GDP impacts.

Four of the studies reviewed assess the impact of the low-carbon energy transition on Türkiye's economy. Two of them, Hallegatte et al. (2023) and Taranto et al. (2021), find positive impacts, while the other two, Kat B., Paltsev S., Yan M. (2018) and Aydin L. (2018), report negative GDP impacts. The studies vary in scope and approach: for example, Aydin L. (2018) focus on the effects of three different carbon tax levels (7, 20, and 35 USD/ton), while the other studies also consider measures promoting the adoption of renewable energy in power generation. In addition, Hallegatte et al. (2023) incorporate assumptions on the electrification rate and other efficiency measures via the uptake of advanced production processes.

[6] Lower operating costs due to lower energy needs. Lower maintenance costs due to less wear and tear due to higher efficiencies.

Aydin L. (2018) finds that a carbon tax of 35 USD/ton results in a nearly 17% reduction in GHG emissions, with a corresponding GDP cost of –0.33%. Kat B., Paltsev S., and Yan M. (2018) estimate that a carbon tax between 50 and 70 USD/ton is necessary to achieve a 21% reduction in emissions compared to their business as usual (BAU) scenario, under nuclear development and renewable energy (RES) development, respectively. They find that the nuclear scenario has a lower negative impact on GDP compared to the RES scenario (–0.82% vs. –1.01% in 2030). In Hallegatte et al. (2023), the carbon tax starts at USD 11 in 2022 and rises to USD 211 by 2040, resulting in a 55% reduction in net cumulative emissions compared to the BAU scenario, with gross emissions declining by 43.8%. The cumulative investment requirement is estimated at USD 313 billion (or approximately USD 17.3 billion per year). The NETZERO transition results in higher GDP compared to the BAU scenario, driven by energy savings in the transport and residential sectors, as well as increased activity in the services sector. Other factors influencing GDP impacts include assumptions about investment financing (external vs. crowding out) and the inclusion of co-benefits, such as health benefits from avoided emissions. GDP impacts range from 0.97% to 1.66% in 2030, depending on wage adjustment and financing assumptions, and between –0.33% and 2.23% in 2040.

Finally, in SHURA (2021), a USD 25 carbon tax along with measures for the transformation of electricity production leads to a reduction in CO2 intensity of power generation by 21%. Approximately USD 12.3 billion per annum will be needed for the transformation of the energy system in Türkiye (almost double the BAU scenario). The largest part (58%) of these investments will be directed to the electricity system, with 36% being directed into the development of renewable energy sources, while 22% of the investments will be directed to energy efficiency improvements and the rest to the electrification of transport and heating. The study estimates that the power sector restructuring will lead to GDP gains of 1% in 2030 and of 1.4% in 2040 compared to the Baseline scenario. These gains are driven by electricity savings from energy efficiency, which reduce energy bills and free up capital and labour for use in other sectors as electricity production decreases.

2.2. The GEM-E3M model

The GEM-E3[7] model is a multi-regional, multi-sectoral, recursive dynamic computable general equilibrium (CGE) model that provides macroeconomic details and their interaction with the environment and the energy system. The model has global coverage and includes 20 countries/regions of the world. In terms of greenhouse gases, the model includes emissions of CO2 (both from fossil fuel combustion and from processes), methane (CH4), nitrous oxide (N20), and F-gases.

[7] Full model documentation is available at https://e3modelling.com/modelling-tools/gem-e3/.

The model includes 55 activities and 12 power generation technologies. The sectors producing the necessary goods for the clean energy transition (e.g., PV equipment, wind turbines, electric vehicles etc.) are individually represented, a feature which allows the model to better capture the dynamics in the demand for manufactured goods associated with decarbonization. Additional information on the model is available in the Annex (Section 7.1).

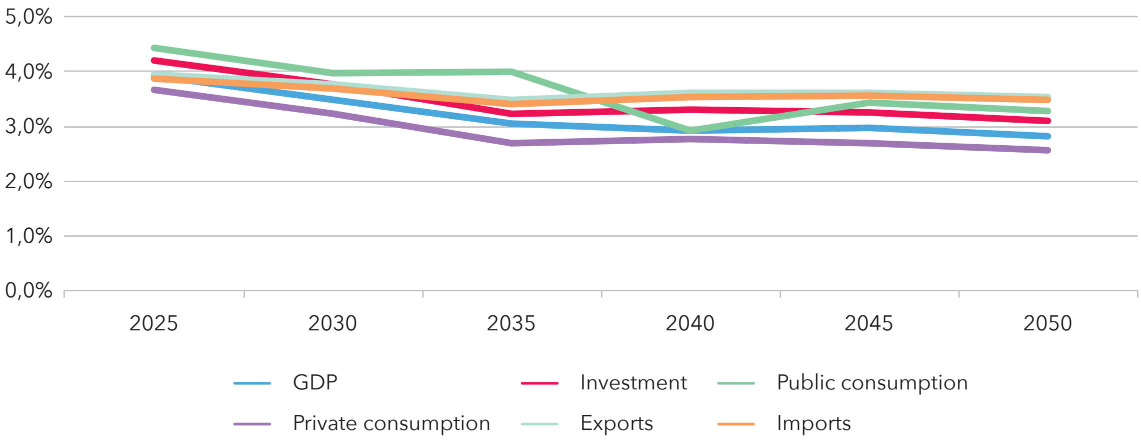
SECTION 3
Scenario Design

3.1. Baseline scenario

The Baseline Scenario is a "constructed" scenario, in the sense that the model is calibrated in a way that replicates exogenous projections on economic and sectoral growth and employment. However, the model ensures that overall economic growth is consistent with empirical findings regarding productivity and from an accounting perspective (e.g., that exports are driven by demand in other countries, etc.).

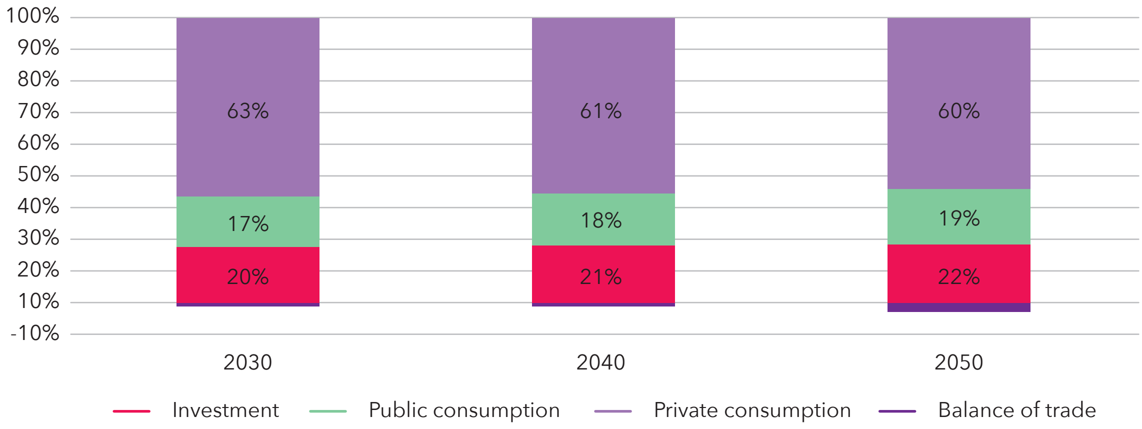
In the Baseline Scenario, Türkiye's real GDP grows with an average annual rate of 3.2% between 2020 and 2050. In absolute terms, GDP (expressed in 2014 constant dollars) is projected to reach USD 2.4 trillion by 2050. Economic growth is driven mainly by higher investment rates,[8] which are necessary to expand domestic production to meet increased demand (population is expected to grow by 15% reaching almost 100 million people in 2055). The overall export performance of the country is expected to be slightly higher than import demand, leading to a decrease in trade deficits (from 1.1% of GDP in 2020 to 0.6% of GDP in 2050). The contribution of private consumption to GDP decreases slightly, partly due to the increased funding requirements of investment projects.

Figure 1. Annual growth rates of GDP and of main macroeconomic aggregates (baseline scenario)



[8] Measured as the ratio of investments to GDP

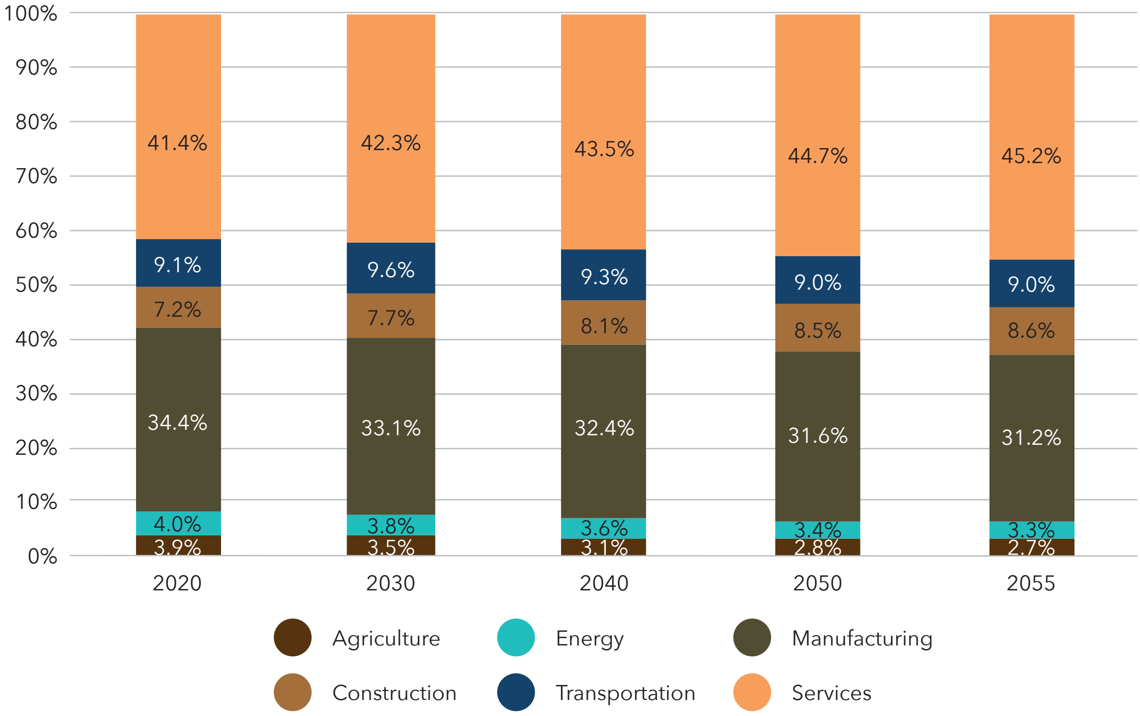
Figure 2. Macroeconomic aggregates and their contribution to Türkiye's GDP (Baseline scenario)



For the purpose of the net-zero study, the Baseline scenario was constructed in a way that would facilitate the dual goals of higher value-added and lower energy/carbon intensity. Similarly, transport modes in the Baseline scenario emphasize less carbon-intensive rail and sea transport over land and air transport where possible.[9] In terms of sectoral production, there is a shift from manufacturing and primary activities towards services. Between 2020 and 2050, service sectors grow at an annual rate of 3.4%, reaching a total output of approximately USD 2 trillion in 2050, while (total) manufacturing activities grow annually by 2.9% and primary activities by 0.7%. Total manufacturing output accounts for approximately USD 1.4 trillion, while agricultural output reaches USD 78 billion in 2050. Increased investments lead to higher demand for construction services and the sector records an annual growth rate of 3.5% for the period up to 2050.

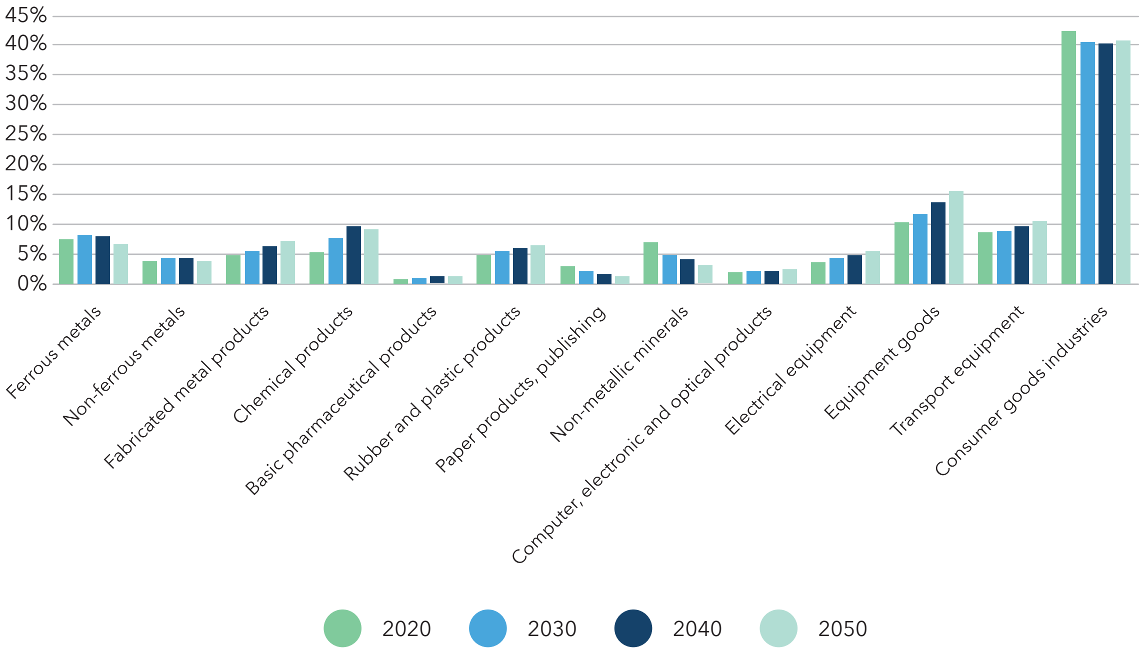
[9] More detail on the Baseline Scenario may be accessed at https://shura.org.tr/en/net-zero-2053-a-roadmap-for-the-turkish-electricity-sector/

Figure 3. Sectoral activity as a share of total domestic production (Baseline scenario)



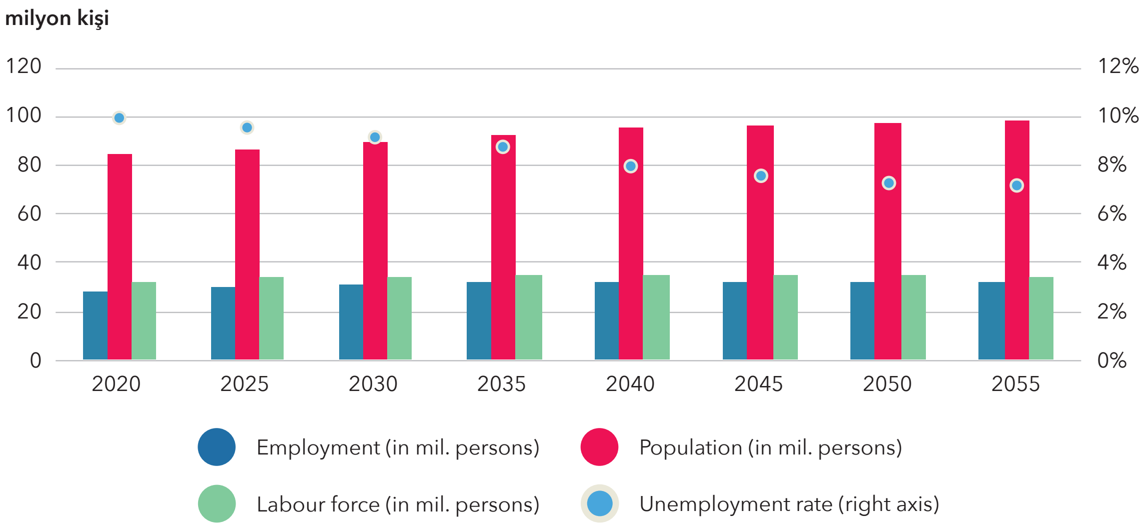
Türkiye's manufacturing is projected to shift (Figure 4) gradually from consumer goods (0.8% average annual growth rate), transport equipment, and ferrous metals to chemical production (4.2%), manufacturing of computer and electronics (6.7%), electrical equipment (4.8%), machinery and equipment (5.4%), and fabricated metal products (4.4%).

Figure 4. Share of selected industries in manufacturing output (Baseline scenario)



Economic expansion and the shift towards activities that are labour-intensive and have low import exposure like services and construction lead to higher employment rates when compared to 2020 levels throughout the projection period. Unemployment drops at a slow pace over the projection period and reaches 7.1% in 2055.

Figure 5. Main demographic and aggregate labour market indicators (Baseline scenario)



Overall, based on the macroeconomic assumptions underpinning this analysis, Türkiye is projected to experience significant economic growth over the entire projection period, which pushes up total demand for energy. The country is set to retain its manufacturing capacity with higher value-added and less energy-intensive products. Construction grows alongside population, catering to the domestic market, while transport also rises with rising GDP.

3.2. Net Zero 2053 (NZ2053) and NETZERO scenarios

The Net-Zero 2053 (NZ2053) scenario, which covers actions, investments, and key assumptions for Türkiye to achieve its net-zero carbon target by 2053, is taken from SHURA's report *Net Zero 2053: A Roadmap for the Turkish Electricity Sector* (SHURA, 2023). The current study, in turn, aims to quantify the socioeconomic impacts of the transition projected under the NZ2053 scenario. For this purpose, NETZERO scenarios and sensitivity analyses, which are detailed in Section 3.3, have been developed to be compared with the Baseline scenario outlined in Section 3.1.

The investments and energy mix associated with the decarbonized energy system are introduced into the GEM-E3 model (from PRIMES) to calculate the impact on GDP, sectoral production, employment, welfare, and transport[10].

The decarbonization of the power sector lies at the heart of the NZ2053 scenario. The NZ2053 scenario considers timely and climate-focused actions adopted in the power sector as soon as

[10] For more information, please see Net Zero 2053: A Roadmap for the Turkish Electricity Sector, SHURA, 2023.

2020 and will speed up after 2030. In 2055, final energy demand reaches 1,170 terawatt-hours (TWh) and electricity consumption 637 TWh. Compared to 2020, the share of electricity in total energy demand more than doubles, increasing from 21% to 54%.

Energy transition of end-use sectors focuses on energy efficiency and electrification. E-fuels (such as emission-free liquids and gaseous energy carriers) are used mostly in hard-to-electrify sectors such as industry (requiring high temperature heat) and long-haul transportation. In the scenario, both electricity and e-fuels are generated via the use of renewable energy power plants.

The goal to reach net-zero carbon emissions by 2053 is made possible for Türkiye through the displacement of fossil fuels by renewable energy, improved energy efficiency, and increased electrification in end-use sectors. Under the Net-Zero 2053 (NZ2053) scenario, total carbon emissions peak in 2025, and in 2035 they reduce to 62.8% of 2025 levels.

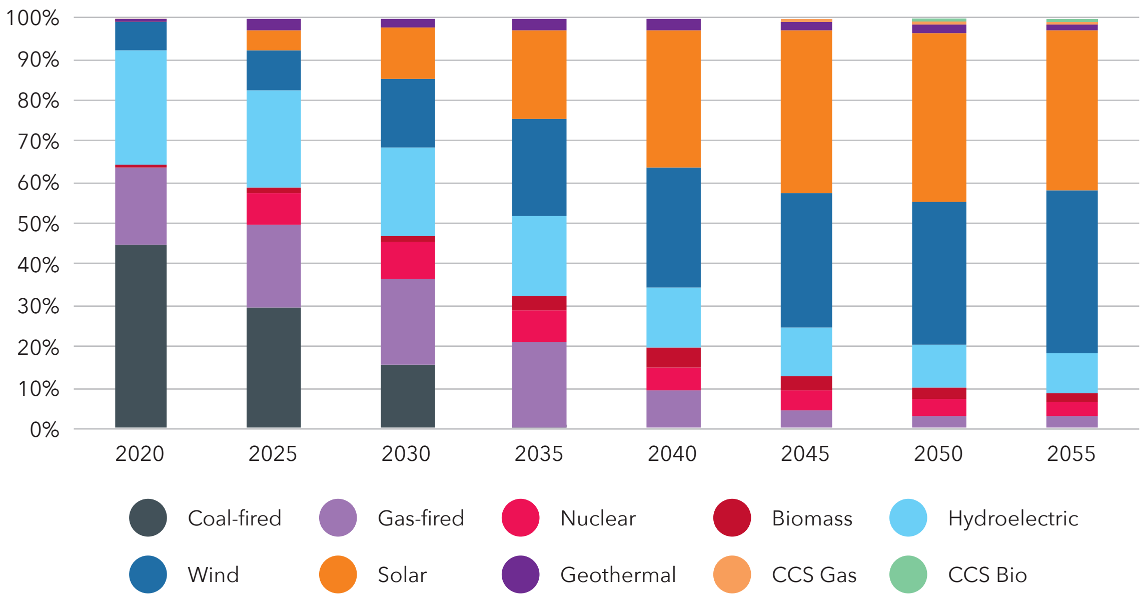
The main driver behind the early peak in emissions (2025) is the rapid coal phase-out in the power sector. Already in the current decade, coal shares are assumed to drop by more than half. In the scenario, the operating hours of the most inefficient coal and lignite power plants decrease, a trend that is further accelerated after 2030 because of a regulated coal phase-out, where all coal-fired power plants cease power generation by 2035 and close down completely by 2040. Moreover, primary energy consumption peaks in 2030 and regresses to its 2020 levels by the end of the projection period.

Indeed, the Turkish electricity system in 2053 is assumed to be radically different from the current power system owing to two major trends:

- a considerable increase in electricity generation due to electrification of end-use sectors and an increase in green hydrogen and synthetic fuels; and
- an increasing share of variable RES.

Wind and solar PV become the dominant sources of electricity generation, with their share reaching 79% in 2055. Together with hydro, biomass, and geothermal, RES provide more than 92% of power generation in 2055 (Figure 6).

Figure 6. Technology shares in power generation in the NZ2053 scenario



Rapidly growing electricity demand and the deployment of new renewable energy sources drive up total installed capacities. During 2020–2055, total installed capacity goes up from 100 gigawatts (GW) to 572 GW and total RES capacity goes up from 56 GW to 403 GW. RES capacity additions speed up during 2040–2050, increasing from 217 GW to 514 GW, owing especially to the uptake in e-fuel demand in end-use sectors.

Although solar PV and wind have an equal share in electricity generation, the total required capacity for solar PV is much higher due to its lower capacity factors. Solar capacities reach 119 GW by 2040 and 220 GW by 2053. With most investments concentrated from 2035–2045, the average rate of PV capacity additions between 2020 and 2055 is 6.1 GW per year. These investments are feasible from an economic point of view, given the growth prospects of the Turkish economy. The increase in RES is accompanied by investment in grid capacity and battery storage.

Throughout the projection period, the total nuclear power plant capacity remains stable, while the capacity of clean gas-fired power plants increases to meet the need for reserves and to secure energy supply. Geothermal capacities and biomass steam turbines add a further 9 GW to the power system in the long run (by 2055). These plants have high utilization rates providing stable electricity to the grid. A biomass with CCS power plant is commissioned in 2050, with a total capacity of 1.3 GW.

Table 2 shows the scale of investment needed to achieve the net-zero goals. In fact, the investment rate increases gradually over time. From 2021 to 2050, close to USD 288 billion worth of investments are required to finance the power sector transformation.

Investments speed up after 2030, peak during 2036–2045, and are channelled to the installation of 86.6 GW of power generation capacity, mainly solar PV and wind, necessary to meet the rapidly growing demand for electricity and support the production of e-fuels. Investment requirements are equal to 0.6% of GDP cumulatively over the projection period.

Table 2. Investment expenditures in the power sector (USD billion) in the NZ2053 scenario.

	2020	2025	2030	2035	2040	2045	2050	2055
Coal-fired	1.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Gas-fired[11]	0.8	0.0	0.0	0.0	0.6	0.6	1.0	1.1
Nuclear	0.0	2.6	0.9	0.0	0.0	0.0	0.0	0.0
Biomass	0.2	0.0	1.2	0.0	0.0	0.1	0.0	0.0
Hydroelectric	1.0	0.4	0.4	0.5	0.2	0.0	0.3	0.2
Wind	0.4	0.8	2.3	3.4	6.0	6.5	5.7	6.3
PV	0.3	0.5	1.7	2.3	4.5	4.4	2.7	0.7
Geothermal	0.2	0.1	0.0	0.4	0.8	0.1	0.7	0.2
CCS Gas	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0
CCS Bio	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0

With respect to final demand sectors, households undertake expenditures to improve the energy performance of dwellings. The cumulative energy efficiency expenditures are approximately equal to USD 59 billion (0.13% of household income). Contrary to power generation investments, the bulk of energy efficiency expenditures take place until 2035 (approximately 57% of total expenditures).

Table 3. Energy efficiency expenditures in the NZ2053 scenario (US billion)

	2025	2030	2035	2040	2045	2050	2055
Industry	0.10	0.20	0.52	1.64	2.77	3.74	5.42
Services	0.12	0.51	0.52	1.16	1.51	1.62	1.32
Residential	0.73	3.12	2.69	2.11	2.19	0.70	0.29

Finally, with regard to the transport sector, there is a shift from vehicles with internal combustion engines to hybrid and battery electric vehicles (BEVs). In 2055, only about 1% of total vehicles in circulation use solely internal combustion engines. It is assumed that BEVs cost is on average 1.35 times higher than the cost of conventional vehicles.

[11] It should be noted that after 2030 gas-fired facilities use clean gas.

Table 4. Share of private vehicles by engine type in the NZ2053 Scenario.

	2020	2025	2030	2035	2040	2045	2050	2055
Conventional	98%	97%	78%	51%	23%	17%	8%	1%
Plug-in Hybrid	1%	2%	8%	19%	18%	13%	8%	4%
Pure Electric	1%	1%	14%	30%	59%	71%	84%	94%

3.3. Macroeconomic setup

In order to measure the macroeconomic impacts of the NZ 2053 scenario, the NETZERO scenarios presented in Sections 3.3.1 and 3.3.2 were developed. The impact assessment considers two important factors that influence the response of the economy to the projected changes: financing options and rigidities in the markets of primary production factors,[12] which affect the response of wages and capital rents.

3.3.1. NETZERO financing schemes

The expansion of RES capacities in electricity production and grid development will require additional resources. The additional financing requirements will exert pressure on capital markets. The extent to which capital costs will increase will determine the overall effect on the economy. It is important to examine alternative financing setups to measure the importance of financial constraints in the transition.

The alternative financing schemes examined represent broadly two extremes and one middle of the road case (central case) simulating alternative conditions in the financial markets. In the central case (NETZERO), it is assumed investments are financed by loans that are fully repaid after ten years with an interest rate of 5%. In the unfavourable case (NETZERO_CO), it is assumed that investments are financed through domestic resources and, more specifically, by crowding out investments of an equal amount in other sectors. This alternative simulates a condition where firms compete for a given amount of financial resources. Finally, an alternative, more favourable-case setup (NETZERO_FI), is examined, where it is assumed that investments are financed by a combination of domestic and external resources (but no repayment is assumed).

- **NETZERO:** (The central variant) Investments in power generation and the grid are financed through loans that are repaid in subsequent periods at a given interest rate
- **NETZERO_FI:** Loan-based scenario–revolving financing with no repayment within the simulation period.
- **NETZERO_CO:** Self-financing scenario.

[12] In economic literature, the main factors necessary for production (production factors) are defined as land (or natural resources), labour, and capital. The degree of flexibility in the markets where wages (unit labour income) and profits (unit capital rents) are formed is one of the main determinants of these values.

3.3.2. NETZERO labour market adjustment

The additional demand generated from investments and the transition towards a capital expenditure (CAPEX)-based pattern will change the structure of the economic activity. These changes will influence economy-wide labour and capital costs. As demand for labour increases, wages tend to increase to balance total demand and supply within the economy. The extent to which wages adjust to changes in demand depends on several factors, such as unions' power, skills mismatch, etc. The adjustment of primary production factor prices affects to a very large extent the sectoral production costs and their competitiveness to both the domestic and the international markets. Economic models use alternative approaches to model the labour market; these approaches lead to different response rates in wages and capital rents. In the GEM-E3 model, labour market imperfections lead to equilibrium wages higher than those implied by the full-employment approach, hence involuntary unemployment arises in equilibrium. In the sensitivity runs, we assume that wages are fixed to their baseline levels.

With respect to labour and capital market response, a case with fully flexible wages and capital rents and a case with no adjustment are considered. Alternative financing schemes and market conditions allows to investigate the influence of key economic elements in the transition process and allows to provide a robust range of estimate of macroeconomic impacts. The naming of scenario variants and the specifications are the following:

- **NETZERO_TT:** Sticky wages together with loans which are repaid
- **NETZERO_TT_FI:** Sticky wages together with revolving financing (no repayment)
- **NETZERO_TT_CO:** Self-financing scenario together with sticky wages

3.4. Investment matrix

In GEM-E3, power generation investments are translated into demand for goods and services with the use of a matrix of fixed technical coefficients. This matrix is referred as an investment matrix. The construction of the investment matrix is based on data drawn from "Capital Cost and Performance Characteristic Estimates for Utility Scale Electric Power Generating Technologies" (EIA,2020) and from Renewable Power Generation Costs in 2019 (IRENA, 2020). The matrix shows by technology type the ratio of spending triggered for machinery/equipment, construction, and other market services by each unit of investment. It serves as a good indicator of the impact created in related sectors by the investments in major power generation technologies.

Table 5. The investment matrix[13]

	Coal-fired	Gas-fired	Biomass	Hydroelectric	Wind	PV	CCS coal	CCS Gas	CCS Bio
Machinery and equipment	56%	61%	57%	19%					
Construction	23%	17%	23%	65%	25%	36%	23%	17%	17%
Other Market Services	21%	22%	20%	16%	20%	7%	22%	21%	22%
Equipment for wind power technology					55%				
Equipment for PV panels						57%			
Equipment for CCS power technology							56%	61%	61%

The investment matrix has a central role in the assessment of the NETZERO implications as it indicates the sectors that will benefit the most from additional spending.

[13] This is the default matrix of the GEM-E3 model.

SECTION 4
Scenario Results

4.1. NETZERO

The NETZERO scenario leads to cumulative[14] GDP gains compared to the Baseline case over the projection period (2020–2055). The estimated gains amount to approximately USD 787 billion, primarily driven by increased investments. The higher deployment of RES capacities and grid development stimulates demand in the economy, leading to increased activity, particularly in construction services. This sector is characterized by relatively low import dependence[15] and a high multiplier effect.[16]

The impact on GDP is detailed as follows:

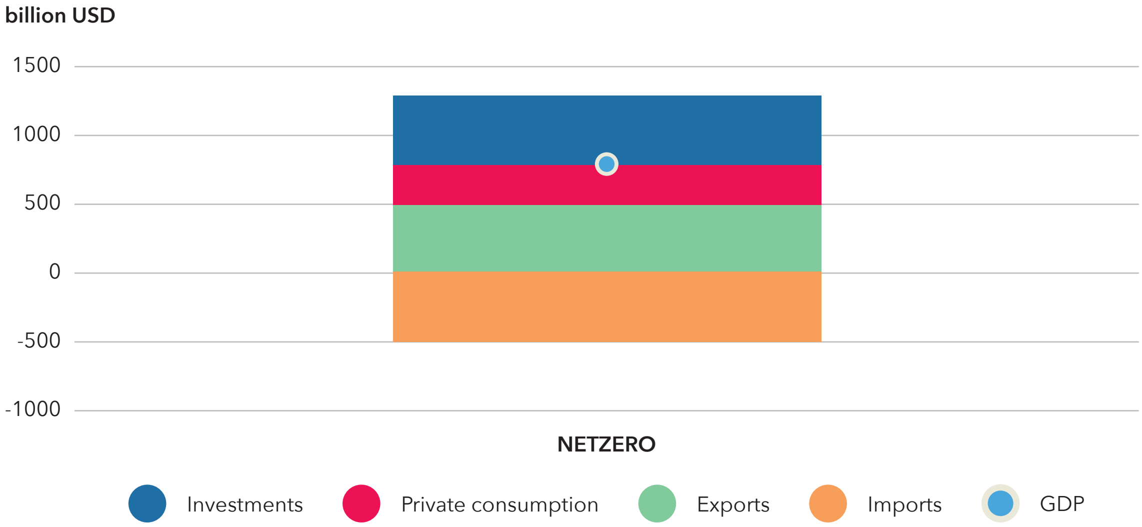
a) investments increase as the transition is capital-intensive,
b) imports are reduced compared to Baseline due to the decreasing dependence on fossil fuels,
c) private consumption increases due to higher economic activity, employment, and energy savings (by 0.92% cumulatively compared to the Baseline case), and
d) production cost increases due to increased energy costs[17] are assumed to reduce the competitiveness of domestically produced goods resulting in lower exports compared to the BBaseline scenario. This impact is dependant mainly on assumptions related to the energy and climate policies of other countries. In our setup, it is assumed that other countries do not aim for emissions reduction. However, in a global action context, other countries would potentially face higher production costs associated with the transition. This would imply i) a smaller adjustment in relative prices (i.e., to the price of Turkish products with respect to the price of foreign goods) potentially leading to smaller changes in exports and ii) potentially higher demand for goods associated with the transition and for which Türkiye has productive capacities (e.g., electric vehicles).

In the early stages of the transition (up to 2035), where household expenditures on energy efficiency improvements and equipment are higher (hence the impacts of higher capital costs on household budgets are greater than energy savings), private consumption falls; while in the longer-term energy savings imply lower energy bills and higher consumption of other goods and services. While Türkiye's economy shifts away from traditional manufacturing activities, "clean energy" manufacturing and construction are the sectors that benefit the most from the NETZERO transition.

[14] Henceforth, we will use the term cumulative change to refer to aggregate changes during the period 2020–2055 and growth rate to refer to annual % change of a variable within the time period examined, while the rest of the described changes refer to the comparison between the Baseline and the scenario in a specific year.
[15] Imports as share of total domestic demand. Imports of construction services account on average for 0.6% of total domestic demand.
[16] The Leontief multiplier measures the effects on the economy from an increase in demand (or production) of a sector by USD 1. A multiplier of two means that for each USD 1 of additional demand, the economy generates USD 2 in total, recording a net benefit of USD 1. For example, construction has an average output multiplier of 2.1, and an employment multiplier of 21 (which means that for each million dollar invested, 21 additional jobs are created).
[17] Especially in the transition period, increasing investments in renewable energy, grid infrastructure, and energy storage lead to increased system costs, thereby causing energy costs to be higher than those in the Baseline scenario.

The external trade balance does not change significantly in the net-zero case in comparison to the Baseline scenario. Lower imports (lower fossil fuels, shift from OPEX to CAPEX consumption patterns) are coupled with a small decrease in exports, the latter due to the increase in production costs.[18]

Figure 7. Cumulative GDP impacts with respect to the Baseline scenario[19]



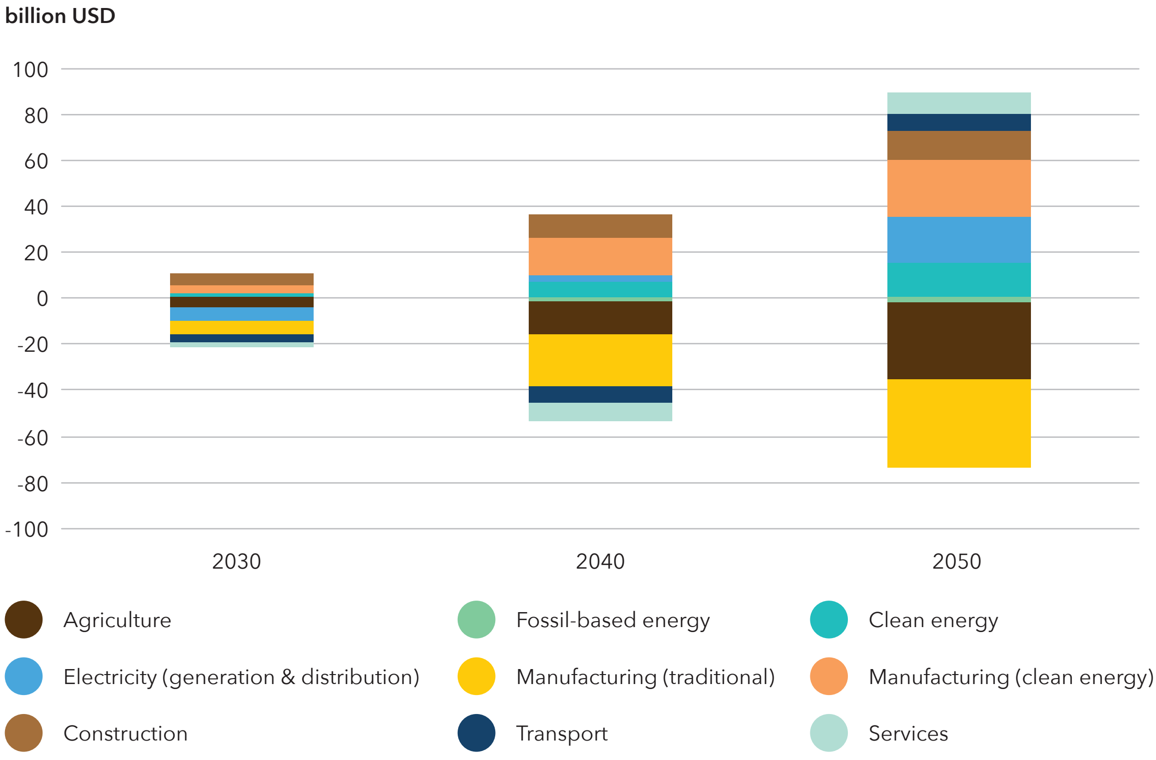
Source: GEM-E3

Production-wise, the sectors that benefit most from the transition are services, construction, and the manufacturing of "clean energy" equipment; more specifically, the production of electric vehicles increases by USD 8.4 billion annually on average over the projection period, households' appliances and equipment by USD 0.8 billion annually, and manufacturing of RES equipment by USD 1 billion. On the other hand, traditional manufacturing activities record losses of approximately 2% compared to the Baseline (for the period 2020–2055). This decrease is attributed partly to the shift towards the purchase of electric vehicles over conventional vehicles, the renewal of household appliances and the purchase of more efficient equipment, and to competitiveness losses associated with higher production costs (especially for consumer goods industries).

The output of service-related sectors increases cumulatively by 0.2% compared to the Baseline case. The sectors that benefit the most are those related to wholesale and retail trade (+1.2%), accommodation and food services (+0.4%), and other market services (+0.3%).

[18] The increase in production costs comes from the adjustment of wages and capital costs to a higher level due to higher growth compared to the Baseline case. In the model, wages and capital rents are adjusted to clear the relative markets (i.e., to equilibrate supply with demand). The degree of adjustment and its impact on macroeconomic performance is examined in the sensitivity scenarios.
[19] As public expenditures are assumed to be equal in the base and net-zero scenarios, only the impact on private consumption is shown in this and the following figures.

Figure 8. Sectoral production (change from Baseline)



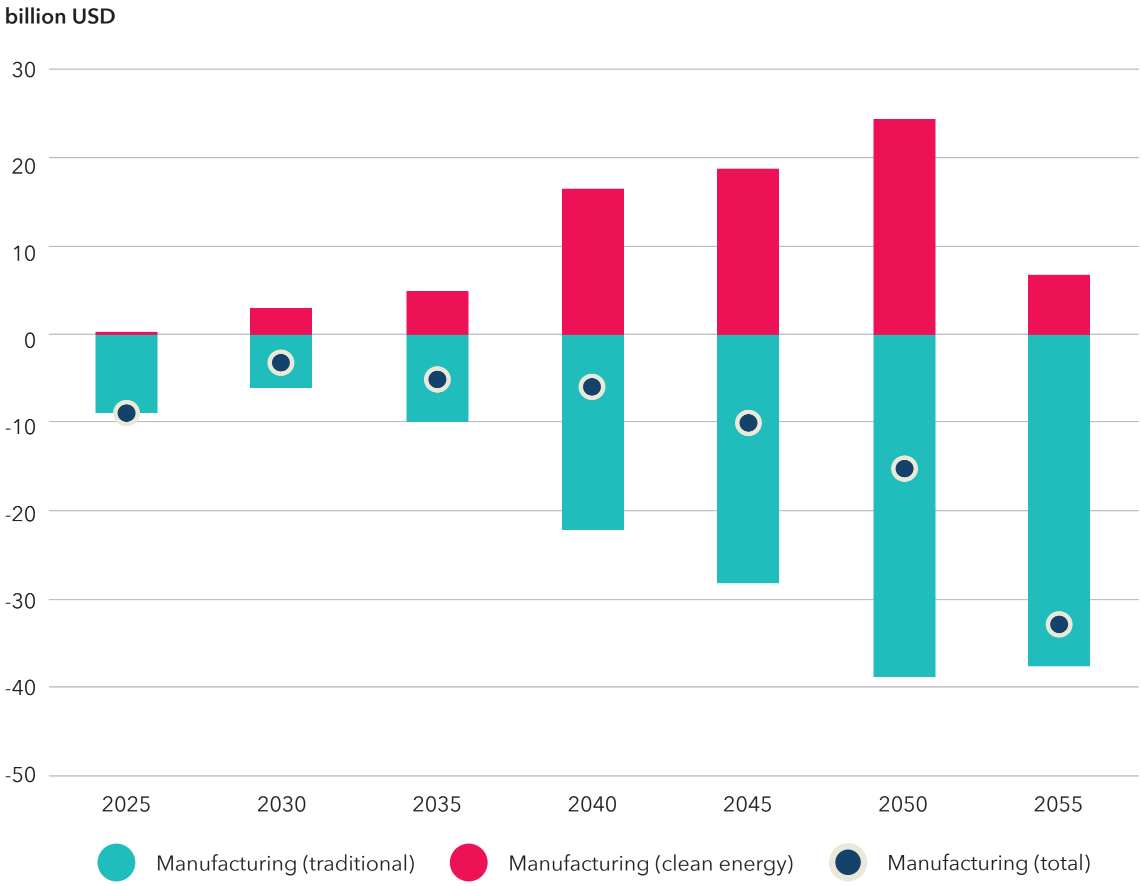
Source: GEM-E3

The manufacturing sector in total records a relative slow-down of its activity levels compared to the Baseline case. On average, the growth rate of total manufacturing output in Türkiye for the period 2020–2055 is equal to 2.5% compared to 2.6% in the Baseline case (this corresponds to a 1% decrease in the contribution of manufacturing to national gross value added). This change is driven mainly by the activities of "traditional" manufacturing sectors,[20] whose output decreases by 2.1% compared to the Baseline, while the output of "clean energy" manufacturing doubles during the projection period.

The output of the transport equipment sector (i.e., the production of both internal combustion engine vehicles and electric/plug-in vehicles) increases by 4.8% compared to the Baseline case. This increase is mainly attributed to the higher production of electric vehicles, which outweighs the decrease in the sales of vehicles with internal combustion engines. With respect to the other manufacturing activities, the activities that are found to be most affected are non-ferrous metals (–4.9% with respect to the Baseline), the electrical equipment and industries producing rubber and plastics (–3.8% and –3.1%, respectively), while the least affected are the non-metallic minerals industries and ferrous metals (0.14% and –0.7%, respectively).

[20] A detailed correspondence table between the aggregate sectoral resolution and the model sectors is provided in the Annex (Section 7.2).

Figure 9. Manufacturing output changes with respect to the Baseline scenario

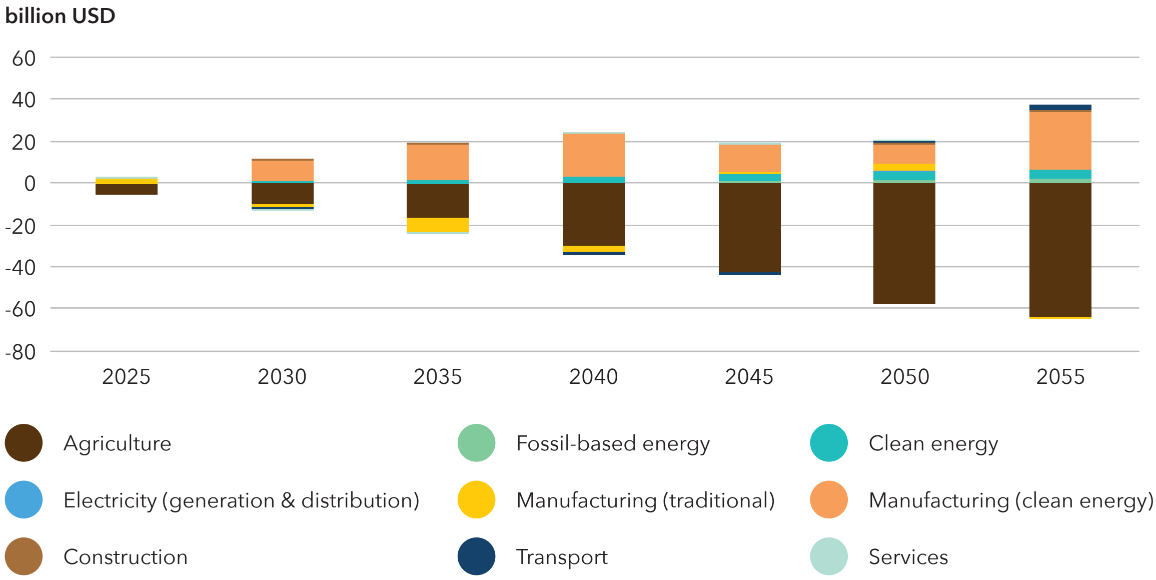


Source: GEM-E3

Trade-wise, exports are higher in comparison to the Baseline in the short- to medium-term but lower after 2040. In the early periods, capital costs are low as financing is available at low interest rates, and no interest is yet paid. In the long run, higher loan repayment costs coupled with higher capital costs lead to production cost changes. The impacts are more pronounced for consumer goods industries, ferrous metal industries, and manufacturers of transport equipment with internal combustion engine vehicles. These goods are affected because they are carbon intensive, they have high exposure to foreign competition, and do not contribute directly to the decarbonization process (e.g., demand for internal combustion engines is reduced).

Imports increase in the period up to 2040 and fall afterwards. At early stages, the increased demand for RES equipment and new appliances leads to an increase in imports. In the long run, domestic "clean energy" sectors have increased their production capacities, and energy savings are higher, leading to a decrease in imports. The benefit from lower imports of fossil fuel (–43% over the period 2020–2055 compared to the Baseline) is partly offset by the increased imports of manufacturing products (+3.7%) and of clean energy (i.e., higher imports of RES equipment, electric vehicles and biofuels, hydrogen etc.).

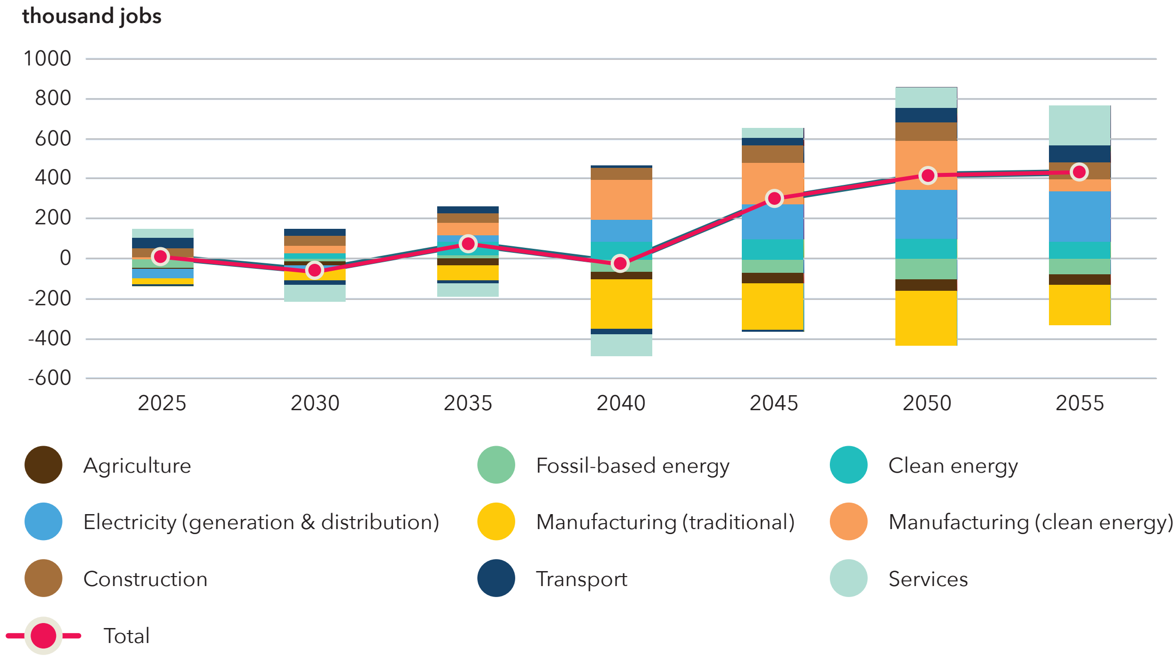
Figure 10. Change in sectoral imports with respect to the Baseline scenario



Source: GEM-E3

Employment is higher compared to the Baseline in most years of the transition. Job losses in the "traditional" manufacturing sectors and in fuel sectors are partly compensated by increased activity in the manufacturing of RES, energy saving appliances, and clean energy (on average, annual employment increases in the latter sectors is equal to 183,000 jobs). Furthermore, the transport equipment industry records annual average employment gains of approximately 51,000 jobs. Job creation in clean energy and in equipment associated with the clean energy transition is lower during the early years of the transition, as demand shifts towards goods that are mainly imported, and the economy has not completed its structural adjustment (which is mostly achieved in the long run when investments made in early periods to increase productive capacity pay off). Energy-intensive industries record marginal employment differences. Finally, investments in power generation and the grid are higher, which leads to increased activity in construction (+66,000 jobs per year) and services (these sectors account for approximately 34% of total employment in the economy in the Baseline case). In services, on average, approximately 20,000 jobs are created per year. With respect to average wages, these increase overall (+1.7%) during the transition period primarily due to the higher activity of construction and services (especially the latter are labour-intensive and have higher demand compared to, e.g., the manufacturing sectors).

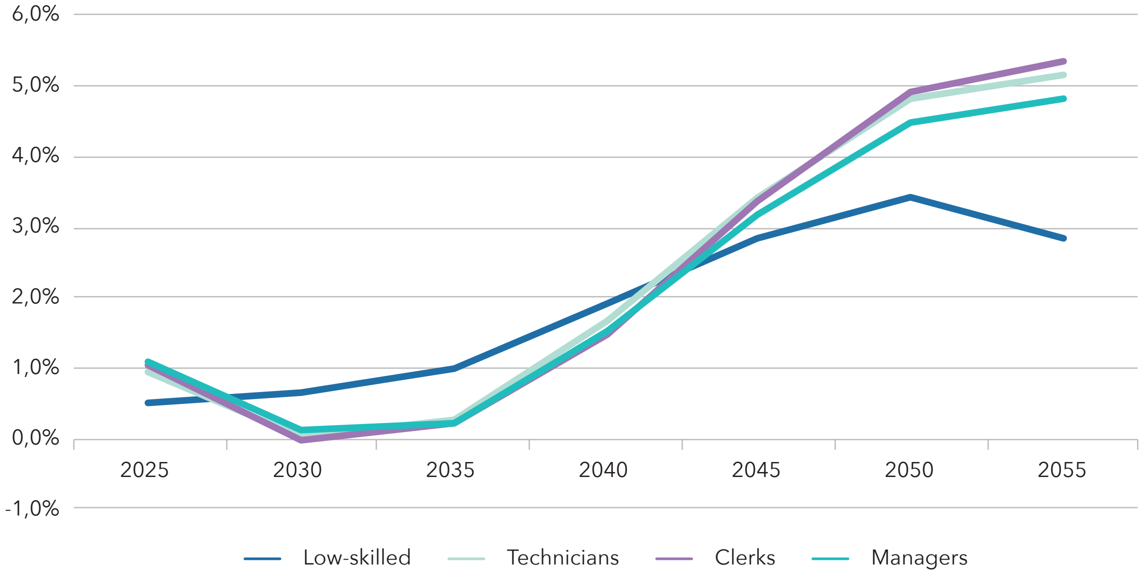
Figure 11. Change in sectoral employment with respect to the Baseline scenario



Source: GEM-E3

The NETZERO transition is a capital-intensive process. This is reflected in income generation. Compared to the Baseline scenario, the share of capital in total national income increases by 1%. The overall income in Türkiye increases by 2.9% over the projection period (labour income increases by 2.3% and capital income by 3.2%). An analysis of the change in labour income by occupation or skill level reveals that in comparison to the Baseline scenario, the net-zero transition will lead to higher income levels for all categories regardless of skill level. However, the increase in income will be slower for unskilled workers in comparison to those with higher skill levels, and the positive difference with the Baseline scenario will decline after 2050. While a direct measurement of the impact on income distribution was not possible in this study, the differences in income change between both capital and labour income as well as among different labour groups indicate that the impact of the transition on income distribution needs to be monitored

Figure 12. Labour income change by occupation/skill level with respect to the Baseline scenario (% changes)



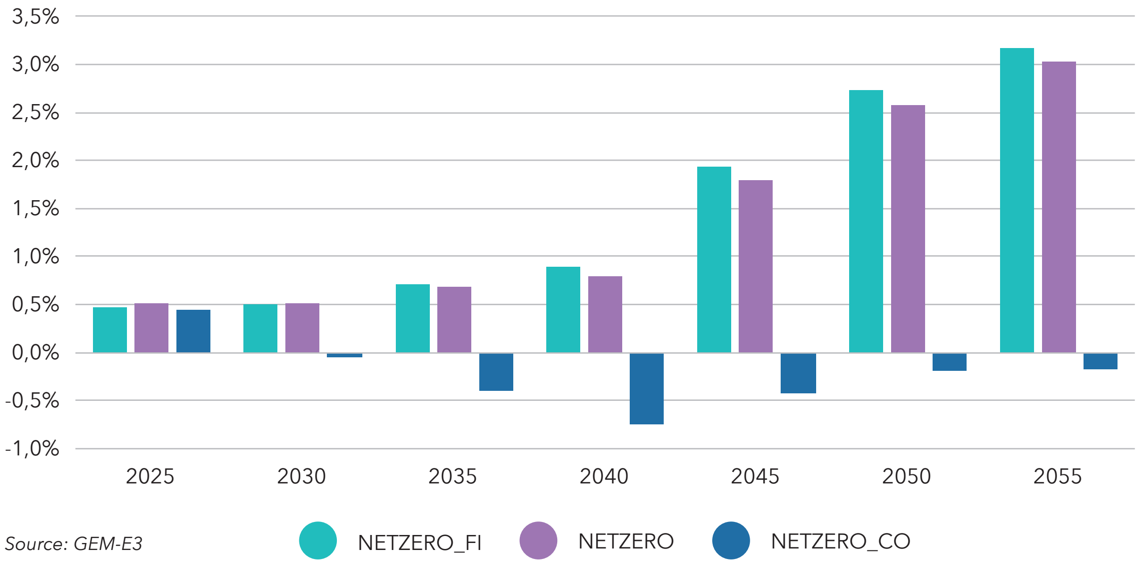
Source: GEM-E3

4.2. Sensitivity analysis

4.2.1. The role of financing

The NETZERO scenario also produces positive impacts in the case where external financing is available at no additional costs, but it produces negative results in the case where the investments must be financed using the country's own resources. As previously presented, in the central case (NETZERO) cumulative GDP increases by 1.4% compared to the Baseline case for the period 2020–2055. In the mixed financing setup (NETZERO_FI), the impacts are positive and marginally higher than the central case scenario (as GDP increases by 1.5%). The crowding out scenario leads to cumulative GDP losses, meaning unfavourable financing conditions hinder the growth potentials of the clean energy transition (–0.25%). The main reason behind the GDP losses in the latter scenario is that the multiplier effect of (crowding out) non-energy investments is higher than the multiplier effect of power generation sectors.

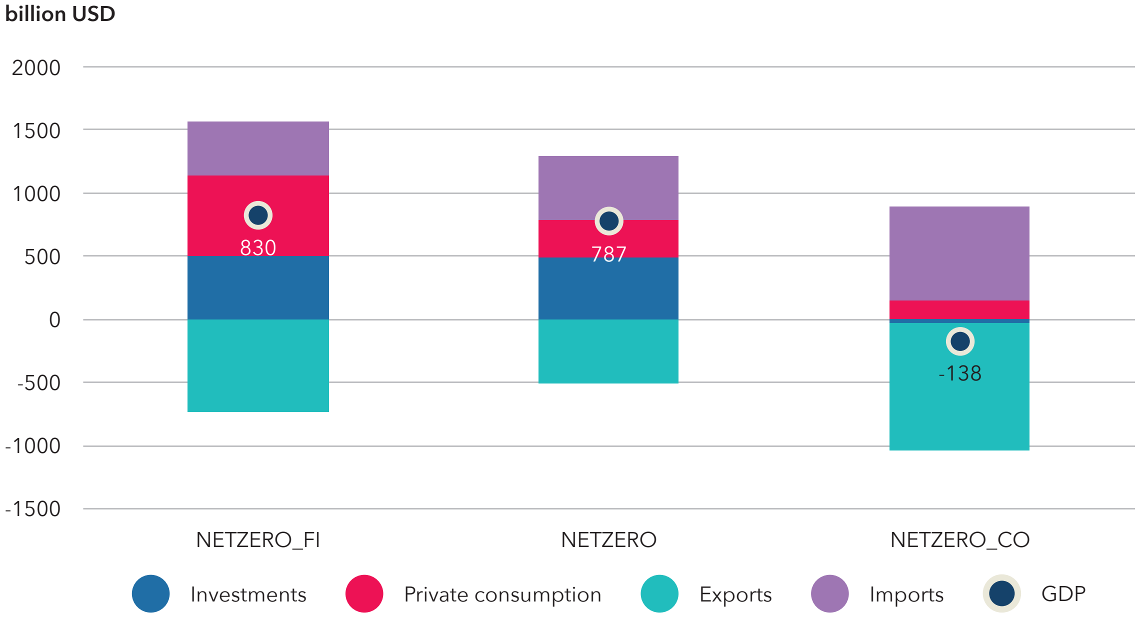
Figure 13. Change in GDP from the Baseline scenario under alternative financing schemes



Source: GEM-E3

In the external financing scenarios (NETZERO, NETZERO_FI), the positive impacts are driven mainly by investments, while in the self-financing setup, the economy suffers losses in GDP. Under the NETZERO_CO setup, investments required for the decarbonization of the electricity system and the development of the grid comes at the expense of other productive investments (leading to the reduction of overall investments in the economy) and requires higher savings rates; hence, the positive impacts on private consumption are lessened compared to the other financing scenarios. Moreover, in the NETZERO_CO scenario, increased investment requirements stress capital markets, leading to higher capital costs, which in turn translates into higher production costs and competitiveness losses. The impact on exports is higher than that of the other two setups.

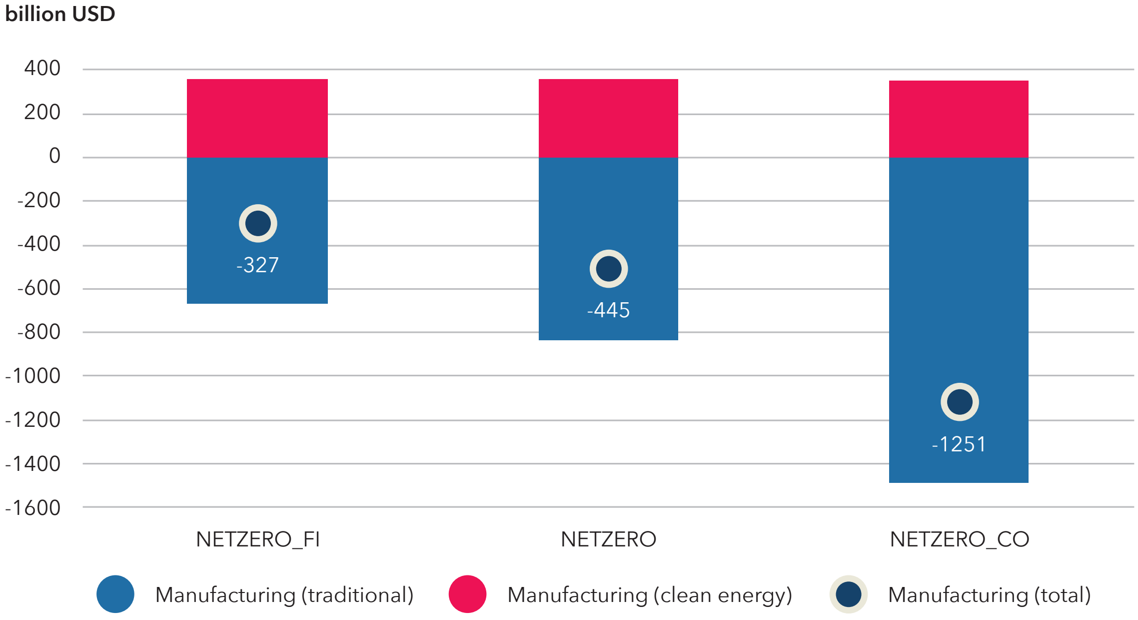
Figure 14. Cumulative change in main GDP aggregates with respect to the Baseline scenario under different financing schemes (2021–2053)



Source: GEM-E3

Total cumulative manufacturing output is reduced in the self-financing case compared to the Baseline scenario by approximately 2.2% as investments fail to compensate for the increased investments in the deployment of RES. Lower investments imply lower productive capacities and higher capital costs. The latter drives upwards the relative cost of domestically produced goods, which triggers substitution of Turkish products with products of other origin.

Figure 15. Cumulative change in manufacturing with respect to the Baseline scenario under different financing schemes (2021–2053)



Source: GEM-E3

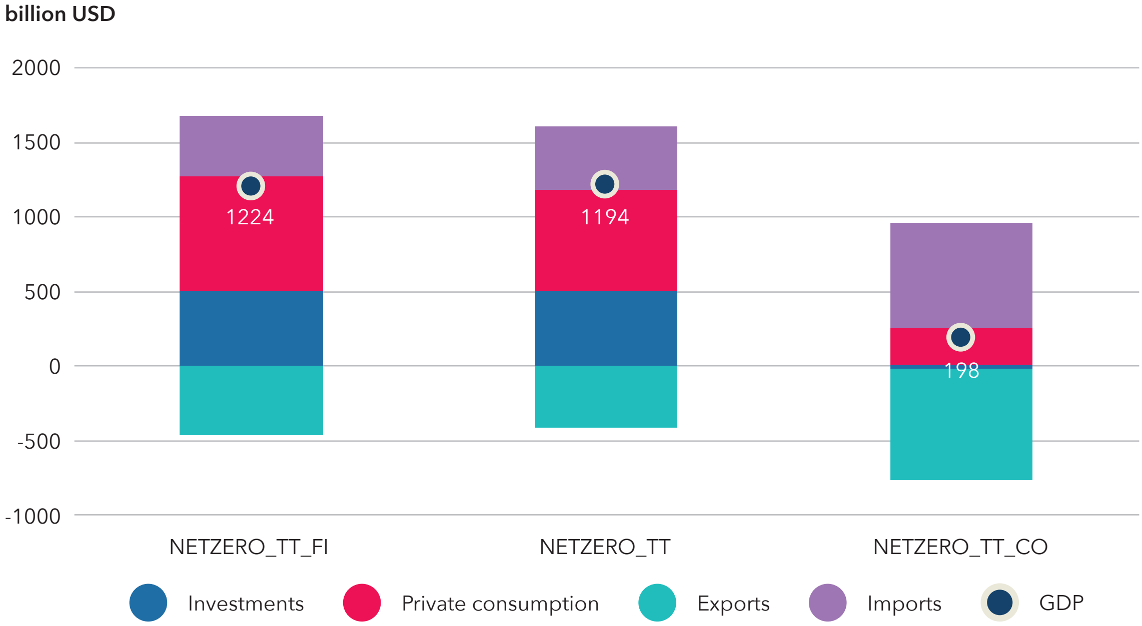
4.2.2. The role of wages

The impact of wages of the NETZERO transition was also evaluated in the context of our analysis. Wages determine to a large extent production costs, hence the overall level of prices in the economy and the competitiveness of Turkish products in international markets. Wages adjust to demand changes to clear the labour market.[21] The responsiveness of wages depends on various factors (such as minimum wages, unions, labour policies, etc.) and varies between countries.

In the NETZERO_TT scenarios, it is assumed that frictions and/or labour policies lead to sticky wages (and equal to their Baseline levels). The sensitivity runs combine assumptions on the financing of investments with fixed wages. In the central case scenario (where financing comes from loans), constant primary production factor costs lead to higher GDP gains compared to the central case (NETZERO), and GDP increases by 2.24% over the period from 2020–2055. The negative impacts on production costs and competitiveness are lower compared to the scenarios with flexible labour markets. Hence, the negative impact of higher production costs on exports is alleviated, and the additional demand generated from increased activity benefits is recycled back into the economy.[22]

[21] Supply = demand
[22] It is assumed that the additional benefits created by lower production costs will remain in the domestic economy and will return to the economy as increased demand.

Figure 16. Cumulative change in main GDP aggregates with respect to the Baseline scenario under different financing schemes together with sticky wages (2021–2053)

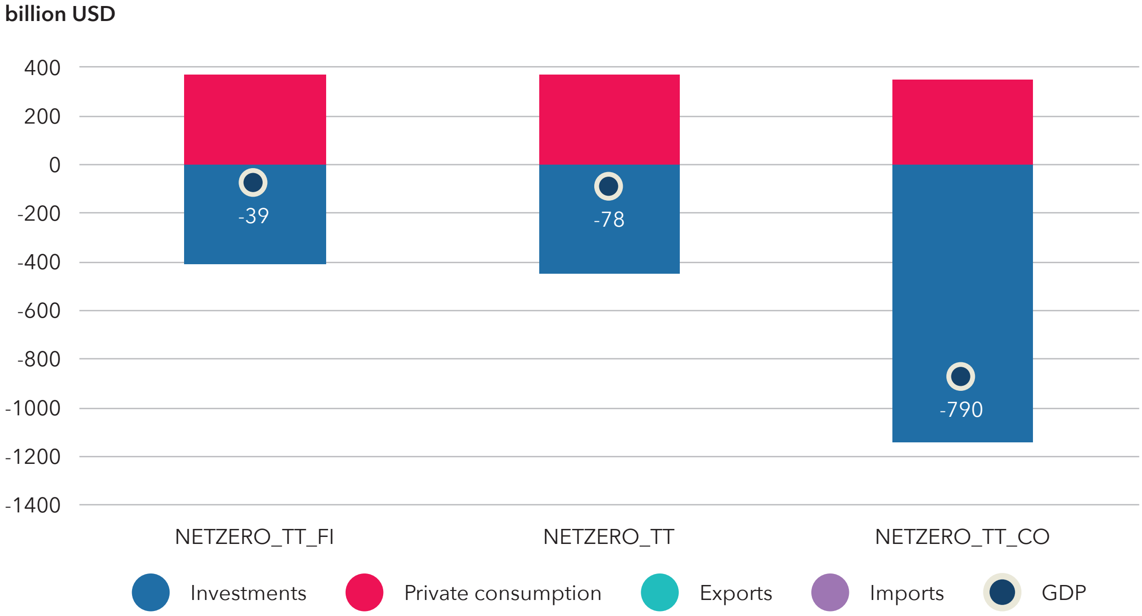


Source: GEM-E3

The variant with sticky wages and capital rents (NETZERO_TT) also produces positive results in the rest of the financing scenarios. In the self-financing case (CO), the scenario with flexible wages generates a cumulative loss of approximately USD 138 billion over the projection period while the variant with constant wages leads to a cumulative gain of approximately USD 198 billion.

The impacts on the output of the manufacturing industries are lessened compared to the flexible wage scenarios. For example, in the central case scenario, total manufacturing output falls by approximately USD 308 billion cumulatively, while in its counterpart with fixed wages (NETZERO_TT) output decreases only by USD 39 billion.

Figure 17. Cumulative change in manufacturing with respect to the Baseline scenario under different financing schemes together with sticky wages (2021–2053)



Source: GEM-E3

SECTION 5
Overall Impact
and Cost-Benefit
Analysis

GDP, wages, and total employment increase in real terms from 2020–2055 in both the baseline and net-zero scenarios. While GDP grows 2.7-fold, the number of people employed grows by 6.4 million in the baseline and 6.8 million in the central net-zero scenario. In other words, there are no losses in absolute terms in either scenario. The impact of the transition is measured in terms of the difference between the baseline and net-zero scenarios.

Table 6. Impact summary table NETZERO (central case) in comparison to the Baseline scenario

As Percentage of Baseline GDP*	Cumulative (2021-2055)	2030	2040	2055
National Income Impact (GDP)	**1.4%**	**0.5%**	**0.8%**	**3.0%**
Manufacturing Impact	**-0.6%**	**-0.3%**	**-0.3%**	**-0.8%**
Overall International Trade Balance Impact	**0.0%**	**-0.1%**	**-0.1%**	**-0.3%**
Total Energy Security Impact	**1.8%**	**0.6%**	**1.9%**	**2.4%**
Socioeconomic Welfare Impact	**2.4%**	**0.7%**	**2.5%**	**3.3%**
Wage Income	0.6%	0.0%	0.4%	1.1%
Health & Environment Impact	0.7%	0.1%	0.9%	0.7%
Climate Change Impact	1.1%	0.5%	1.2%	1.4%
As Percentage of Baseline Total Employment**				
Net Additional Employment	1.6%	-0.2%	0.1%	1.4%

** The first column shows the difference between the cumulative indicator in the NETZERO and baseline scenarios as a percentage of the total cumulative baseline GDP. The next three columns show the difference between the Net-Zero and Baseline scenarios as a percentage of the baseline GDP in the specified year.*

***Each column shows the difference between the net-zero and the Baseline scenario in the increase in the number of people employed between the base and target year as a percentage of the employment in the base year. The base year for the cumulative and 2030 columns is 2020, whereas for 2030 it is the 2040 column and 2040 for the 2055 column.*

National income impact: Measured by the change in GDP. The impact on GDP is positive and increases with time.

Manufacturing impact: Measured by the change in manufacturing value added. The cumulative impact is small, negative, and increases in magnitude after 2040.

Overall international trade balance impact: The international trade balance is defined as exports minus imports. The overall international trade balance impact is close to zero.

Total energy security impact: For the purposes of this report, energy security is defined as lower reliance on imports for energy and energy generation goods and equipment as a result of the energy transition. The indicator used to measure the energy security impact is the trade balance (exports minus imports) of energy (mostly fossil fuels) and equipment used for clean energy generation and consumption (batteries, advanced electrical appliances, advanced heating and cooking appliances, equipment for wind energy, PV panels, hydrogen and CCS). The cumulative energy security impact is relatively high and increases over time.

Socioeconomic welfare impact: For the purposes of this report, the socioeconomic welfare impact is defined as the increase in total wage income and the avoidance of health and climate change risks associated with the use of fossil fuels. The cumulative impact on total wage income is small but increases over time. The health and environmental impacts stemming from air pollution are remunerated based on SHURA's externality study released in 2020 (SHURA, 2020). To assess the climate change impact, a carbon value of 70 EUR/ton adjusted by purchasing power parity GDP per capita (PPP GDP/capita) differential between Türkiye and a reference EU country was used.[23] Despite this rather modest estimate of external costs, the impact is significant and increases over time. The methodology and assumptions for estimating the external costs are summarized in the Annex (Section 7.4)

Employment impact: The cumulative impact on employment creation, measured by the difference in net additional employment, is positive. Nevertheless, the 20-year period until 2040 needs particular attention as the net impact during this period is close to zero.

Table 7. Cumulative impact range in comparison to Baseline scenario (2020–2055)

As Percentage of Baseline GDP	Minimum	Central	Maximum	Sc. Min.	Sc. Max
National Income Impact	-0.2%	1.4%	2.1%	NZ_CO	NZ_TT_FI
Manufacturing Impact	-2.2%	-0.6%	-0.1%	NZ_CO	NZ_TT
Overall International Trade Balance Impact	-0.5%	0.0%	0.0%	NZ_CO	NZ_TT_FI
Total Energy Security Impact	1.8%	1.8%	1.8%	-	-
Socioeconomic Welfare Impact	2.3%	2.4%	2.5%	NZ_CO	NZ_TT_FI
As Percentage of Baseline Total Employment					
Cumulative Net Additional Employment	0.2%	1.6%	6.2%	NZ_CO	NZ_TT

Table 7 shows the range of cumulative impacts and the scenario conditions under which the minimum and maximum values occur in relation to the central NETZERO scenario. In nearly all cases, maximum positive impact is achieved in the loan-based scenario combined with sticky wages, and the minimum impact occurs in the self-financing case with flexible wages. However, the net impact of financing (1.6%) on GDP is higher than that of sticky wages (0.7%).[24] On the other hand, the sticky wages scenario incorporating financing with loan repayment creates the maximum number of jobs by a wide margin.

[23] As in the externality study, the reference country used was Germany, and PPP GDP/capita was assumed to gradually converge to that of Germany starting from 59% in 2022, reaching 85% in 2055. The resulting carbon value was 35 EUR/ton in 2022, gradually going up to 49 EUR/ton by 2055.

[24] The impact of financing is calculated by subtracting the impact of the self-financing scenario from that of the NETZERO (central) scenario. The impact of sticky wages is calculated by subtracting the impact of the central scenario from the loan-based sticky wages scenario.

5.1. Overall costs and benefits

Table 6 summarizes the magnitude of the impacts of the transition on the main socioeconomic areas likely to be impacted by the transition. While the table provides a perspective on the net socioeconomic benefits of the transition after accounting for the socioeconomic costs, it does not include the net financial cost. The figures in the table do not account for the additional cost of setting up and running the new energy system, stemming mainly from investments in renewable energy facilities, power grid improvements, batteries, digitalization, etc., which are reflected in the system costs. The benefits of the transition have to be weighed against the financial costs to be incurred. Table 8 shows the balance of annual benefits and costs of the transition.

The net benefits of the transition that are part of national accounting can be captured by the difference in GDP. Total benefits also include the benefits not captured in GDP, such as social welfare impacts related to avoided air pollution and carbon emissions. The costs are represented by the system costs.

Table 8. Cost-benefit table, NETZERO in comparison to the Baseline scenario (2014 USD billion)

	Annual Average (2021-2055)	2030	2035	2040	2045	2050	2055
Benefits	**51.4**	**13.8**	**26.5**	**46.9**	**67.2**	**90.4**	**114.5**
Difference in National Income	22.5	6.0	9.8	13.0	33.4	54.1	70.8
Health, Environment & Climate Change Impact	28.9	7.8	16.7	33.9	33.8	36.3	43.8
Costs	**26.0**	**8.9**	**15.9**	**43.5**	**56.0**	**45.1**	**36.0**
System Costs	26.0	8.9	15.9	43.5	56.0	45.1	36.0
Net Benefit	**25.4**	**4.9**	**10.6**	**3.4**	**11.2**	**45.3**	**78.5**
Benefit/Cost	**2.0**	**1.5**	**1.7**	**1.1**	**1.2**	**2.0**	**3.2**

On average, the benefits of the transition will be twice as much as the costs. Following investment peaks during 2036–2045, system costs rise rapidly and temporarily approach the level of net benefits around 2040. Particular attention will be needed around this period to develop appropriate industrial and just transition policies to increase the positive impacts on GDP.

SECTION 6
Conclusion

The impact assessment of the NZ2053 pathway in Türkiye reveals that the transition will reap several economic benefits such as increased investments and lower fossil fuel imports. Increased investments provide a boost for the domestic economy mainly through the construction sector, while the restructuring of the energy system implies additional benefits. Fossil fuels are mainly imported, while the development of RES in electricity production and the electrification of the economy leads to gains due to the higher domestic content of clean energy and electricity sectors. Furthermore, the development of RES coupled with energy savings and transport electrification leads to higher activity in domestic manufacturing sectors providing clean energy equipment goods, which partly compensates for the losses in traditional manufacturing sectors (either due to lower demand or to competitiveness losses). Employment is found to be higher in the NETZERO compared to the Baseline case, and labour income is found to be higher across all labour classes.

The analysis also covers factors of uncertainty such as the availability of financial resources and the degree of labour cost response to the shift in demand structure. The analysis shows that the degree to which primary production markets adjust to demand as well as the ease of financing the necessary investments influence the impact of the clean energy transition. Higher wage rigidity and external financing further enhance the gains from the decarbonization of Türkiye's energy system. Cumulative GDP impacts are found to be in the range of USD –138 billion to USD 1,224 billion (–0.2% to +2.1% of cumulative GDP) over the period 2020–2055. The central case scenario, where a modest financing cost is assumed for the additional investments and labour markets adjust to demand-side changes, leads to cumulative gains of USD 787 billion. The overall results are in line with those reported in the literature (considering differences in energy-related inputs and sectoral scope): in 2030, the GEM-E3 NETZERO study estimates GDP changes of +0.5%, and SHURA (2021) estimates changes of 1.01%; meanwhile, in 2040, the respective changes are estimated as 0.8% and 1.4%, respectively, for the two studies. The sensitivity results also highlight the fact that labour market adjustments and the ease of financing positively influence the economy during the transition as in Hallegate et al. (2023).

The transition will transform the economy as new sectors emerge, while others will experience a slowdown and even a decrease in their activity levels compared to the Baseline case. The sectors that are expected to benefit more are those providing the necessary goods for the NETZERO scenario to come true. In other words, sectors that are active in the fields of renewable equipment, energy efficiency equipment, and electric vehicles are expected to experience a large increase in their activity levels.

This study, which examines the implications of a defined net-zero energy transition pathway on socioeconomic indicators and which is essentially a quantitative modelling exercise, should be considered as a starting point for policy guidance rather than a definitive outcome. Supporting this study with qualitative research and discussions centred on the principles of just transformation that address the national economy and sustainable development as a whole will contribute to the planning of a healthy transition process. As part of this effort, the SHURA Energy Transition Center published two discussion papers, one on industrial policy alternatives for Türkiye (SHURA 2024a) and the other on regional employment policy options

(SHURA 2024b). In this context, it is of critical importance to continue studies and to maintain dialogues on all technical, economic, and social aspects of the transition, involving the public and private sectors, professional associations, non-governmental organisations (NGOs), labour and employers' organisations, universities, and other research institutions.

The main policy areas that can be addressed in the short term to respond to the impacts addressed in this report are listed below.

Energy and Climate Policies: Clearly identifying and publicising the intermediate steps of Türkiye's net-zero emissions target for 2053 and the interim targets and actions towards this target will increase predictability. Redirecting existing subsidies and incentives in the energy sector from fossil fuels to clean electricity and promoting electrification in industry, transport, and households are essential for the transition process. Establishing a national emissions trading system in Türkiye and implementing it in support of the transition should also be part of the transition agenda.

Economic Policies: Shifting the focus of Türkiye's macroeconomic agenda from tackling current issues such as high inflation, exchange rate, and interest rate toward structural issues such as value-added production, labour force improvement, and ensuring sustainable development in a way that includes industrial policy is important for the healthy execution of the transition process.

Industrial Policy: The low-tech, low value-added, and carbon-intensive production composition of the industry in Türkiye is found to be at the root of macroeconomic issues such as the foreign trade deficit and the middle-income trap. Therefore, addressing the energy transition in conjunction with industrial transformation to raise the technology level of production in conjunction with decarbonization will be essential. Adopting holistic industrial, transport, finance, and trade policies that ensure structural transformation in key sectors with enhanced integration into international value chains can ensure that the positive effects of the transition exceed current projections. In this context, supporting decarbonization together with a shift in the product composition toward more-value added products, especially in energy-intensive industries, can mitigate the negative impacts associated with the transition. In this context, it will be important to consider the effects of the Carbon Border Adjustment Mechanism (CBAM) and to develop appropriate trade policies and strategies.

Employment Policy: In addition to active employment policies aimed at developing new skills that will be needed with the transition and facilitating the employment of the labour force in new fields, it is also crucial to plan for alternative policies such as retraining, compensation, re-employment, and early retirement for employees who may face the risk of losing their jobs in sectors that are shrinking as a result of the transformation. Adoption of regional development policies with a just transition perspective in regions having a high concentration of jobs in carbon-intensive sectors with the participation of all stakeholders will reinforce the benefits of the transition while mitigating the negative impacts.

Financing Policies: The results of this study indicate that financing provided under favourable conditions will increase the positive impacts of the transition. Difficulties in the macroeconomic environment and access to finance worldwide as well as in Türkiye bring forth new challenges, increasing the pertinence of strategic planning for climate diplomacy, development, and financing. In order to increase access to finance and diversify financial resources, financial structures and funding mechanisms should be established within the scope of the long-term energy transition strategy with the active participation of the public sector, private sector, financial institutions, and NGOs (SHURA, 2022).

In conclusion, Türkiye's net-zero carbon roadmap provides important opportunities for economic development, employment growth, and energy security, while contributing to the solution of pressing environmental and health issues. The transition requires substantial investments and a rigorous planning process, especially with regard to financing and labour markets, but promises benefits far beyond its costs. Provided that Türkiye strikes a strategic balance between industrial policy, access to finance, and just transition measures, it can amplify the positive effects of this transition and ensure that the transition to a decarbonized economy is both sustainable and equitable for all stakeholders.

Annexes

Additional information on the GEM-E3M model

The GEM-E3 model incorporates microeconomic mechanisms and institutional features within a consistent macroeconomic framework and avoids the representation of behaviour in reduced form. The model features perfect competition market regimes, discrete representation of power producing technologies, semi-endogenous learning by doing effects, equilibrium unemployment, the option to introduce energy efficiency standards, and formulated emissions permits for GHG and atmospheric pollutants. Its scope is general in two terms: it includes all simultaneously interrelated markets and represents the system at the appropriate level with respect to geography, the sub-system (energy, environment, economy), and the dynamic mechanisms of agents' behaviour. It formulates the supply or demand behaviour of the economic agents separately, which are considered to optimize their objectives individually, while market-derived prices guarantee global equilibrium, allowing the consistent evaluation of the distributional effects of policies. It explicitly considers the market clearing mechanisms and the related price formation in the energy, environment, and economy markets: prices are computed by the model as a result of supply and demand interactions in the markets, and different market clearing mechanisms, in addition to perfect competition, are allowed.

The model formulates production technologies endogenously, allowing for price-driven derivation of all intermediate consumption and the services from capital and labour. In the electricity sector, it adopts a bottom-up approach to represent the different power generation technologies. On the demand side, the model formulates consumer behaviour and distinguishes between durable (equipment) and consumption goods and services. The model is dynamic, recursive over time, and driven by the accumulation of capital and equipment. Technological progress is explicitly represented in the production function, either exogenously or endogenously, depending on research and development (R&D) expenditure by the private and public sector, and accounts for spillover effects. Additionally, the model operates based on the participating agents' myopic expectations. The design of GEM-E3 model was developed following four main guidelines:

1) Model design around a basic general equilibrium core in a modular way so that different modelling options, market regimes, and closure rules are supported by the same model specification.
2) Fully flexible (endogenous) coefficients in production and in consumer demand.
3) Calibration to a base year data set, incorporating detailed Social Accounting Matrices as statistically observed.
4) Dynamic mechanisms, through the accumulation of capital stock and learning effects.

GEM-E3 is built based on a Social Accounting Matrix (SAM). Technical coefficients in production and demand are flexible in the sense that producers can alternate the mix of production not only regarding the primary production factors but also the intermediate goods. Production is modelled through KLEM (capital, labour, energy and materials) production functions involving many factors (all intermediate products and three primary factors—capital, natural resources, and labour). At the same time consumers can also endogenously decide on the structure of their demand for goods and services. Their consumption mix is decided through a flexible expenditure system involving durable and non-durable goods.

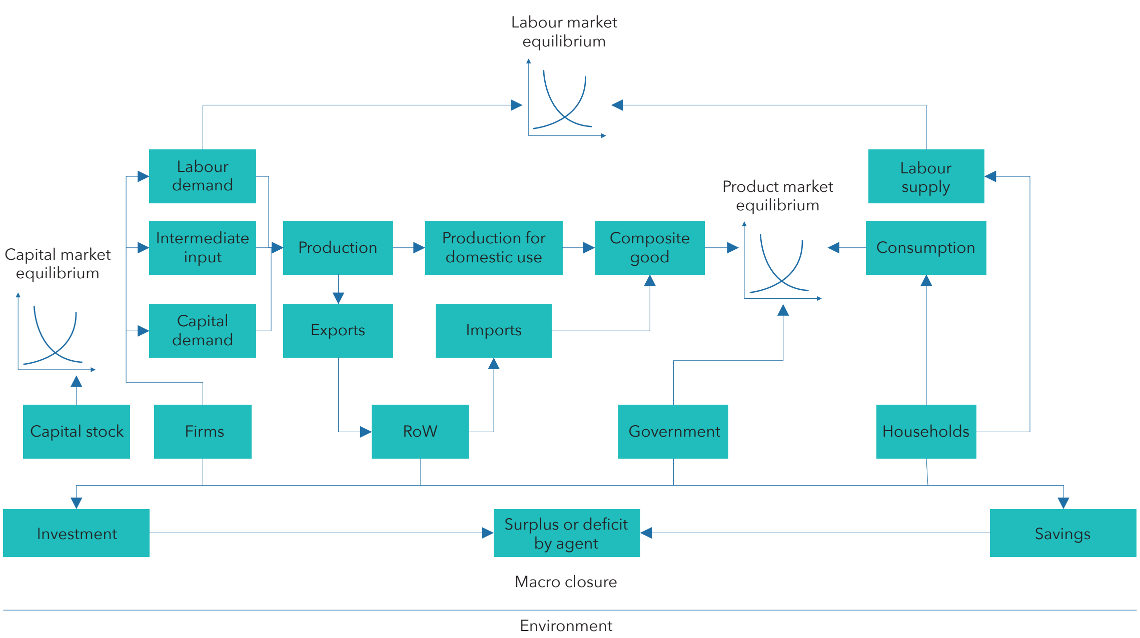
The GEM-E3 model is built in a modular way around its central CGE core. It supports defining several alternative regimes and closure rules without having to respecify or recalibrate the model. The most important of these options are presented below:

- Capital mobility across sectors and/or countries
- Flexible or fixed current account (with respect to the foreign sector)
- Flexible or fixed labour supply
- Market for GHG allowances national/international, environmental constraints
- Fixed or flexible public deficit

The model is dynamic in the sense that projections change over time. Its properties are mainly manifested through stock/flow relationships, technical progress, capital accumulation, and agents' (myopic) expectations. Total demand (final and intermediate) in each country is optimally allocated between domestic and imported goods, under the hypothesis that these are considered as imperfect substitutes (the "Armington" assumption of imperfect substitution between locally produced goods and imports). Economies in the model are linked through bilateral trade flows considering trade margins and transport costs. Consumption and investment are built around transition matrices linking consumption by purpose to demand for goods and investment by origin to investment by destination. Figure 1 provides a schematic representation of the key linkages between the economic agents of the GEM-E3 model.

Institutional regimes that affect agent behaviour and market clearing are explicitly represented, including public finance, taxation, and social policy. The model represents goods that are external to the economy, for example, damages to the environment.

Figure 18. GEM-E3 economic circuit



Source: GEM-E3 manual

The internalization of environmental externalities is achieved either through taxation or global system constraints, with the shadow costs influencing the decisions of economic agents. In the GEM-E3 model, global/regional/sectoral constraints are linked to environmental emissions, changes in consumption or production patterns, external costs/benefits, taxation, pollution abatement investments, and pollution permits. The model evaluates the impact of policy changes on the environment by calculating the change in emissions and damages and determines costs and benefits through an equivalent variation measurement of global welfare (inclusive environmental impact).

Sectoral scope

The following table presents the GEM-E3 sectoral scope and the correspondence between the aggregate sectors as presented in this report and the GEM-E3 sectors.

Table 9. Sectoral resolution

Agriculture	Agriculture
	Wheat, Cereals and Grains, Sugar Cane, Sugar Beet
	Oil and Seeds
	Forestry
Energy	Coal
	Crude Oil
	Oil
	Gas Extraction
	Gas
Clean energy	Biomass Solid
	Ethanol
	Bio-diesel
	Hydrogen
	Clean Gas
	CO_2 Capture
Electricity (generation & distribution)	Power Supply
Manufacturing (traditional)	Ferrous Metals
	Non-ferrous Metals
	Fabricated Metal Products
	Chemical Products
	Basic Pharmaceutical Products
	Rubber and Plastic Products
	Paper Products, Publishing
	Non-Metallic Minerals
	Computer, Electronic and Optical Products
	Electrical Equipment
	Machinery and Equipment
	Transport Equipment (Excluding EV)
	Other Equipment Goods
	Consumer Goods Industries

Manufacturing (clean energy)	Batteries
	EV Transport Equipment
	Advanced Electric Appliances
	Advanced Heating and Cooking Appliances
	Equipment for Wind Power Technology
	Equipment for PV Panels
	Equipment for CCS Power Technology
Construction	Construction
Transport (passengers)	Air Transport
	Road-Passenger transport
	Rail-Passenger transport
	Water-Passenger transport
Transport (freight)	Water-Freight Transport
	Warehousing and Support Activities
	Road-Freight Transport
	Rail-Freight Transport
Services	Trade
	Accommodation, Food and Service Activities
	Financial Services
	Insurance
	Recreational and Other Services
	Education
	Other Market Services
	Other Non-Market Services
	R&D

Results NETZERO

Table 10. Change in key macroeconomic variables with respect to the Baseline scenario (in USD billion)

	2030	2040	2050	2055
GDP	**6.4**	**13.0**	**54.1**	**70.5**
Private consumption	0.0	-4.1	23.6	56.8
Investments	7.8	19.3	24.4	19.6
Exports	-3.4	-13.3	-32.3	-34.4
Imports	-2.0	-11.1	-38.5	-28.5
Production				
Agriculture	-0.2	-0.9	-1.8	-1.2
Energy	-3.8	-14.9	-33.1	-36.5
Clean energy	1.8	7.5	15.7	15.0
Electricity (generation & distribution)	-5.5	2.5	19.9	22.3
Manufacturing (traditional)	-6.1	-22.2	-38.8	-37.7
Manufacturing (clean energy)	3.0	16.6	24.4	6.8
Construction	5.6	10.2	13.4	12.5
Transport (passengers)	-1.9	-4.2	6.3	11.2
Transport (freight)	-1.2	-3.1	0.4	0.0
Services	-2.3	-8.0	9.6	0.0

Source: GEM-E3

Table 11. Change in sectoral output with respect to the Baseline scenario (in USD billion) for selected sectors

	2030	2040	2050	2055
Manufacturing	**-3.1**	**-5.6**	**-14.4**	**-19.2**
Ferrous Metals	-0.5	-0.2	0.1	2.2
Non-ferrous Metals	-0.3	-1.5	-2.7	-2.9
Fabricated Metal Products	0.1	-0.2	-1.1	0.1
Chemical Products	0.3	-1.1	-2.0	-6.9
Basic Pharmaceutical Products	0.0	-0.2	-0.5	-0.3
Rubber and Plastic Products	-0.3	-1.6	-3.3	-3.0
Paper Products, Publishing	-0.1	-0.4	-0.5	-0.1
Non-metallic Minerals	0.1	-0.1	1.1	0.4
Computer, Electronic and Optical Products	-0.1	-0.1	-0.5	-0.4
Electrical Equipment	-0.3	-1.3	-3.3	-2.2
Equipment Goods	1.0	1.1	-2.0	-0.9
Machinery and Equipment	-0.2	-1.1	-3.3	-1.6
Advanced Electric Appliances	0.5	0.4	0.2	0.4
Advanced Heating and Cooking Appliances	0.6	0.5	0.4	0.6
Equipment for Wind Power Technology	0.1	1.7	2.2	0.0
Equipment for PV Panels	0.0	0.2	0.1	-0.1
Equipment for CCS Power Technology	0.0	0.0	0.1	0.0
Other Equipment Goods	0.1	-0.5	-1.7	-0.2
Transport Equipment	-0.3	7.9	13.2	-2.1
Transport Equipment (excluding EV)	-2.1	-5.9	-8.2	-8.4
EV Transport Equipment	1.8	13.8	21.4	6.4
Consumer Goods Industries	-2.5	-8.0	-12.9	-3.1
Batteries	0.0	0.0	0.0	0.0
Construction	**5.6**	**10.2**	**13.4**	**11.5**
Services	**-2.3**	**-7.9**	**9.7**	**39.7**
Trade	0.7	0.9	7.3	15.1
Accommodation, Food and Service Activities	-0.7	-1.7	1.8	7.2
Financial Services	-0.4	-0.9	0.4	2.6
Insurance	-0.1	-0.3	-0.5	0.0
Recreational and Other Services	-0.3	-1.0	0.0	2.7
Education	-0.4	-1.3	-1.3	-0.4
Other Market Services	-0.8	-2.9	1.7	10.5
Other Non-Market Services	-0.2	-0.7	0.3	2.0

Table 12. Change in sectoral employment with respect to the Baseline scenario (in '000 persons) for selected sectors

	2030	2040	2050	2055
Manufacturing	**-17.0**	**-42.3**	**-27.6**	**-67.9**
Ferrous Metals	1.2	0.1	2.4	4.1
Non-ferrous Metals	-0.9	-6.7	-7.9	-7.4
Fabricated Metal Products	-2.8	-11.2	-15.3	-3.8
Chemical Products	4.9	-4.8	-6.0	-21.7
Basic Pharmaceutical Products	-0.5	-2.0	-2.7	-1.4
Rubber and Plastic Products	-9.1	-26.5	-39.8	-31.5
Paper Products. Publishing	-0.3	-4.8	-3.1	0.5
Non-metallic Minerals	0.5	6.1	18.7	15.8
Computer. Electronic and Optical Products	-0.3	-1.4	-2.8	-2.0
Electrical Equipment	-2.6	-15.4	-27.6	-15.8
Equipment Goods	10.3	4.9	-13.7	-3.5
Machinery and Equipment	-1.0	-14.8	-31.1	-11.1
Advanced Electric Appliances	6.7	3.8	2.0	2.8
Advanced Heating and Cooking Appliances	7.1	4.8	3.5	4.3
Equipment for Wind Power Technology	0.9	20.4	21.2	0.0
Equipment for PV Panels	0.2	1.8	1.2	-0.6
Equipment for CCS Power Technology	0.0	0.0	0.9	0.0
Other Equipment Goods	-3.7	-11.1	-11.3	1.1
Transport Equipment	-2.9	110.9	157.6	3.0
Transport Equipment (excluding EVs)	-29.2	-59.8	-60.7	-55.7
EV Transport Equipment	26.2	170.7	218.4	58.7
Consumer Goods Industries	-14.4	-91.6	-87.6	-4.2
Batteries	0.0	0.1	0.1	0.0
Construction	**54.0**	**59.3**	**89.1**	**70.4**
Services	**-85.8**	**-115.8**	**107.6**	**229.4**
Trade	-12.7	-14.3	46.0	76.1
Accommodation. Food and Service Activities	-15.9	-25.6	11.1	36.1
Financial Services	-8.4	-11.8	3.7	12.9
Insurance	-0.8	-2.0	-2.0	-0.6
Recreational and Other Services	-6.0	-10.4	0.1	14.0
Education	-15.9	-18.3	-4.9	14.9
Other Market Services	-10.6	-28.9	4.6	18.3
Other Non-Market Services	-15.5	-4.5	49.0	57.6

Health, environment and climate change impacts

Externalities due to Türkiye's fossil fuel use in power generation, land transport, industry, and heating in 2018 were estimated to be USD 8 billion per year, corresponding to 1.5% of Türkiye's 2018 GDP and one-third of Türkiye's health expenditures (SHURA, 2020). About 0.42% of this total stemmed from power generation, while other studies related to the power sector estimated that both emissions and external costs could be more than twice this figure, exceeding 1% of GDP (HEAL, 2021; Greenpeace, 2020). The external cost estimates of the SHURA study rely on actual power generation, heat use, and passenger and load-km values for transportation in 2018.[25]

The unit external cost of health and environmental impacts (including air pollutant emissions of CH_4, CO, N_20, NMVOC, NO_x, PM, PM_{10}, $PM_{2.5}$[26]) per MWh of electricity produced was calculated to be EUR 39.9 for lignite power plants, EUR 16.1 for hard coal-fired power plants, EUR 5.2 for natural gas-fired plants, and EUR 5.9 for oil-burning power plants. Average technological conditions for fossil fuel generation and emissions were assumed to be similar through 2053, and therefore, the same external costs calculated were adapted to the baseline and transition scenarios in this study to quantify the health and environmental impacts resulting from power generation. The same figures were used to calculate external costs of other energy uses. However, while adapting the external costs from 2018, estimated changes in real GDP/capita (PPP) in the baseline and transition scenarios relative to estimated changes in real GDP/capita (PPP) in reference countries in the target years were considered according to the methodology developed by IRENA (2016).

[25] The study calculates the emissions of each pollutant and CO2 for each fossil fuel plant for 2018 and estimates the external costs by fuel type, plant type, and emission type based on actual generation. The costs are based on those quoted in internationally accepted databases designed for the purpose of quantifying the impacts of pollutants for a selection of countries, mostly EU countries, whose costs were then adapted to Türkiye using GDP/capita (PPP) multiplier.

[26] CH_4: Methane, CO: Carbon Monoxide, N_20: Nitrous Oxide, NMVOC: Non-methane Volatile Organic Compounds, NO_x: Nitrogen Oxides, PM: Particulate matter PM_{10}: Inhalable Particles, $PM_{2.5}$: Fine Inhalable Particles SO_X: Sulphur Oxide.

In the absence of a domestic carbon price and taking into account current European carbon prices, a base carbon value of EUR 70 was assumed and adjusted for differences in real GDP/capita (PPP) relative to the reference countries, as stated above. The adjusted effective carbon value is thus estimated to be 42.7 EUR/ton in 2025, gradually reaching 59.5 EUR/ton in 2055.

Avoided externalities due to the transition were calculated to reach EUR 572 billion for CO_2, and EUR 348 billion for air pollutants equivalent to 1.8% of total cumulative baseline GDP by 2055.

Bibliography

Aydın, L., 2018. The possible macroeconomic and sectoral impacts of carbon taxation on Turkey's economy: A computable general equilibrium analysis. https://www.researchgate.net/publication/323313255_The_possible_macroeconomic_and_sectoral_impacts_of_carbon_taxation_on_Turkey's_economy_A_computable_general_equilibrium_analyses

EİA, 2020. Capital Cost and Performance Characteristic Estimates for Utility Scale Electric Power Generating Technologies. https://www.eia.gov/analysis/studies/powerplants/capitalcost/pdf/capital_cost_AEO2020.pdf

Erker, R., Dominko, M., 2022. Energy efficiency in residential and non-residential buildings: Short-term macroeconomic implications. https://www.researchgate.net/publication/361968067_Energy_efficiency_in_residential_and_non-residential_buildings_Short-term_macroeconomic_implications

E3-Modelling,t.y. GEM-E3. https://e3modelling.com/modelling-tools/gem-e3/

Garcia-Casals, X., Ferroukhi, R., Parajuli, B., 2019. Measuring the socio-economic footprint of the energy transition. https://link.springer.com/article/10.1007/s41825-019-00018-6

Greenpeace, 2020. Toxic air: the price of fossil fuels. https://www.greenpeace.org/southeastasia/publication/3603/toxic-air-the-price-of-fossil-fuels-full-report/

HEAL, 2021. Chronic coal pollution in Turkey: the health burden caused by coal power in Turkey and how to stop the coal addiction. https://www.env-health.org/wp-content/uploads/2021/02/Chronic-Coal-Pollution-Turkey_web.pdf

Hallegatte, S., McIsaac, F., Dudu, H., Jooste, C., Knudsen, C., Beck, H., 2023. The Macroeconomic Implications of a Transition to Zero Net Emissions: A Modelling Framework https://openknowledge.worldbank.org/entities/publication/659cc0e8-38a4-4657-b8bd-6aa4373a9dc2

IEA, 2022. Solar PV manufacturing capacity by country and region, 2021. https://www.iea.org/data-and-statistics/charts/solar-pv-manufacturing-capacity-by-country-and-region-2021

IRENA, 2020. Renewable Power Generation Costs in 2019. https://www.irena.org/publications/2020/Jun/Renewable-Power-Costs-in-2019

IRENA (2016). The true cost of fossil fuels: externality cost assessment methodology (Background to the Brief "The true cost of fossil fuels: Saving on the externalities of air pollution and climateREhange"). https://www.irena.org/-/media/Irena/Files/REmap/IRENA_REmap_externality_methodology_2016.pdf?rev=f8f2045a8ee74e9a96144366ba73b62d&hash=574C67113520F78875BD494D218AC9C5

Kat, B., Yuan, M., 2018. Turkish energy sector development and the Paris Agreement goals: A CGE model assessment. https://open.metu.edu.tr/handle/11511/30361

Lutz, C., Banning, M., Ahmann, L., Flaute, M., 2021.Energy efficiency and rebound effects in German industry – evidence from macro econometric modelling. https://www.tandfonline.com/doi/full/10.1080/09535314.2021.1937953#:~:text=The%20mesoeconomic%20rebound%20effect%20of,2021%20and%2018%25%20in%202030.

Mercure, J., Pollitt, H., 2018. Environmental impact assessment for climate change policy with the simulation-based integrated assessment model E3ME-FTT-GENIE. https://www.researchgate.net/publication/323869409_Environmental_impact_assessment_for_climate_change_policy_with_the_simulation-based_integrated_assessment_model_E3ME-FTT-GENIE

SHURA, 2020. The external cost of fossil fuel use in power generation, heating and road transport in Turkey: https://shura.org.tr/en/the-external-cost-of-fossil-fuel-use-in-power-generation-heating-and-road-transport-in-turkey/

SHURA, 2021. Socioeconomic impact of the power system transition in Turkey. https://shura.org.tr/en/socioeconomic-impact-of-the-power-system-transition-in-turkey/

SHURA, 2022. Yeşil Yeni Düzen Bağlamında Türkiye’de Enerji Dönüşümünün Finansmanı. https://shura.org.tr/wp-content/uploads/2022/06/SHURA-2022-06-Yesil-Yeni-Duzen-Baglaminda-Turkiyede-Enerji-Donusumunun-Finansmani.pdf. For the executive summary in English: https://shura.org.tr/en/financing_the_energy_transition_in_turkey/

SHURA, 2023. Net Zero 2053:A roadmap for the Turkish electricity sector https://shura.org.tr/en/net-zero-2053-a-roadmap-for-the-turkish-electricity-sector/

SHURA, 2024a. Adil Dönüşüm Kapsamında Türkiye İçin Sanayi Politikası Alternatifleri. https://shura.org.tr/adil-donusum-kapsaminda-turkiye-icin-sanayi-politikasi-alternatifleri/
For the executive summary in English:
https://shura.org.tr/en/industrial-policy-alternatives-for-turkiye-within-the-framework-of-a-just-transition/

SHURA, 2024b. Adil Dönüşüm ve Bölgesel İstihdam: Türkiye İçin Politika Seçenekleri. https://shura.org.tr/adil-donusum-ve-bolgesel-istihdam-turkiye-icin-politika-secenekleri/
For the executive summary in English:
https://shura.org.tr/en/just-transition-and-regional-employment-policy-choices-for-turkiye/

Vrontisi, Z., Fragkiadakis, K., Kannavou, M., Capros, P., 2020. Energy system transition and macroeconomic impacts of a European decarbonization action towards a below 2 °C climate stabilization.
https://www.researchgate.net/publication/332854880_Energy_system_transition_and_macroeconomic_impacts_of_a_European_decarbonization_action_towards_a_below_2_C_climate_stabilization

Vrontisi, Z., Charalampidis, I., Paroussos, L., 2020. What are the impacts of climate policies on trade? A quantified assessment of the Paris Agreement for the G20 economies. https://www.sciencedirect.com/science/article/pii/S0301421520301324

Weitzel, M., Vandyck, T., Rey Los Santos, L., Tamba, M., Temursho, U., Wojtowicz, K., 2022. A comprehensive socio-economic assessment of EU climate policy pathways. https://www.sciencedirect.com/science/article/pii/S0921800922003214

Wind Europe, 2020. Wind energy and economic recovery in Europe: How wind energy will put communities at the heart of the green recovery. https://windeurope.org/intelligence-platform/product/wind-energy-and-economic-recovery-in-europe/

About Istanbul Policy Center at Sabancı University

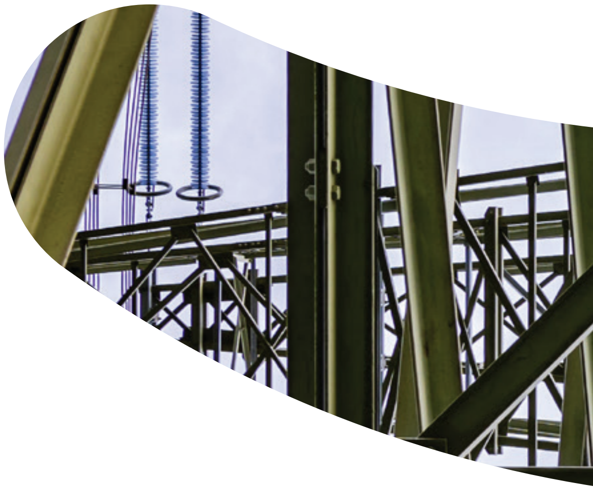
Istanbul Policy Center (IPC) is a global policy research institution that specializes in key social and political issues ranging from democratization to climate change, transatlantic relations to conflict resolution and mediation. IPC organizes and conducts its research under three main clusters: The Istanbul Policy Center–Sabancı University–Stiftung Mercator Initiative, Democratization and Institutional Reform, and Conflict Resolution and Mediation. Since 2001, IPC has provided decision makers, opinion leaders, and other major stakeholders with objective analyses and innovative policy recommendations.

About European Climate Foundation

The European Climate Foundation (ECF) was established as a major philanthropic initiative to help Europe foster the development of a low-carbon society and play an even stronger international leadership role to mitigate climate change. The ECF seeks to address the "how" of the low-carbon transition in a non-ideological manner. In collaboration with its partners, the ECF contributes to the debate by highlighting key path dependencies and the implications of different options in this transition.

About Agora Energiewende

Agora Energiewende develops evidence-based and politically viable strategies for ensuring the success of the clean energy transition in Germany, Europe and the rest of the world. As a think tank and policy laboratory, Agora aims to share knowledge with stakeholders in the worlds of politics, business and academia while enabling a productive exchange of ideas. As a non-profit foundation primarily financed through philanthropic donations, Agora is not beholden to narrow corporate or political interests, but rather to its commitment to confronting climate change.



SHURA
ENERGY TRANSITION CENTER

Bankalar Caddesi, No:2, Minerva Han,
Kat:3, 34420 Karaköy, İstanbul/Türkiye
T: +90 (212) 292 49 39
E-mail: info@shura.org.tr
www.shura.org.tr

SHURA is founded by

İPM | IPC İSTANBUL POLİTİKALAR MERKEZİ SABANCI ÜNİVERSİTESİ KAMPUSU İSTANBUL POLICY CENTER AT SABANCI UNIVERSITY

European Climate Foundation

Agora Energiewende

SHURAEDM   SHURAEDM   SHURA Enerji Dönüşümü Merkezi   /company/shura   @shuraedm