

TURKEY'S DECARBONIZATION PATHWAY NET ZERO IN 2050 EXECUTIVE SUMMARY

EDITOR ÜMİT ŞAHİN

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1. INTRODUCTION

The Paris Agreement, adopted in 2015 as an important step in the fight against climate change, is an international climate agreement that aims to keep the global average temperature rise well below 2 degrees Celsius, and pursuing efforts to limit it below 1.5 degrees Celsius. Since the Paris Agreement was adopted in 2015, the parties have submitted their Nationally Determined Contributions (NDCs), containing their targets and roadmaps on how to limit greenhouse gases that cause global warming, to the UNFCCC Secretariat. This year, in the fifth year following the entry into force of the Paris Agreement, 118 countries have updated their NDCs or have announced that they will submit it to the Secretariat. Article 4 of the Paris Agreement envisages that Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, and establishing a balance in the second half of the century between anthropogenic emissions and removals. The concept of Net-Zero Emissions is used to express this equilibrium point.

Following the adoption of the Paris Agreement, the IPCC's Special Report on Global Warming of 1.5°C was published in 2018 as a result of the task given by the parties to the Intergovernmental Panel on Climate Change (IPCC). Limiting temperature rise to 1.5 degrees is vital, according to the report, and to achieve this goal, global emissions need to be reduced by 45% below 2010 levels by 2030 and reach net zero by 2050. This roadmap was also confirmed in the IPCC's 6th Assessment Report (AR6) published in 2021, and the remaining global carbon budget for the 1.5-degree target was updated. According to AR6, if the current global emissions level is maintained, the carbon budget will be consumed in the early 2030s, and the 1.5-degree limit in average global temperature will be exceeded in the 2030s. Under the guidance of the IPCC, the parties have begun to declare their commitment to the goal of the Paris Agreement to limit the average global temperature rise to 1.5 degrees, not 2 degrees, and to achieve the Net-Zero Emissions target in 2050. Today, many countries that are among the ones with largest share in the global emissions, including the United States, China, the EU, the UK, Japan, and South Korea, have announced a Net-Zero Emissions target.

In a statement made by Turkish President Recep Tayyip Erdoğan at the United Nations General Assembly on September 21, 2021, Turkey declared that it would be a party to the Paris Agreement and that it would accept the Net-Zero Emissions target in 2053. This move was unanimously adopted in the Turkish Grand National Assembly. Prior to this, Turkey's NDC, which was announced as a declaration of intent just before the Paris Agreement, was made in 2015, and Turkey signed the agreement thereafter, although its NDC was not in line with the Net-Zero target. For this reason, Turkey should first determine a medium- and long-term roadmap in line with the Net-Zero target in 2053 and prepare a new NDC by updating its targets. Studies on how the Turkish economy will be decarbonized by 2053 have therefore gained special importance.

The report "Turkey's Decarbonization Roadmap: Net Zero in 2050" brings together the results of a study initiated by Sabancı University Istanbul Policy Center in 2020. The aim of the research is to prepare a roadmap that will reveal what kind of transformation Turkey's economy should undergo following its ratification of the Paris Agreement and accepting the Net-Zero target in 2050. This study is the first published study that reveals the course of carbon emissions from Turkey's economic activities until 2050 and the possible pathway it

should follow to reset its emissions by 2050 and update its NDC in line with the Net-Zero target.

The fact that Turkey is a party to the Paris Agreement and that the Net-Zero target was announced when this report was about to be completed further increases the importance of this study. This and similar scientific studies should guide the determination of Turkey's new NDC and the planning of the economic transformation to be completed by the 2050s. The purpose of this report is to initiate a scientifically based climate policy debate on Turkey's new emissions reduction pathway and to contribute to scientific studies that will determine the roadmap for this transformation.

2. METHOD

This research is based on Turkey's economic indicators and emissions in 2018. In this study, carbon dioxide (CO_2) emissions originating from energy emitted from the electricity sector, transportation sector, buildings, and industry as well as industrial processes are discussed. (Table ES.1)

Table ES.1. Sectors included in the study

Sectors
Electricity
Transportation
Buildings
Industry
Services
Agriculture

In the study, Turkey's CO_2 emissions pathway between 2018 and 2050 is compared under two scenarios. (Table ES.2)

- In the Baseline Scenario, the course of CO₂ emissions is given according to the current state of Turkey's economy, energy consumption, and energy resources as well as international developments, but in the absence of any policy to reduce emissions to combat climate change. Projections were made up until 2070 according to this Baseline Scenario.
- In the Net-Zero Scenario, the course of CO₂ emissions until 2050 is assessed by preserving macroeconomic assumptions, such as Turkey's current economic structure, population growth, and economic growth, as well as the necessary policies are followed to reduce emissions in line with the Net-Zero Emissions target in 2050.

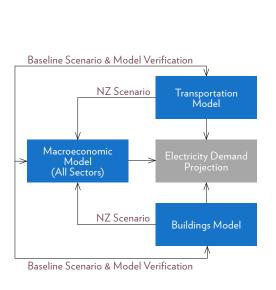
In addition, in the electricity sector scenario, the possibilities of nuclear energy as an energy source in the power system and not in the power system were compared.

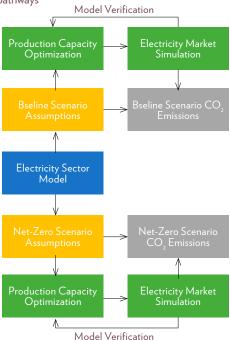
Table ES.2. Scenarios used in the study

Scenarios	Emissions	Target	Period
Baseline Scenario (BS)	CO ₂	-	2018-2070
Net-Zero Scenario (NZS)	CO ₂	1.5 °C	2018-2050

The modeling study, which forms the basis of the research, is based on the combination of the electricity sector model, the transportation model, the buildings model, and the macroeconomic model. The main input used in the Baseline Scenario is the generation path of the electricity sector in accordance with the Baseline Scenario for the 2018-2030 period. Consumption projections in the Baseline Scenario created for the electricity sector were also used as inputs for other sectors; therefore, the Baseline Scenario consumption projections used for all sectors were created in accordance with the Electricity Sector Baseline Scenario. For the 2050-2070 period, the Baseline Scenario consumption projections were created using the macroeconomic model and provided input to other sectors. Based on these projections, total/sectoral growth, total factor productivity, and energy efficiency paths were created to support this path. The Macroeconomic Baseline Scenario created under these assumptions has been harmonized with other sector models due to the inputs it gives primarily to the electricity sector and also to transportation and industry models. As a result, the 2018-2070 path was recreated under the same set of assumptions by following the trends in the path to 2030 (Figure ES.1).

Figure ES.1. Relationship between the assumptions and scenarios within each sector included in the study and models as well as verification pathways





In the generation capacity expansion model, which aims to minimize the cost of the power system by taking into account annual investment, operating and fuel costs, and power outage costs in the electricity sector model, the additional electricity demand and demand projections to be created by electrification are clarified using the data coming from the macroeconomic model, transportation, and building models. The outputs of the generation capacity expansion model are verified using the electricity market simulation model (with hourly resolution). In the models, priority is given to lignite power plants that are old and far from the main load centers while determining which coal plants will be decommissioned. In addition, it is assumed that the natural gas and renewable energy plants that will be added to the power system will be located close to the main load centers.

It is assumed that the location of storage systems will also be given priority, i.e., close to the main load centers, and will be centrally controlled according to the flexibility needs of the network. The infrastructure and market mechanisms required for this central control are beyond the scope of the study.

It is assumed that the net transfer capacities of the interconnection lines will also be used according to the flexibility needs of the network thanks to market consolidation mechanisms. However, these market mechanisms are also beyond the scope of the study.

In the study, cumulative emissions in the Net-Zero Scenario will remain within the limits of Turkey's carbon budget as Turkey's share in the remaining global carbon budget is calculated in accordance with the principle of fair share and equity in order to reach the 1.5-degree target.

3. MAIN RESULTS

3.1. CARBON BUDGET

The carbon budget is defined as "the maximum cumulative amount of global emissions 'permitted' based on the physical characteristics of the climate system to stay below the politically accepted warming limit." According to the IPCC's 1.5 Degree Special Report, the remaining carbon budget to keep warming below 1.5°C after 2018 with a 50% probability is 580 GtCO₂.

Although the Paris Agreement has set a global target, it has not provided a clear method on how countries will determine their emissions reduction obligations or how emissions will be reduced through following a certain path. Thus, various informal approaches have been put forward in scientific research to show how the global carbon budget should be allocated among countries. Among these approaches, the Paris Equity Check (PEC) uses an equity-based method to determine the carbon budgets of the major countries responsible for global greenhouse gas emissions. PEC's Cumulative Per Capita Equality (CPC) approach, which is based on the IPCC's equality principle, envisages that countries with historically high per capita emissions should reduce emissions faster. Following this approach, developing and fastgrowing countries with historically low per capita emissions, as well as underdeveloped countries, receive a larger share from the carbon budget.

Although Turkey's per capita emissions are now close to the global average, this number was half the world average in 1990. Therefore, Turkey's cumulative per capita emissions are considered low. The share of cumulative CO_2 emissions in Turkey (0.6%) is also half of the total share of current annual emissions. The share allocated to Turkey in this study was determined using the

Cumulative Per Capita Equality (CPC) approach, which is suitable for countries that are considered to have less historical responsibility and more development rights according to the PEC.

As a result, Turkey's $\mathrm{CO_2}$ budget for 1.5°C, which is in line with the principle of fair share and equity, constitutes 1.37% of the global budget, with 7.95 $\mathrm{GtCO_2}$ as of 2018. Considering that Turkey emitted 1.2% of global $\mathrm{CO_2}$ emissions as of 2017 according to this calculation method, its share in cumulative carbon emissions will increase by approximately 14% in the future. Therefore, in this study, it is assumed that Turkey will reduce later and more slowly than developed countries and the world average.

3.2. BASELINE SCENARIO

According to the assumptions about basic macroeconomic indicators:

- 1 Turkey's real GDP growth rate is 3.7% annually on average for the 2020–2030 period, 3.5% annually for 2030–2040, 3.0% annually for 2040–2050, 2.9% annually for 2050–2060, and 2.7% annually for 2060–2070.
- **2** In the Baseline Scenario, an annual average energy efficiency increases of 0.3% (TEP/2018 Real Production Value) is assumed.
- **5** While the annual increase rate of electricity demand between 2020 and 2030 is calculated as 4.2%, the increase in electricity demand between 2030 and 2050 is estimated as 2.6% annually and 1.8% for the 2050–2070 period.
- **4** | The annual electricity demand, which was 300 TWh/year in 2018 in the Baseline Scenario, increased by an average of 2.5% annually for the

- entire 2018-2070 period, reaching 460 TWh in 2030, 770 TWh in 2050, and approximately 1,100 TWh in 2070.
- The path of the Baseline Scenario also considers historical change followed by the modeling

Total

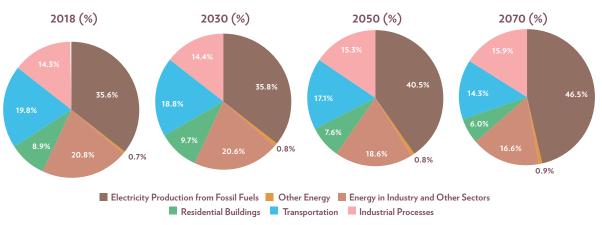
of critical parameters such as greenhouse gas emission intensity and reflects this change in the projections.

As a result, in the Baseline Scenario, Turkey's total $\mathrm{CO_2}$ emissions will increase by 66% compared to

CO, emissions (MtCO) 18 GtCO Cumulative 34 GtCO

Figure ES.2. Increase in CO, emissions from 2018 to 2050 and 2070 according to the Baseline Scenario (MtCO,)





2018 levels in 2050, reaching approximately 700 million tons, and in 2070, they will increase by 120%, reaching 920 million tons. Further, Turkey's total greenhouse gas emissions will increase by 70% compared to 2018 levels in 2050, to approximately 890 million tons, and in 2070, they will increase by 125%, to over 1,170 million tons. In the Baseline Scenario, cumulative $\mathrm{CO_2}$ emissions are 18 $\mathrm{GtCO_2}$ between 2018 and 2050 and 34 $\mathrm{GtCO_2}$ between 2018 and 2070. (Figure ES.2)

In the Baseline Scenario, the share of the electricity sector and industrial processes increases over the years, while the share of electricity consumption in transportation, buildings, and industry decreases (Figure ES.3).

3.3. NET-ZERO SCENARIO

In the Net-Zero Scenario, the following sectoral assumptions were made in addition to the basic macroeconomic indicators outlined in the Baseline Scenario:

- 1 | As interventions that will increase the share of renewable energy in the electricity sector will also decrease the share of fossil fuels, it is important to ensure grid flexibility in the electricity system with market consolidation mechanisms by increasing the storage systems consisting of battery and pumped-hydro dams and international interconnection capacity. Renewable energy potential is used at the highest level and as fast as possible, especially for wind and solar. Thus, coal is largely removed from electricity generation by 2035, while natural gas is reduced to very low capacity in 2050, thus decarbonizing the electricity sector to a large extent by 2050.
- 2 | The transition from roads to railways in individual and public transportation in the transportation sector, increase in efficiency of fossil fuel transportation vehicles, transition from

- fossil fuel vehicles to electric vehicles and other emissions-free fuel types, and green hydrogen in individual transportation, public transportation, and freight transportation are the main assumptions affecting emission estimations. In addition, preferring not to use the means of transportation that cause emissions (e.g., switching from a car to a bicycle, etc.) has been added to the assumptions at low rates as a change in travel behavior.
- In order to reduce emissions in buildings, interventions are added to reduce emissions by using the building renewal rate, new building construction, and demolition rates for residential and commercial/institutional buildings are considered: e.g., energy performance improvement in electrical appliances; changes from coal, liquid fuels, and natural gas to electricity for heating in old and new buildings as well as the change to green hydrogen at low rates; heat pump utilization and improvement in heat pump performance; behavioral changes
- 4 Demand change in high energy-intensive sectors, in line with global demand projections, energy efficiency, electrification, direct use of renewable energy in low energy-intensive industrial sectors, agriculture and services sector are considered as interventions for reducing emissions arising from energy consumption in industry and other sectors. Low rates of green hydrogen and the use of carbon capture, storage and utilization technologies (CCSU) after 2040 are assumed. Process emissions originating from industry, on the other hand, can only be studied to a limited extent in the macroeconomic model, since there are not enough assumptions in the literature for emissions reduction.

Table ES.3. Sectoral distribution and change in CO₂ emissions over the years according to the Baseline and Net-Zero Scenarios (2018–50) (MtCO₂)

CECTORS	В	ASELINE	SCENARI	0	NET-ZERO SCENARIO			
SECTORS	2018	2020	2030	2050	2018	2020	2030	2050
Electricity Production from Fossil Fuels	149.0	133.9	184.0	281.9	149.0	133.9	72.7	15.0
Transportation	82.8	80.7	96.5	119.5	82.8	80.7	65.3	28.9
Buildings	50.9	59.3	69.3	73.8	50.9	58.0	27.5	0.0
Energy in Industry and Other Sectors	77.2	68.7	99.4	108.5	77.2	69.3	60.0	30.2
CO ₂ EMISSONS FROM ENERGY CONSUMPTION	359.9	342.6	449.3	583.6	359.9	341.9	225.5	74.1
Industrial Processes		55.3	73.9	106.9	59.8	55.3	61.8	57.6
TOTAL CO ₂ EMISSIONS	419.7	397.9	523.2	690.5	419.7	397.2	287.3	131.6

Table ES.4. Change in CO₂ emissions in 2030 and 2050 compared to 2018

	2030-201	8	2050-201	8
SECTORS	CO_{2} Emissions $(MtCO_{2})$	%	CO_{2} Emissions $(MtCO_{2})$	%
Electricity Production from Fossil Fuels	-76.3	-51.2	-134.0	-89.9
Transportation	-17.5	-21.1	-53.9	-65.1
Buildings	-23.4	-46.0	-50.9	-100.0
Energy in Industry and Other Sectors	-17.2	-22.3	-47.0	-60.9
CO ₂ EMISSONS FROM ENERGY CONSUMPTION	-134.4	-37.3	-285.8	-79.4
Industrial Processes	2.0	3.3	-2.3	-3.8
TOTAL CO ₂ EMISSIONS	-132.4	-31.5	-288.1	-68.6

As a result, Turkey's total CO_2 emissions, which began to decrease in 2018, continue to decrease after 2020 according to the assumptions that form the basis of the Net-Zero Scenario. CO_2 emissions from energy consumption in all sectors decrease by 37% to 225 million tons in 2030 compared to 2018 levels and decrease by 80% to 74 million tons in 2050. When process emissions from industry are included, CO_2 emissions from all sectors decrease by 32% in 2030 to 287 million tons and in 2050 to

132 million tons, a decrease of nearly 70% (Tables ES.3 and ES.4).

Thus, in this scenario, Turkey's emissions, which have increased by about 130% since 1990, begin to decrease after peaking in 2018. Instead of increasing to 700 million tons in 2050 as predicted in the Baseline Scenario, this number is close to a 70% decrease compared to 2018 under the Net-Zero Scenario. Emissions decrease to 132 million tons and fall 13% below the 1990 level.



Figure ES.4. Change in CO_2 emissions (including process emissions) of all sectors in the Baseline and Net-Zero Scenarios since

The remaining (residual) emissions level in 2050, when industrial processes are not included, decreases by 80% compared to the 2018 level and falls to 74 million tons, 43% below the 1990 level (Figure ES.4).

The largest portion of total residual emissions in 2050 comes from industrial processes, while the largest portion of the residual emissions from energy consumption comes from industry and transportation. Only 15 million tons of residual emissions remain from the electricity sector, while emissions from buildings are zeroed.

In the Net-Zero Scenario, cumulative energy-related CO₂ emissions between 2018 and 2050 are 7.4 GtCO₂, which is below Turkey's carbon budget (7.95 GtCO₂) as determined on the basis of fair sharing and equity. However, when industrial process emissions, which have limited intervention options for emissions reduction, are included,

the cumulative emissions increase to 9.4 ${\rm GtCO_2}$, exceeding Turkey's carbon budget.

4. SECTORAL RESULTS

4.1. ELECTRICITY SECTOR

In the Net-Zero Scenario, there is a faster decrease in emissions in the electricity sector than the sum of all sectors. $\mathrm{CO_2}$ emissions from the electricity sector decrease by 51% to 73 million tons in 2030

compared to 2018 levels and to 15 million tons in 2050, a decrease of 90% (Figure ES.5).

The development of installed capacity in the electricity sector is given in Tables ES.5 and ES.6 according to the Baseline Scenario and Net-Zero Scenario.

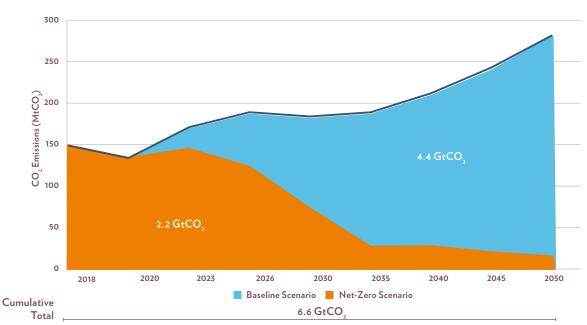


Figure ES.5. Comparing the CO_2 emissions of the electricity sector in the Baseline and Net-Zero Scenarios (Mt CO_2)

Table ES.5. Development of installed power by source according to the Baseline Scenario (GW)

Year	Hard Coal	Imported Coal	Lignite	Natural Gas	Other	Nuclear	HPP (Dam)	HPP (RoR)	Solar	Wind	Geothermal	Biomass	Total
2018	0.6	8.9	9.6	25.7	1.4		20.5	7.8	5.7	7.5	1.3	0.8	89.9
2020	0.7	8.9	9.5	25.6	1.6		23.0	8.2	6.9	8.6	1.5	1.1	95.6
2023	0.7	10.2	10.7	26.1	2.2		23.5	8.2	10.1	11.2	1.8	1.6	106.4
2026	0.8	11.7	12.8	26.6	2.8		23.5	8.2	13.6	14.1	2.0	2.2	118.5
2030	0.9	11.7	14.9	27.1	3.6	4.8	23.5	8.2	18.9	18.2	2.4	3.0	137.3
2035	1.0	11.5	17.1	29.8	4.1	4.8	25.5	8.2	28.1	28.9	3.0	4.5	166.5
2040	1.0	11.5	21.3	32.2	4.7	4.8	27.5	8.2	30.4	42.2	3.0	5.0	191.9
2045	1.0	12.9	21.2	37.3	4.9	4.8	29.5	8.2	38.8	48.0	2.8	4.9	214.4
2050	1.0	16.7	21.2	43.2	5.0	4.8	31.5	8.2	44.6	48.0	2.8	4.8	231.8
2060	1.0	16.6	21.0	59.3	5.0	4.8	33.5	8.2	67.4	48.0	2.8	4.6	272.1
2070	1.0	26.3	25.0	60.0	5.0	4.8	35.5	8.2	88.1	48.0	2.7	4.4	308.9

Table ES.6. Development of installed power by source in the Net-Zero Scenario (GW)

	Hard Coal	Imported Coal	Lignite	Natural Gas	Other	Nuclear	HPP (Dam)	HPP (RoR)	Solar	Wind	Geothermal	Biomass	Total
2018	0.6	8.9	9.6	25.7	1.4		20.5	7.8	5.7	7.5	1.3	0.8	89.9
2020	0.6	8.9	9.5	25.6	1.6		23.0	8.2	6.9	8.6	1.5	1.1	95.6
2023	0.6	9.4	8.6	28.5	1.7		23.5	8.2	14.1	14.4	2.0	2.5	113.5
2026	0.5	8.0	7.2	30.3	1.9		23.5	8.2	22.0	20.9	2.5	3.8	128.9
2030	0.2	4.0	2.9	33.8	2.1	4.8	23.5	9.1	36.4	32.6	3.4	6.1	158.9
2035		1.3		32.5	2.6	4.8	25.5	9.1	59.7	50.1	3.4	13.0	202.1
2040				36.9	2.6	4.8	27.5	9.1	83.5	52.9	3.4	15.0	235.6
2045				34.0	2.7	4.8	29.5	11.5	116.3	59.1	5.1	15.4	278.4
2050				32.7	2.7	4.8	32.0	12.0	192.7	62.4	5.4	16.1	360.8

The change in the aggregated proportional distribution of the installed capacity of fossil fuels, HPPs, nuclear energy, and modern renewable energy in the Baseline Scenario and the Net-Zero Scenario is given in Figures ES.6 and ES.7.

Figure ES.6. Distribution of CO₂ emissions by aggregated source in 2018, 2030, 2050 and 2070 according to the Baseline Scenario (%)

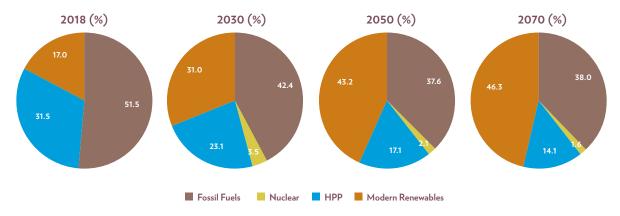
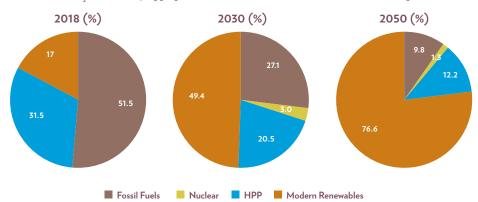


Figure ES.7. Distribution of CO₃ emissions by aggregated source in 2018, 2030, 2050 and 2070 according to the Net-Zero Scenario (%)



In the Net-Zero Scenario, the share of fossil fuel sources in electricity generation decreases significantly earlier and more than in the Baseline Scenario. In particular, the installed capacity of lignite-fired thermal power plants and their share in production decrease considerably before 2030, only 2.9 GW of lignite-fired and coal-fired thermal power plants remain in 2030, and all coal-fired and lignite-fired thermal power plants are closed in the first half of the 2030s. By 2035, only 1.3 GW of installed capacity of thermal power plants operating with imported coal remain; however, they will close before 2040. According to these results,

Turkey will be largely coal-free in the electricity sector by 2035.

The installed capacity of natural gas power plants, on the one hand, does not decrease rapidly due to the need for flexibility following the closure of coal-fired power plants. However, it will decrease slightly after 2040 and remain at around 32.5 GW. The installed capacity of natural gas in 2050 in the Net-Zero Scenario is well below the 43 GW expected in the Baseline Scenario. On the other hand, electricity generation from natural gas decreases to 37.5 TWh in 2050, albeit fluctuating

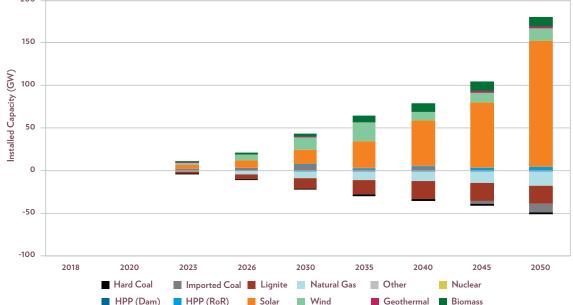
after 2030. This means that natural gas power plants will need to be operated with low capacity factor, due to the increased need for flexibility as the capacity of renewable energy increases in large quantities.

In the Net-Zero Scenario, renewable resource use increases rapidly. In the Baseline Scenario, it was assumed that installed wind capacity, which was 7.5 GW in 2018 and increased rapidly until the 2040s, would then remain constant at 48 GW, which the Ministry of Energy and Natural Resources estimated as Turkey's wind energy potential, until 2070. Installed wind capacity continues to increase in the Net-Zero Scenario and exceeds 62 GW in 2050, and electricity generation rises from 20 TWh in 2018 to 90 TWh in 2030 and to 146 TWh in 2050.

Installed solar power capacity, which rises to higher levels than wind, increases rapidly to reach 36.5 GW in 2030 and 193 GW in 2050, although it was less than 6 GW in 2018. While the energy produced from the solar power was just over 10 TWh in 2018, it reaches 72.5 TWh in 2030 and 362 TWh in 2050.

In the Net-Zero Scenario, the share of modern renewable resources (solar, wind, geothermal, and biomass) in installed capacity which was limited to 17% in 2018, increases to approximately 50% in 2030 and 77% in 2050. While the share of fossil fuels in installed capacity was over 50% in 2018, it drops to 27% in 2030 and to 10% in 2050-all of which will be generated from natural gas. In electricity generation, the share of modern (non-hydro) renewable resources, which was 14% in 2018, approaches 50% in 2030 and 80% in 2050. While the share of HPPs in production was 20% in 2018, it will be 17% in 2030 and 11% in 2050. The share of fossil fuels in production declines rapidly: while 65% of electricity was produced from fossil fuels in

Figure ES.8. Changes in installed capacity in the electricity sector according to the Net-Zero Scenario compared to the Baseline Scenario (GW) 200



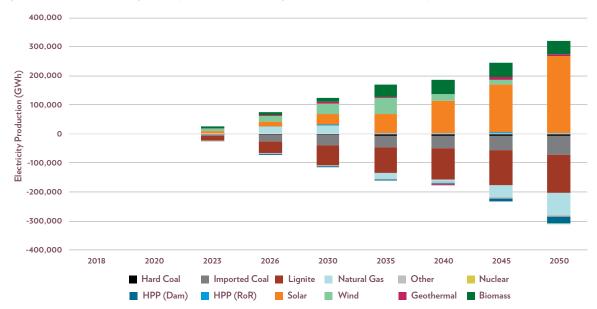


Figure ES.9. Production change in the power sector according to the Net-Zero Scenario compared to the Baseline Scenario (GWh)

2018, this rate decreases to 28% in 2030 and 5% in 2050.

The differences between the installed capacity and generation levels of electricity generation resources in the Net-Zero Scenario vs. the Baseline Scenario are shown in Figures ES.8 and ES.9.

In 2030, 53% of emissions from the electricity sector still originate from coal, the majority of which is lignite. After all lignite power plants

shut down in the first half of the 2030s and the last remaining imported coal power plants in the second half of the 2030s, all remaining emissions in the electricity sector from 2040 originate from natural gas. In 2050, emissions from natural gas power plants are also less than half of 2018 levels. In the Baseline Scenario and Net-Zero Scenario, the course of emissions in the electricity sector and the share of fossil fuel resources are shown in Figures ES.10 and ES.11.

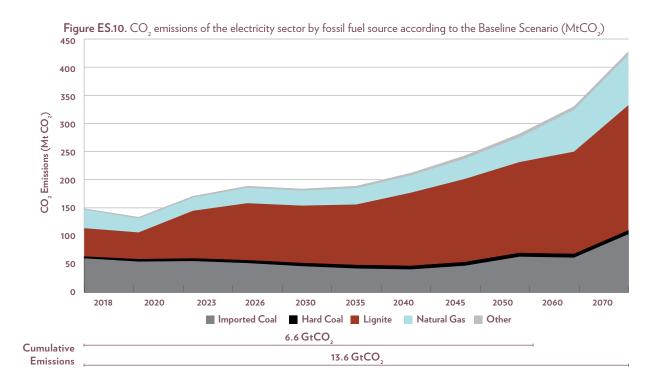
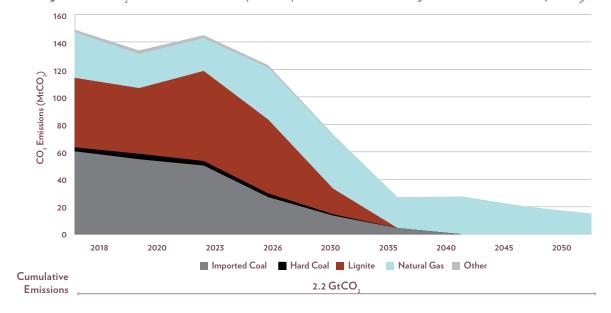


Figure ES.11. CO₂ emissions of the electricity sector by fossil fuel source according to the Net-Zero Scenario (MtCO₂)



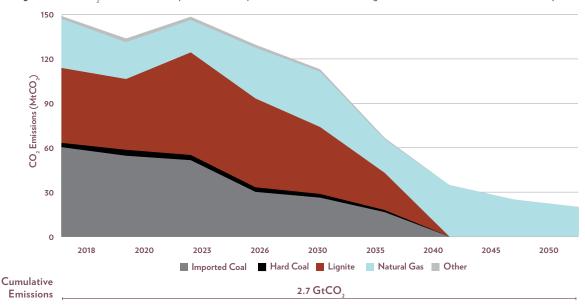
In the Nuclear-Free Net-Zero Scenario, which is studied as an alternative in the electricity sector model, the emissions from the electricity sector decrease to 20 million tons instead of 15 million tons in 2050, leaving extra 5 million tons of residual emissions (Figure ES.12). The difference in the

Nuclear-Free Net-Zero Scenario from the Net-Zero Scenario is that the closing date of coal-fired power plants is several years later (Table ES.7); and after the closure of lignite and imported coal-fired power plants after 2040, all remaining emissions in the sector originate from natural gas.

Table ES.7. Development of installed power by source according to the Nuclear-Free Net-Zero Scenario (GW)

Year	Hard Coal	Imported Coal	Lignite	Natural Gas	Other	HPP (Dam)	HPP (RoR)	Solar	Wind	Geothermal	Biomass	Total
2018	0,6	8,9	9,6	25,7	1,4	20,5	7,8	5,7	7,5	1,3	0,8	89,9
2020	0,7	8,9	9,5	25,6	1,6	23,0	8,2	6,9	8,6	1,5	1,1	95,6
2023	0,6	9,8	9,1	26,0	1,6	23,5	8,2	14,1	14,4	2,0	2,5	111,8
2026	0,5	8,9	8,2	27,8	1,8	23,5	8,2	22,0	20,9	2,5	3,8	128,1
2030	0,4	7,6	6,7	31,3	2,1	23,5	8,2	36,4	32,6	3,4	6,1	158,3
2035	-	4,9	3,8	30,0	2,8	25,5	8,2	68,6	50,1	3,4	10,7	208,3
2040	-	-	-	39,5	2,6	27,5	8,2	94,1	52,9	3,4	15,0	243,2
2045	-	-	-	35,6	2,7	30,0	12,0	133,7	59,1	5,1	15,4	293,6
2050	-	-	-	37,4	2,7	32,0	12,0	243,4	62,4	5,4	16,1	411,4

Figure ES.12. CO, emissions of the power sector by fossil fuel source according the Nuclear-Free Net-Zero Scenario (MtCO₂)



4.2. TRANSPORTATION SECTOR

Emissions reduction in the transportation sector is close to the avarage of all sectors. CO_2 emissions from the transportation sector decrease by 21% compared to 2018 levels in 2030, to approximately 65 million tons, and in 2050 by 65%, to 29 million tons (Figure ES.13).

The differences in the interventions applied to the Net-Zero Scenario from the Baseline Scenario are related to the number of electric vehicles in individual transportation, mass transportation, and freight transport, green hydrogen use in heavy vehicles carrying cargo, transition to the rail system, and travel behavior changes. (Table ES.8, ES.9 and ES.10.)

140 120 100 CO, Emissions (MtCO,) 80 3.3 GtCO 60 40 1.9 GtCO 20 0 2018 2020 2030 2050 Baseline Scenario Net-Zero Scenario Cumulative 5.2 GtCO Total

Figure ES.13. Comparing the CO₂ emissions of the transportation sector in the Baseline and Net-Zero Scenarios (MtCO₂)

Table ES.8. Assumptions about passenger cars in the transportation sector model

		Baselir	ne Scenario		Net-Zero Scenario			
Year	Motorization Rate (per thousand)	Number of E-vehicles (million)	Proportion of E-vehicles among Total Passenger Cars (%)	Travel Behavioral Change (%)	Motorization Rate (per thousand)	Number of E-vehicles (million)	Proportion of E-vehicles among Total Passenger Cars (%)	Travel Behavioral Change (%)
2030	340	1.9	10	0	340	3.8	20	0
2050	408	9.7	33	0	408	19.4	66	5
2070	400	21.3	66	0	-	-	-	-

Table ES.9. Assumptions about the proportion of vehicles using electricity and green hydrogen among the total number of vehicles in public transportation and freight transport in the transportation sector model

		Baseline Scenario		Net-Zero Scenario			
Year	Proportion of E-vehicles among Total Vehicles in Public Transport	Proportion of Proportion of Heavy E-vehicles among Vehicles using Green Total Vehicles in Hydrogen among Freight Transport Total Heavy Vehicles		Proportion of E-vehicles among Total Vehicles in Public Transport	Proportion of E-vehicles among Total Vehicles in Freight Transport	Proportion of Heavy Vehicles using Green Hydrogen among Total Heavy Vehicles	
2030	5	5	0	10	10	0	
2050	10	10	0	20	20	5	
2070	20	20	0	-	-	-	

Table ES.10. Assumptions about the shift from road to railway transportation in the transportation sector model (%)

	Net-Zero Scenario							
Year	Shift from Passenger Cars to Public Railway Transport	Shift from Public Road Transport to Public Railway Transport	Shift from Road Freight Transport to Railway Freight Transport					
2030	5	10	10					
2050	15	50	50					

While in the Baseline Scenario, CO_2 emissions from the transportation sector, which was 83 million tons in 2018, increased to 97 million tons in 2030, 120 million tons in 2050, and 131 million tons in 2070, in the Net-Zero Scenario, CO_2 emissions from the transportation sector reduced to 65 million tons in 2030 and 29 million tons in 2050.

The largest portion of CO_2 emissions in the transportation sector originates from road freight transport. The course of emissions in the transportation sector and the shares of transportation vehicles for both the Baseline Scenario and Net-Zero Scenario are shown in Figures ES.14 and ES.15.

Emissions

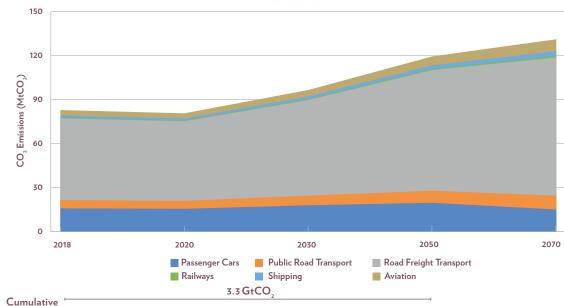
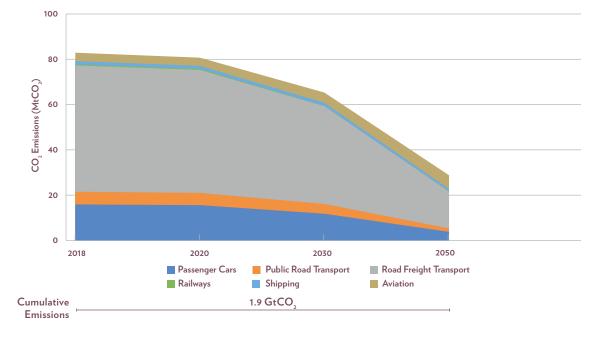


Figure ES.14. Increase in CO_2 emissions from the transportation sector between 2018 and 2070 according to the Baseline Scenario and cumulative emissions

Figure ES.15. Change in CO₂ emissions from the transportation sector between 2018 and 2050 according to the Net-Zero Scenario and cumulative emissions

5.8 GtCO,



4.3. BUILDINGS

Among the sectors, the highest reduction is in emissions from buildings. CO₂ emissions from buildings decrease by 46% in 2030 compared to 2018 levels, decreasing to 28 million tons and reaching zero in 2050 (Table ES.11 and Figure ES.16).

Table ES.11. CO₂ emissions from buildings in 2018, 2030, 2040 and 2050 in the Baseline and Net-Zero Scenarios (MtCO₂)

Year	Baseline Scenario	Net-Zero Scenario
2018	50.9	50.9
2030	69.3	27.5
2040	72.3	8.9
2050	73.8	0.0

The most important intervention that contributes to this reduction in the Net-Zero Scenario is the termination of the use of coal and liquid fuels for heating purposes in residences and commercial/ institutional buildings by 2030 as well as the transition to primarily electrical and partially natural gas heating.

Natural gas and LPG consumption in buildings is also reduced by 13% in residences and 21% in commercial/institutional buildings until 2030 and then ends in the 2040s. Buildings mostly use electricity instead of fossil fuels.

In addition, after 2035, green hydrogen started to be added to the system on a small scale and increased especially after 2045, instead of natural gas for the purposes of heating etc. in buildings. It is also assumed that the equivalent of 10 TWh of green hydrogen is used in 2050.

80 70 60 CO, Emissions (MtCO,) 50 40 30 0.8 MtCO 20 10 2018 2020 2025 2030 2035 2040 2045 2050 Baseline Scenario Net-Zero Scenario 2.3 MtCO Cumulative Total

Figure ES.16. Comparing CO, emissions from buildings in the Baseline and Net-Zero Scenarios (MtCO,)

4.4. INDUSTRY AND OTHER SECTORS

Emissions arising from energy consumption in industry and other sectors (i.e., agriculture and services) can be reduced close to the average of all sectors in the short term, but more slowly in the long term. $\rm CO_2$ emissions from energy in industry and other manufacturing sectors are reduced by 22%, to 60 million tons, in 2030 compared to 2018 levels, and to 30 million tons in 2050, a 61% decrease. (Figure YÖ.17)

Under the intervention assumptions that will provide limited emissions reductions, there is no significant decrease in process emissions, but rather the increase is limited. Thus, CO_2 emissions from industrial processes will be 62 million tons in

2030, 3% above the 2018 level, and decrease by 4%, to 58 million tons, in 2050. However, these values are still 16% and 46% below the values seen in the Baseline Scenario in 2030 and in 2050, respectively.

Changes in demand, energy efficiency, electrification, and direct use of renewable energy, which cause emissions reductions in the High Energy-Intensive Industry (HI) and Low Energy-Intensive Industry (LI) sectors, as well as in the Agriculture (AGR) and Services (SERV) sectors, as a part of the Baseline Scenario and the Net-Zero Scenario are shown in Tables ES.12, ES.13, ES.14 and ES.15.



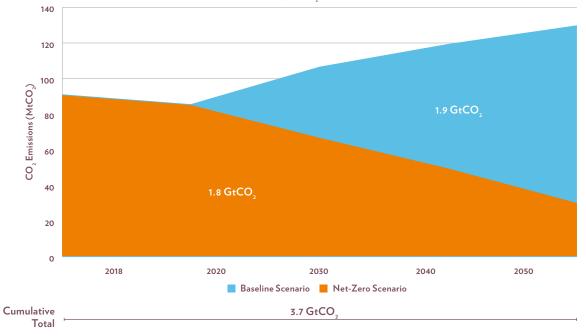


Table ES.12. Demand change over the years in High Energy-Intensive (HI) industrial sectors

HI Sectors	Baseline Scenario					Net-Zero Scenario			
	2020	2030	2040	2050	2070	2020	2030	2040	2050
Non-Metallic Minerals: Cement, etc.	1.00	1.29	1.56	1.84	2.51	1.00	1.12	1.08	1.00
Iron-Steel	1.00	1.34	1.64	1.94	2.60	1.00	1.18	1.15	1.12
Energy-Intensive Manufacturing Sectors	1.00	1.34	1.66	1.99	2.74	1.00	1.32	1.30	1.30

Table ES.13. Assumed energy efficiency increase rate (2018 TL/TOE) over the years in the industry and other sectors (excl. Energy) in the Baseline and Net-Zero Scenarios

S		Baseline	Scenario	Net-Zero Scenario			
Sectors	2030	30 2040 2050	2050	2070	2030	2040	2050
HI	0.62	0.60	0.00	0.93	1.73	1.53	1.02
LI	0.34	1.06	1.36	2.00	3.37	1.50	1.01
AGR	0.24	0.34	0.26	0.56	4.22	1.05	1.17
SERV	0.00	0.00	0.12	0.74	3.93	1.05	1.17

Table ES.14. Assumed change in the share of electricity in total energy consumption over the years in the industry and other sectors (excl. Energy) in the Baseline and Net-Zero Scenarios

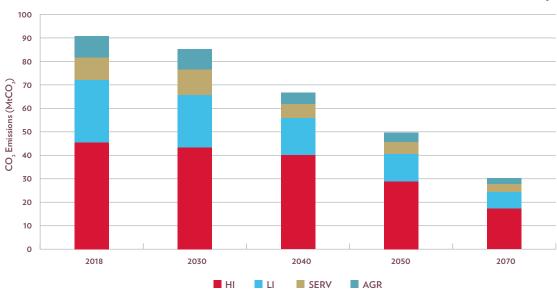
. .		Ва	seline Scenai	rio	Net-Zero Scenario				
Sectors	2018	2030	2040	2050	2070	2018	2030	2040	2050
HI	23.2	23.3	24.7	25.9	27.1	23.2	24.0	26.0	26.0
LI	47.2	49.3	50.9	52.5	55.5	47.2	50.0	60.0	73.0
AGR	20.2	20.5	21.2	21.8	21.2	20.2	25.0	30.0	40.0
SERV	55.9	57.7	59.4	61.1	63.9	55.9	60.0	60.0	73.0

Table ES.15. Assumed change of direct renewables in total energy consumption over the years in the industry and other sectors (excl. HI and Energy) in the Net-Zero Scenario

Sectors	Net-Zero Scenario							
	2018	2030	2040	2050				
Ш	-	12.0	15.0	18.0				
AGR	14.0	16.0	20.0	25.0				
SERV	-	5.0	5.0	5.0				

Figure ES.18. Emissions from energy consumption in the industry and other sectors in the Baseline Scenario (MtCO₂)





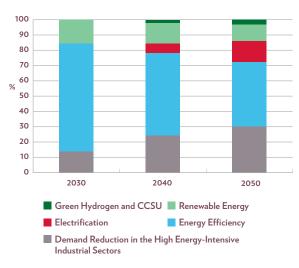
 CO_2 emissions arising from energy consumption in industry, agriculture, and services are shown in Table ES.16 in the Baseline Scenario and Net-Zero Scenario, and their distribution by sector is shown in Figures ES.18 and ES.19.

Table ES.16. Reduction of emissions from energy consumption in the industry and other sectors in the Baseline and Net-Zero Scenario (MtCO₂)

Scenarios	2018	2020	2030	2040	2050
Baseline Scenario	90.7	85.2	106.1	118.8	129.2
Net-Zero Scenario	90.7	85.2	66.8	49.6	30.2

In the Net-Zero Scenario, Figure ES.20 shows which changes (e.g., demand, energy efficiency, electrification, renewable resources, and green hydrogen/CCSU) resulted from the reduction in emissions from energy consumption in industry and other manufacturing sectors.

Figure ES.20. Impact of reduction intervention methods on emissions in the Net-Zero Scenario over the years



5. CONCLUSION AND RECOMMENDATIONS

According to the results of this report—which is the first published study on how Turkey will achieve its current Net-Zero target and what its NDC, which is expected to be updated, should look like-decarbonizing Turkish economy by abandoning fossil fuels, switching to renewable energy, and achieving energy efficiency and electrification in related sectors is not beyond reach. This report argues that it is possible for Turkey to decarbonize its economy to a large extent and approach the Net-Zero target by the early 2050s. The assumptions used in this report preserve the basic characteristics of the current economic structure and show the results of policy changes based mainly on investments in the energy transition and carbon-free technologies. For this, clear and measurable targets should be set in the medium and long term.

The results of this study are as follows:

- 1 | Turkey's emissions, which have increased by approximately 130% since 1990, began to decrease after reaching their peak in 2018. In 2050, instead of 700 million tons as envisaged in the Baseline Scenario, in the Net-Zero Scenario, CO_2 emissions are 132 million tons with a 70% reduction compared to 2018, falling 13% below the 1990 level. The residual emissions level in 2050, when industrial processes are not included, decreases by 80% compared to 2018 levels and falls to 74 million tons, 43% below the 1990 level.
- 2 | In all sectors, CO_2 emissions from energy can be reduced by 37% in 2030 compared to 2018 levels, and all CO_2 emissions including process emissions can be reduced by 32% in 2030 compared to 2018 levels.
- **3** Electricity generation is the sector in which

- the fastest reduction will be achieved; therefore, we can aim to halve emissions from the electricity sector by 2030.
- **4** We can aim to phase-out coal in energy production by 2035.
- 5 Natural gas in electricity generation could be completely phased out before 2050 through more ambitious solutions to grid flexibility.
- **6** | The share of modern renewable energy (wind, solar, geothermal, and biomass) in installed electricity capacity can be increased to 50% in 2030.
- 7 In order to increase the installed capacity of renewable energy to approximately 35 GW by 2030, an average of 3 GW of solar and 2.5 GW of wind power capacity should be installed every year.
- **8** | By 2030, we can aim to increase the ratio of electric vehicles among total passenger vehicles to at least 20% and to at least 10% among the vehicles used in public transportation and freight transport.
- **9** By ending the use of coal in buildings as soon as possible, switching from natural gas to electricity, and accelerating the use of heat pumps, a 50% emissions reduction target can be achieved in 2030 compared to 2018 levels.
- 10 | Emissions from energy consumption in industry and other sectors can be reduced by 26% in 2030 and 67% in 2050 compared to 2018 levels. However, in order to reduce emissions from industrial processes and reduce all industry emissions faster, energy efficiency, electrification, new technologies, and research

and development studies on green hydrogen and CCSU are needed.

Assessing the effects of the assumptions envisaged in this study, the net-zero target in 2050 cannot be completely reached. The reasons for this can be listed as follows:

- 1 Negative emissions technologies such as Carbon Capture Storage and Utilization (CCSU), which are included in the similar studies conducted in other countries in more ambitious assumptions, are not included in the electricity sector model, and it is assumed that they will be used at very low rates for high energy-intensive industrial sectors.
- 2 New and underdeveloped technologies are included in the model very late and at low rates. For example, the use of green hydrogen in industry, heating, and transportation; alternatives to petroleum use such as electrification in heavy vehicles; and alternative production techniques in industry are included in the model at very low rates. We assumed that the use of electric vehicles in individual transportation will also increase more slowly than projections in developed countries.
- 3 Individual behavioral changes in ecological direction, especially in reducing consumption, are included in the model at very low rates. Lifestyle changes that can reduce emissions, such as not using a motor vehicle, reducing long-distance vacations, reducing food consumption that will require long-distance transport, changing diet, limiting electricity consumption completely or at certain hours, are either not included in the model or included at very low rates as seen in the travel behavior change.
- **4** In the Net-Zero Scenario, the structural change that the economy may experience in

case of carbon pricing in the national economy is not modeled. The production structure, sectoral shares, etc., under the Baseline Scenario are not modeled. For this reason, the importance of construction sector, for example, which has a significant impact on greenhouse gas emissions (due to sectors such as cement, iron and steel, etc.), has not been reduced, but its growth has been restricted in accordance with international projections.

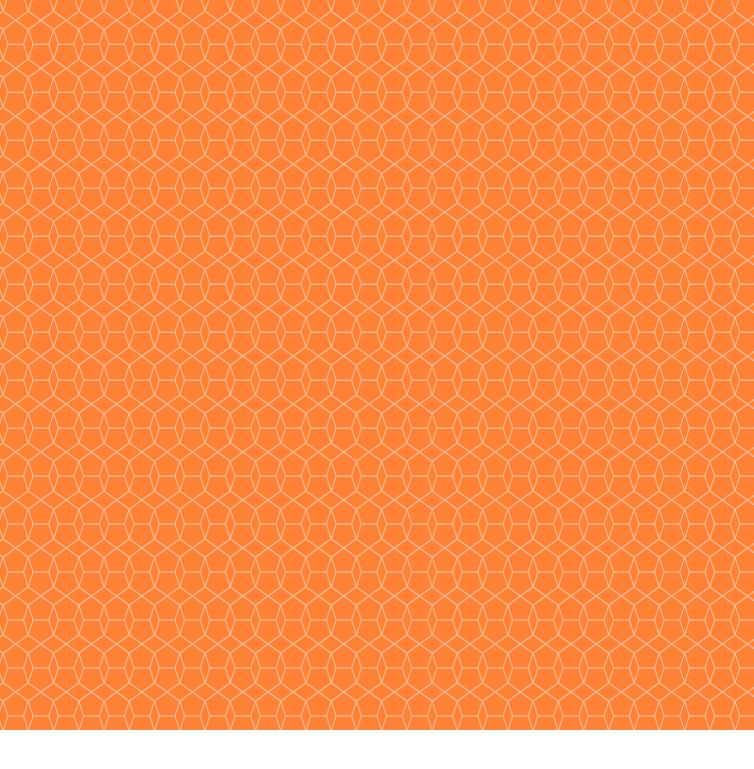
The largest portion of total residual emissions in 2050 comes from industrial processes, while the largest portion of residual emissions from energy consumption comes from industry and transportation. Only 15 million tons of residual emissions remain from the electricity sector, while emissions from buildings are zeroed. Therefore, the following policies should be added to the assumptions in the current Net-Zero Scenario to reduce emissions to real Net Zero by 2050:

- 1 Reducing emissions intensity in the economy, formulating a carbon pricing strategy that can be implemented in parallel with international dynamics, ensuring that the production structure is transformed with high added-value and low emissions intensity;
- 2 | Facilitating the transition from road freight transport to railway transport in the transportation sector, more electrification of heavy vehicles, the implementation of energy efficiency measures, electrification of all passenger vehicles by 2050 in individual transport and identifying an exit year in which oil use will be terminated, more railways in public transport and the use of electric public transportation such as bicycles instead of passenger car use, as well as behavioral changes, such as reducing air travel;
- **3** Developing new technologies to reduce energy consumption and process emissions in indus-

try, using more renewable resources and electrification, circular economic approaches, efficiency in raw material consumption, recycling and zero waste methods;

- 4 | The use of alternative materials in the industry that will reduce the demand for the products of high energy-intensive sectors (such as cement, iron and steel);
- **5** | Rapidly increasing the use of green hydrogen in transportation, industry, and buildings;
- 6 | In order to establish more flexibility in the grid, in addition to market coupling mechanisms over storage systems and interconnection lines, demand management supported by demand aggregation mechanisms, providing hot reserves from renewable power plants, preventing natural gas power plants from being available, and reducing the remaining emissions from natural gas by 2050;
- 7 | The use of CCUS in high energy-intensive industries and the introduction of new negative emissions technologies to be developed toward 2050.

One of the most important limitations of this study is that it does not cover all greenhouse gases and does not foresee economy-wide emissions reductions. Solely taking measures to prevent the use of fossil fuels and reconfigure industrial production are not sufficient to reduce the emissions of CH and N₂O, which comprise the most important share in greenhouse gases in addition to CO₂. Additional policies should be developed to reduce emissions from agriculture and waste management. Studies that model how to reduce greenhouse gases other than CO₂ are needed in order to determine Turkey's economy-wide greenhouse gas emissions reduction target and to achieve the net-zero greenhouse gas emissions target in the 2050s. It is important to understand that the scenarios which are similar in this study must be studied over and over, using different methodologies and assumptions, as well as that research that determines the costs and co-benefits of the transformation is carried out, and that the results of the studies must be shared with the public in a transparent manner. Turkey's climate policies can only be improved through assessing scientific studies and formulating a deliberative policy-making process.



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