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

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Industrial Development and Green Transformation: A Firm-level Study on Turkish Manufacturing

Abstract

The Turkish economy nearly doubled its GDP from 2000 to 2022, with an average annual growth rate of 4.9%. The manufacturing sector had a slightly higher growth rate of 5.5%. During the same period, greenhouse gas emissions (in CO2 equivalent, CO2e) increased at a rate of 2.8% per year, from 306 to 558 million tons. The majority of CO2e emissions come from energy production by burning fuels (about 72% over these years). Emissions from industrial processes and product use (IPPU) account for about 12.5% of total emissions, with the remainder coming from agriculture and waste.

In this paper, we examine the development of the manufacturing sector in Türkiye and analyze the sources of the declining CO2 intensity. Our results indicate that manufacturing has a higher CO2 intensity than services, and its share in employment and value-added decreased continuously from 2007 to 2017. Since 2017, there has been a slight increase in the share of manufacturing, but this may be due to conjectural factors such as the 2018-2019 crisis, Covid-19, and policy mistakes since 2021.

We have classified manufacturing sectors as “dirty” and “clean” according to their CO2 intensity and total emissions. We find that the share of dirty sectors in manufacturing has declined almost continuously since 2007. In the same period, the CO2 intensity of the manufacturing sector decreased from 0.31 kg/TL in 2007 to 0.18 kg/TL in 2021. The decomposition analysis of the factors behind the decline in CO2 shows that improvements in CO2 intensity at the firm level play an insignificant role. The main reason for the decline in CO2 intensity is the inter- and intra-sectoral reallocation of value-added.

Based on an evaluation of climate change and decarbonization policies, the paper suggests that Türkiye should aim at decarbonizing electricity generation and structural change from dirty sectors, mainly cement and iron and steel, to clean activities and sectors.

Contents

KEYWORDS: Green Transition, Decarbonisation, Structural Transformation, Climate Change, Türkiye

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Introduction

Türkiye faces four challenges in the coming decades: digital transformation, climate crisis, restructuring of the global economy, and achieving equitable income distribution.

As digital technologies are spreading rapidly, the Turkish economy needs to adopt these technologies to sustain economic growth and become competitive and innovative in digital technologies to catch up with developed countries.

The climate crisis[1] calls for rapid decarbonization, and, in parallel with the global trend, by ratifying the Paris Agreement in 2021, Türkiye committed to achieving net zero emissions by 2053. Türkiye reaffirmed its the net zero commitment at the World Climate Action Summit held as part of the 28th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP28) in Dubai. [2] Although this commitment is non-binding, the European Union (EU) has introduced the Carbon Border Adjustment Mechanism (CBAM). The final regime of the CBAM will be applied from 2026 after the transitional period from 2023 to 2025. As the EU is Türkiye's main trading partner, exporters in Türkiye will either reduce their carbon intensity by adopting green technologies or accept a loss of market share in the EU.

The process of “globalization” seems to have stopped and even reversed after the global financial crisis of 2007-2008. The global economy has been restructuring due to the changing balance of power in the world, especially between the US and China. This process has accelerated after the disruption of the so-called “global value chains” following the Covid-19 rupture and regional wars (Ukraine-Russia and Israel-Palestine). A new international division of labor is being reshaped with a focus on greater self-sufficiency and regional value chains. Türkiye needs to reposition itself in the new international division of labor.

Finally, income and wealth inequality is one of the main economic and social problems in most developing countries. Türkiye has long failed to improve income inequality and share the benefits of growth with workers. Rapid changes in digital technologies, relocation of industries and increasing uncertainty make equitable growth an urgent task for the Turkish economy.

The manufacturing sector plays an important role in addressing all these four challenges and achieving sustainable growth and green transformation in Türkiye because:

- It is a major hub for the creation and diffusion of new (including green) technologies;
- It is the main energy consumer and source of greenhouse gases (GHG);
- It produces most of the (manufactured) exports and determines how the Turkish economy is integrated into the global economy; and
- It is a major source of (good/decent) jobs and enables other sectors to create good/decent jobs.

This paper studies the development of the Turkish manufacturing industry since 2006 with a special focus on its energy consumption and CO2 emissions. The paper is structured as follows: After this brief introduction, the second section provides

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1 We use the term "climate crisis" instead of "environmental crisis" because the paper focuses on CO2 emissions. Note, however, that the climate crisis should be seen as part of a broader environmental crisis facing humanity.

2 For the timeline of the “2053 Net-Zero Target and Türkiye’s Long-Term Climate Change Strategy”, see https://netsifirturkiye.org/en/the-2053-net-zero-target-and-turkiyes-long-term-climate-change-strategy/

information on the level and sources of CO_2 emissions in Türkiye. Section 3 provides an overview of the structural changes in the Turkish economy with respect to manufacturing and services. Changes in the composition of manufacturing in terms of “dirty” and “clean” sectors are discussed in section 4. The analysis shows that the CO_2 intensity of the manufacturing sector, both in dirty and clean sectors, has decreased significantly since 2006. Section 5 presents a decomposition analysis to understand how CO_2 intensity has decreased in the Turkish manufacturing sector. Section 6 outlines the policies pursued by the Turkish government in the last two decades. The last section summarizes the main findings of our study.

1. Sources of CO2 emissions in Türkiye

In 2001, the Turkish economy experienced one of its worst economic crises since the establishment of the Republic. The economy recovered quickly after the crisis, partly due to favorable international conditions, until the global financial crisis. Since then, GDP growth rates have fluctuated widely around a declining long-term trend, and the economy experienced another crisis in 2018-2019. In the wake of the Covid-19 pandemic, the government sought to bolster growth through a reduction in interest rates in 2021 (a period characterized by the "New Economic Model"). However, this strategy was subsequently reversed following the 2023 general election, in response to the uncontrollable surge in inflation.

Despite all these shocks and policy reversals, the Turkish economy almost doubled its GDP from 2000 to 2022, with an average annual growth rate of 4.9% (see Figure 1). Manufacturing had a slightly higher growth rate of 5.5%.3 During the same period, greenhouse gas emissions (in CO2 equivalent, CO2e) increased at a rate of 2.8% per year, from 306 to 558 million tons (see Figure 1). The majority of CO2e emissions come from energy production by burning fuels (about 72% over these years, 401 million tons in 2022, see Figure 2). Emissions from industrial processes and product use (IPPU) increased their share of total emissions from 8.5% in 2000 to 12.5% in 2022, while the share of agriculture and waste decreased slightly (from 19.8 to 15.7%). As GHG emissions increased at a lower rate than GDP, the emission intensity (emissions/GDP) decreased almost continuously, from 0.42 kg/TL to 0.26 kg/TL.[4]

CO2 alone accounts for about 80% of GHG emissions, and there is no significant change in the share of CO2 in total GHG since 2000. The shares of methane (CH4) and nitrous oxide (N2O) are 13% and 6%, respectively. Fluorinated greenhouse gases (F-gases) account for the remainder.

Table 1 shows CO2 emissions by source since 2000. The share of energy declined slightly from 89% to 86% in the first decade of 2000s, and remained around that level until 2022. Almost all energy emissions are due to fuel combustion. Energy industries (electricity and heat) accounts for around one third of fuel combustion CO2 emissions. Note that energy industries include a heterogeneous set of producers: it includes public and private electricity producers that are classified in the electricity sector, and autoproducers that are classified in their respective (manufacturing) sectors.

Fuel combustion in manufacturing and construction was responsible for about one quarter of CO2 emissions in 2000, but their share declined gradually to 14-15% in 2016-2017, with no discernible trend thereafter.

The share of transportation has increased almost 5 percentage points, from around 15% in 2000 to 20% in 2022. “Transportation” is also a heterogeneous category, and it includes households, the transportation sector, and all other firms’ own transportation activities.

Another major source of CO2 emissions is industrial processes and product use (IPPU). IPPU emissions are generated by an industrial process as a by-product and are not

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3 Growth rates are calculated for chain linked indices (see TurkStat, *Annual Gross Domestic Product, 2023,* https://data.tuik.gov.tr/Kategori/GetKategori?p=ulusal-hesaplar-113&dil=1).

4 The base year for the chain linked volume of GDP is 2009.

directly a result of energy consumed during the process.[5] For example, in cement production, limestone is heated by burning fuel to produce lime. During this process, calcium carbonate ($CaCO_3$) is calcined and breaks down into lime (CaO) and carbon dioxide (CO_2). The CO_2 emitted during the calcination process is included in "IPPU", and the CO_2 emitted by burning fuel to heat the limestone is included in "Energy". Almost all IPPU emissions are generated by a few sectors (the mineral products, chemicals and metals industries).

The data on GHG and CO_2 emissions by sector in 2021 are presented in Table 2. Almost all of the manufacturing sector's emissions consist of CO_2, while the vast majority of non-CO_2 GHG emissions come from the agriculture, mining, and waste sectors.[6]

Manufacturing and electricity generation are by far the largest emitters, each accounting for about 26-27% of GHG and 31-33% of CO_2 emissions. The manufacturing CO_2 emission share is higher than its share due to fuel combustion plus IPPU, because manufacturing is also responsible for a part of energy (auto producers) and transportation emissions. Transportation is the third main CO_2 emitting sector, but its share is much lower than those of manufacturing and energy (4.7%) because the transportation sector's emissions include only those by firms whose main activity is to provide transportation services, i.e., it does not include manufacturing firms' and households' own transportation.

Türkiye has five major primary energy sources: coal, lignite, natural gas, crude oil and petroleum products. Data on the supply of primary energy sources (domestic production plus imports) are presented in Figure 3 (by weight) and Figure 4 (by CO_2 content).[7] Lignite is largely supplied by domestic production, while almost all other products are imported.[8] Petroleum products are the only energy source exported in significant quantities (about 9.2 million tons in 2022).

Lignite production fluctuates significantly over time but its (domestic) supply increased rapidly after 2015, reaching 92 million tons in 2022, as a result of policies encouraging domestic production. Imports of coal, natural gas, and crude oil increased steadily throughout the period, while imports of petroleum products declined after 2018. The quantity of imports of coal and crude oil increased by almost two times since 2006, whereas the growth rate of petroleum products and natural gas was around 70-80% in the same period.

Since the CO_2 intensity of lignite is much lower than others, its CO_2 level is lower relative to its weight. Because of increasing domestic supply, the CO_2 emissions from lignite reached 80 million tons in 2022. Natural gas, crude oil and petroleum products have each contributed to around 100 million tons of CO_2 emissions in recent years.[9]

5 IPPU also includes GHG by product use, like refrigerators, foams or aerosol cans.

6 Since non-CO_2 emissions from manufacturing is insignificant, this study will focus on only CO_2 emissions.

7 CO_2 content was calculated from Energy Balance Tables by using product-specific CO_2 content coefficients. No data are available for crude oil and petroleum products before 2009, because they were classified as separate categories since 2009.

8 Petroleum products produced domestically using imported crude oil are not defined as primary energy sources because they are produced by transforming imported primary sources.

9 Of course, some crude oil and petroleum products are used as inputs rather than energy sources in some sectors, such as plastics. As a result, actual CO_2 emissions are slightly lower than the figures presented here.

As mentioned above, energy industries (mainly electricity generation) account for slightly more than one third of CO2 emissions in Türkiye. Electricity generation uses a diverse set of energy sources including renewable sources, like wind and solar, and hydropower that has almost no CO2 emissions. Figure 5 presents the data on the shares of energy sources in electricity generation. As may be expected, the share of renewable sources and waste has increased rapidly in the last decade, and reached 22% in 2022. The share of coal increased almost steadily, from around 25% in early the 2000s to almost 35% in 2018. It declined to some extent during the Covid-19 pandemic. Hydro-electric accounted for about 20-30% of electricity production since 2000, whereas the share of natural gas started to decline after the global financial crisis. The share of natural gas reached 50% at its peak in 2007, but it now accounts for only about 25% of electricity generation. Thanks to the change in the composition of energy sources, the CO2 intensity of electricity consumption (production) declined from 873 (716) ton/GWh in 2006 to 749 (647) ton/GWh in 2022, i.e. 14.2% (9.7%) decline in CO2 intensity in consumption (production).[10]

Over the past 20 years, about 50% of the electricity consumed has gone to industry. The commercial sector's share of electricity consumption gradually increased from 10% in 2000 to 18% in 2022. The shares of households, government, illumination, and other sectors have decreased slightly over this period. In 2022, the shares of households, government, and illumination in electricity consumption are 22%, 5%, and 2%, respectively.[11]

As shown in Table 2, the manufacturing sector accounts for 33% of total CO2 emissions (including IPPU) in 2021, while the electricity sector accounts for 31%. Industry alone accounts for almost half of the total CO2 emissions when its share in electricity consumption is taken into account (33 + 31/2). Since the manufacturing sector's contribution to CO2 emissions from electricity consumption is quite significant, this study examines the direct (fuel combustion and IPPU, Scope 1) and indirect (electricity consumption, Scope 2) CO2 emissions caused by the manufacturing sector together.

2. Structural change and manufacturing

The manufacturing sector accounts for almost half of Türkiye's CO2 emissions, including indirect emissions from electricity consumption. Since it is one of the main emitters, in this section we will analyze how it has evolved since 2006.

We use data from the Entrepreneur Information System (EIS) of the Ministry of Industry and Technology (MoIT).[12] The EIS provides firm-level data for the period 2006-2022, compiled from various administrative sources. The dataset covers only the formal (registered) non-financial business sector (it excludes households, government and

10 The CO2 intensity in electricity consumption is higher than the CO2 intensity in production because of electricity generators own consumption and transmission losses. The CO2 intensity calculation is based on the data provided by the MoENR (Energy Balance Tables).

11 The source of the data on electricity consumption is TurkStat, Energy Statistics.

12 For a description of the data, see the EIS website [https://eis.sanayi.gov.tr/Home/Index]. Firm-level energy and CO2 calculations include companies that provide balance sheet data to the Ministry of Finance, i.e. limited liability companies and joint stock companies. They account for more than 90% of total value-added in manufacturing.

agriculture; firms engaged in agricultural activities are included but account for a very small share of agricultural production).

In this and the following sections, unless otherwise noted, all data are from our calculations based on the EIS, where we calculated energy consumption and CO2 emissions at the firm level, under certain assumptions, using the foreign trade, balance sheet, and inter-firm transactions datasets for the period 2007-2021, as the data on inter-firm flows are not yet available for 2022. As shown in Figure A1 in the Appendix, our calculations at the aggregate level are quite consistent with the TurkStat data.

The data on the share of manufacturing[13] in formal non-financial corporate sector employment, wage bill, value-added, exports and R&D expenditure are presented in Figure 6. As can be seen in the figure, the share of manufacturing in employment declines steadily from 36.8% in 2007 to 30.6% in 2017, before recovering slightly to 34.0% in 2021. The increase in the share of manufacturing in employment after 2017 is partly due to the sharp contraction in the construction sector since 2016, and the restrictions on hospitality services (hotels and restaurants) in 2020 following the Covid-19 pandemic. Manufacturing's share of the wage bill (total gross wages) follows the same pattern as employment, but is about 2-3 percentage points higher, as manufacturing pays higher wages than other sectors.[14] Moreover, the wage gap between manufacturing and other sectors has not changed much over the period.

The share of manufacturing in value-added also followed a similar pattern. It decreased slightly from 37.3% in 2007 to 32.5% in 2015 and increased slightly until 2021 (34.6%). Manufacturing's share of value-added is slightly higher than its share of employment due to differences in labor productivity between manufacturing and other sectors. However, this difference is generally smaller than that observed for wages.[15]

The manufacturing sector's export share fell sharply after the global financial crisis until 2012 and has remained stable at around 46-47% since then. It should be noted that manufacturing produces almost all exported products, but they are also exported by and through trading companies.

Finally, we use data on R&D expenditure as a proxy for technological activity. The manufacturing sector's share of R&D expenditure is constant until 2014 (around 45-50%) and declines rapidly until 2021 (33.3%). However, this is not due to a decrease in R&D intensity in manufacturing, but to an increase in R&D expenditure in services. R&D intensity in manufacturing does not change at all during this period, remaining at 0.20-0.22% since 2007, but R&D intensity in services, after remaining almost constant at 0.08-0.09% until 2016, increases rapidly to 0.16% in 2021. However, despite the increase in R&D expenditure in services in recent years, manufacturing is still more R&D intensive than services.[16]

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13 The manufacturing industry covers sectors 10-33 according to the NACE (Rev.2) classification.

14 "Others" include all other sectors except manufacturing (NACE 10-33) and electricity, gas, steam and air conditioning supply (NACE 35).

15 The value-added share is calculated using nominal values. When using real value-added (value-added deflated by output price indices, base 2021), the share of manufacturing declines continuously from 41.0% in 2007 to 34.4% in 2021. In other words, the increase in the nominal value-added share of manufacturing in recent years can be explained by relative price changes.

16 R&D intensity in services increased after 2016 thanks to rising R&D investment in some services sectors, such as information and communication services (NACE Section J).

There is a significant difference in CO2 intensity[17] between manufacturing and other sectors. The CO2 intensity of the manufacturing sector was 0.31 kg/TL in 2007, but it decreases especially after 2012 and its value is almost 50% lower in 2021 (0.18 kg/TL). The CO2 intensity of other sectors did not change much during the same period, fluctuating between 0.08-0.09 kg/TL. The CO2 intensity of non-manufacturing sectors decreased to 0.06 kg/TL in 2021, but it is too early to assume that this is a long-term trend similar to the one observed in manufacturing.

Thanks to decreasing CO2 intensity, the share of manufacturing in CO2 emissions decreased from 72.3 % in 2007 to 59.7 % in 2019 and increased slightly in 2020 and 2021 (64.5 %) due to the decreasing CO2 intensity of other sectors.

CO2 emissions are mainly generated by energy use in the form of fuel combustion and electricity use. In a sense, CO2 is a by-product of energy demand. Energy demand data do not show a long-term declining trend. For example, if we use the energy expenditure (fuel plus electricity) as a share of output ("energy share"), there is no long-term persistent trend in manufacturing, while it is increasing in other sectors (Figure 7). Throughout the period considered, manufacturing enterprises spent about 3% of their output on energy inputs. In other sectors, the energy share almost doubled between 2006 and 2021 (from 1.3% to 2.7%).

The share of energy expenditures in output is determined by a number of factors, including changes in relative prices (energy prices vs. output prices), technological change, and changes in sectoral composition. The latter factors will be discussed in Section 5 using a decomposition analysis. Figure 8 shows the data on the ratio of real energy expenditure to real output[18] in order to understand the effect of changes in relative prices. It appears that the ratio between real energy expenditures and real output is gradually declining in the manufacturing sector, while it is increasing in other sectors until 2017 and declining thereafter. A comparison of these two figures shows that energy prices have increased faster than output prices since 2006. In fact, since 2006 (until 2021), (average) output prices in manufacturing have increased by a factor of 5, but energy prices for manufacturing have increased by a factor of 8.[19]

As we have seen above, electricity is an important energy source for manufacturing, and the share of environmentally friendly renewable energy sources in electricity generation is increasing. Figure 10 shows the data on the share of electricity in energy expenditures. In both sectors, the share of electricity expenditures tends to increase over time, and the rate of change is somewhat faster in other sectors than in manufacturing. On average, manufacturing companies spend 35% of their energy expenditures on electricity, while the figure for other sectors is close to 45%. The use of electricity as an energy source, combined with the use of renewable sources for electricity generation, may have contributed to the reduction of CO2 emissions.

In summary, manufacturing has higher labor productivity, wage rate, R&D intensity, and CO2 intensity than other sectors, reflecting the fact that it is technologically dynamic and provides more “good” jobs than others. However, it also has a much higher CO2 intensity and contributes a large share of Türkiye's CO2 emissions. The share of manufacturing

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17 “CO2 intensity” is defined as the ratio between CO2 emissions and real value-added (nominal value-added deflated by output price index, base year 2021). Its unit is kg/TL. “CO2 emissions” includes CO2 emissions due to fuel combustion and IPPU as well as CO2 embodied in electricity consumed.

18 Nominal output is deflated by sectoral price indices at the NACE 3-digit level. energy expenditures are deflated by a weighted average of energy product prices where the weights are firm-specific. The base year for both price series is 2021.

19 Although there is an 8-fold increase in energy prices during this period, it is not a smooth increase. There are significant ups and downs in energy prices due to fluctuations in the international market.

has decreased significantly since 2007 until 2017. There is a slight increase in the employment and value-added share of manufacturing after 2017, but this may be a temporary change due to the economic and political shocks the economy has experienced in recent years. Although the CO_2 intensity of manufacturing is high, it has a strong declining trend. In the following sections, we will analyze how the CO_2 intensity has been reduced.

3. Dirty industries in Türkiye

Manufacturing has a higher CO2 intensity than other sectors but manufacturing itself is not a homogeneous sector. In fact, there are a small number of sectors with very high CO2 emissions.

To analyze changes in CO2 emissions, we classify all manufacturing sectors at the NACE 4-digit level into “dirty” and “clean” sectors according to their volume of CO2 emissions and CO2 intensity. A sector is defined as “dirty” if it emitted more than 2 million tons of CO2 in 2021, or if it emitted more than 200 thousand tons and its CO2 intensity was higher than 0.6 kg/TL in the same year. We use a similar criterion for 2007 (1 million tons of CO2 or 100 thousand tons and a CO2 intensity higher than 3.5 kg/TL).

The data on the share of dirty sectors in manufacturing is shown in Figure 11. There are two sectors that are responsible for the majority of CO2 emissions: the manufacture of cement (NACE 2351) and the manufacture of basic iron and steel and of ferro-alloys (NACE 2410). These two sectors alone contribute 80% of the CO2 emissions (including IPPU) of all dirty sectors in 2021 and 38% of all companies including services. The contribution of other sectors to CO2 is quite small.

Dirty sectors accounted for 20.7% of manufacturing employment in 2007, but their share decreases almost monotonically until 2021 (16.7%). The wage share of the dirty sectors has almost the same trend, but it is about one percentage point higher than the employment share. This means that the average wage rate in dirty sectors is about 5-6% higher than in clean sectors.

The share of dirty industries in manufacturing value-added also has a downward trend with some fluctuations, and there is a jump in the last two years, 2020 and 2021. As both the employment and value-added share of dirty sectors have decreased over time, relative labor productivity has remained constant around 1.4 with some fluctuations, i.e. the labor productivity of dirty sectors was 40% higher than that of clean sectors. Dirty sectors have higher labor productivity apparently because they employ more skilled workers (higher wages) and are more capital intensive.

The export share of dirty sectors is a few percentage points lower than their value-added share and shows a similar pattern of decline. The export/value-added ratio of dirty sectors is lower than that of clean sectors.

The dirty sectors' share of R&D expenditure is much lower and declining rapidly. This means that the R&D intensity of these sectors is much lower than that of other sectors. Although dirty sectors pay higher wages, implying that they employ skilled workers (technicians and engineers), the low R&D intensity reflects that they produce standard products using mature technologies without the need and opportunity for radical innovation.

The CO2 intensity of dirty industries increased somewhat in the early years of our sample period, but declined significantly by 2012 (Figure 12). The decrease in CO2 intensity of dirty sectors was almost 50% from 2012 (0.94 kg/TL) to 2021 (0.51 kg/TL). Interestingly, clean sectors experienced a similar trend, achieving a 40% reduction in CO2 intensity since 2012. In other words, the decline in CO2 intensity is not specific to dirty sectors.

Note that we define CO2 intensity as CO2 emissions per unit of (real) value-added. As labor productivity increases over time, the CO2/employment ratio has not changed much, remaining around 240-250 ton per employee in dirty sectors, and this ratio is about 15 times higher than the level in clean sectors. In other words, CO2 emissions increase on average by 250 tons per year when a new job is created in a dirty sector, while a new job in a clean sector means only 15-16 ton of CO2 per year.

Figure 13 presents data on energy expenditures as a share of output in dirty and clean manufacturing sectors. After a significant increase during the global financial crisis, the energy share in dirty sectors declined from its peak of 10.6% in 2009 to 7.1% in 2016 and remains at about the same level until 2021. Clean sectors pay less for energy: although their energy share had a slight increase from 2007 to 2010 (1.2% to 1.6%), it remained in the 1.4-1.7% range over the last decade, with slight annual fluctuations.

It seems that the decline in the energy share of the manufacturing sector mentioned in the previous section is mainly due to two factors: I) the decline in the share of dirty sectors in manufacturing, and ii) the decline in the energy share of dirty sectors.

The ratio of real energy expenditure to real output shows a downward trend in both dirty and clean manufacturing sectors up to now (Figure 14), although the trend is more pronounced in the dirty sectors. There is no discernible change in the real energy/output ratio since 2014. The stability of the real energy/output ratio at the disaggregated level may indicate that fluctuations in energy prices have little impact on energy consumption at the aggregate level in Turkish manufacturing.

Clean sectors spend less on energy than dirty sectors, and they also spend proportionally more on electricity than dirty sectors. The share of electricity expenditure was almost constant at around 30-35% in the dirty sectors, but it increased somewhat in the clean sector, reaching almost 45% in 2021. As a result of these trends, the share of dirty sectors in CO2 emissions due to electricity consumption in the manufacturing sector decreased from 60-65% in 2007-2008 to 45-46% in 2021.[20]

Our analysis shows that dirty sectors account for about 75% of manufacturing CO2 emissions (including IPPU), and the cement and iron and steel sectors alone account for 80% of all dirty sector CO2 emissions. They have higher labor productivity than clean manufacturing sectors because they use capital-intensive technologies and employ relatively more high-wage workers. However, they do not spend much on R&D and their share of employment, wage bill and value-added tends to decline.

20 Dirty sectors' share in CO2 emission due to fuel combustion declined slightly from 77.7% in 2007 to 73.4% in 2021, and their share in IPPU CO2 emission was almost 100% throughout the period.

The CO2 intensity of both dirty and clean sectors has been declining since 2007, and almost all individual dirty sectors (at the 4-digit NACE level) have experienced a decline in CO2 intensity since 2007. The only major exception to this trend is the cement industry (NACE 2351).[21] The CO2 intensity of the cement industry shows fluctuations from 3.6 kg CO2/TL in 2007 to 5.5 in 2010, 4.2 in 2013 and finally 5.8 in 2023. The CO2 intensity of cement fluctuates strongly mainly because of changes in real value-added, which is driven by changes in relative prices. The share of value-added in output in cement production decreases from 50% in 2007 to 30% in 2021, its pattern of change seems to be influenced by the level of construction activities in Türkiye.[22]

4. Why is CO2 intensity in Turkish manufacturing declining?

The analysis presented in the previous sections shows that the CO2 intensity in Türkiye has a tendency to decrease in almost all sectors, manufacturing and others, dirty and clean.

There are a number of factors that can explain the decline in CO2 intensity.

First, we have seen a significant increase in the share of renewable sources in electricity. The share of renewable sources (wind and solar) was less than 1% in 2007, but it reached almost 20% in 2021.[23] Since renewable sources do not directly cause CO2 emissions, this will have a positive effect on the CO2 intensity of all sectors that use electricity.

Figure 16 presents the data on CO2 intensity by type (fuel combustion, electricity and IPPU) in manufacturing. As shown in the figure, there is a sharp decline in the CO2 intensity due to electricity used,[24] but the CO2 intensity in fuel combustion and IPPU also has a visible and strong downward trend. Therefore, the increasing reliance on renewable energy sources explains part of the decline in CO2 intensity, but there is still a significant unexplained part.

Second, changing the mix of energy sources can reduce CO2 intensity. If companies switch to energy sources with lower CO2 content, their CO2 emissions can decrease even if they use the same amount of energy. In other words, CO2 intensity can decrease without a decrease in energy intensity.

Figure 17 shows data for two energy intensity series. The first series (EIS energy intensity) is defined as the real expenditure on energy (fuel and electricity) per unit of real output, and is calculated based on the EIS data. It measures the “volume” of energy consumed per unit of output. The second series is calculated by the International Energy

21 Another exception is the manufacture of sugar (NACE 1081) but its share in dirty industries is much smaller.
22 Since the changes in CO2 intensity and the share of value-added in output moved in opposite directions, the CO2 intensity in relation to output (CO2/real output) remained almost constant at 1.8-2.0 kg/TL during this period.
23 During this period, he share of hydropower fluctuated around 20-25%.
24 The CO2 intensity of the electricity used is defined as the ratio between the CO2 emissions embodied in the electricity consumed and the real value-added (2021 prices).

Agency (IEA) and measures the energy content (megajoules, MJ) per unit of output (in 2015 USD, adjusted for purchasing power parity, PPP). As shown in the figure, these two series follow almost the same downward trend.

The EIS energy intensity variable in Figure 17 includes two sources, (fossil) fuels and electricity. To understand whether their trends are different, we calculated the energy intensity for two energy sources separately (see Figure 18). These two energy intensity variables show almost parallel trends over the period. It appears that changes in the composition of energy sources do not explain the decline in CO2 intensity.

Third, as we have seen above, the share of manufacturing in the economy and the share of dirty sectors in manufacturing are declining over time. The structural shift towards clean sectors and services can certainly explain some of the decline in overall CO2 intensity.

The decline in CO2 intensity within dirty sectors may indicate that there is another factor, the fourth, that can cause declining CO2 intensity: improvements at the firm level. Firm-level CO2 intensity can be reduced through either technological change or changes in product mix. For example, firms may adopt new energy-efficient process technologies to produce the same product, or change product design to use less energy. Or companies can change their product mix to less energy-intensive products. In either case, energy intensity, and therefore CO2 intensity, is reduced.

Finally, there may be a reallocation within sectors from high to low CO2 intensity firms. Although we define “sector” at the most detailed level (NACE 4-digit) allowed by the data available to us, firms within sectors are quite heterogeneous in terms of products and processes. Moreover, even if firms produce the same product, some of them may be more efficient, and if more efficient firms increase their market share, the CO2 intensity at the sectoral level will decrease.

Since we have calculated energy use and CO2 emissions at the firm level, it is possible to identify the effects of allocation between sectors, allocation within sectors (between firms in the same sector), and within firms using a decomposition analysis.[25]

The CO2 intensity at the level of the manufacturing industry at time t is defined as

$C_t = CO2_t / VA_t = \Sigma_M co2_{it} / \Sigma_M va_{it}$

25 There are a number of decomposition analyses for Türkiye for different time periods, e.g. (Lise 2006; İpek Tunç, Türüt-Aşık, and Akbostancı 2009; Yilmaz and Atak 2010; Akbostancı, Tunç, and Türüt-Aşık 2011; Kumbaroğlu 2011; Akbostancı, Tunç, and Türüt-Aşık 2018; Karakaya, Bostan, and Özçağ 2019; Akyürek 2020; Ozdemir 2023). Since these studies use the data at the sectoral level, they cannot identify the effects of changes in efficiency at the firm level. Most of these studies decompose the change in energy consumption, not intensity, and found that the change in output explains most of the change in energy consumption.

Sahin (2017) is the only study that uses firm-level data. She uses the data for the period 2005-2012, and decomposes changes in nominal energy expenditures, and finds that “the activity effect [change in the level of output] and the firm intensity effect were the drivers of the change in energy consumption in Turkish manufacturing industry.” She suggests that the increase in energy efficiency within sectors is due to “the increase in firm level efficiency rather than shift of production towards more energy efficient firms within sectors.” However, since the nominal values are used, changes in relative prices may also explain changes in energy intensity at the firm level.

where *CO2* means total CO2 emissions, *VA* total (real) value-added and *M* the set of firms in the manufacturing industry. *co2* and *va* are firm level CO2 emissions and value-added. The subscripts *i* and *t* denote firm and time, respectively.

Since

$$\Sigma_M co2_{it} / \Sigma_M va_{it} = \Sigma_M (co2_{it} / va_{it})(va_{it} / \Sigma_m va_{it})$$

$$C_t = \Sigma_M c_{it} s_{it}$$

where c_{it} is the CO2 intensity of firm *i* at time *t*, and s_{it} is that firm's share in total value-added.

Change in CO2 intensity from time 1 to 2 can be written as

$$C_2 - C_1 = \Sigma_M c_{i2} s_{i2} - \Sigma_M c_{i1} s_{i1} = \Sigma_P c_{i2} s_{i2} + \Sigma_N c_{i2} s_{i2} - \Sigma_P c_{i1} s_{i1} - \Sigma_X c_{i1} s_{i1}$$

where *P* is the set of firms that operate in both years, *N* the set of entrants at time 2 and *X* the set of exiting firms at time 1. By rearranging terms, we get the following:

$$C_2 - C_1 = \Sigma_P (s_{i2} - s_{i1}) c_i^a + \Sigma_P (c_{i2} - c_{i1}) s_i^a + \Sigma_N s_{i2} c_{i2} - \Sigma_X s_{i1} c_{i1}$$

$$= \Sigma_P (s_{i2} - s_{i1})(c_i^a - C^a) + \qquad \text{Allocation effect}$$

$$\Sigma_P (c_{i2} - c_{i1}) s_i^a + \qquad \text{Within effect}$$

$$\Sigma_N s_{i2}(c_{i2} - C^a) - \Sigma_X s_{i1}(c_{i1} - C^a) \qquad \text{Entry-exit effect}$$

where c_i^a is the average CO2 intensity of firm *i* (average of time 1 and 2), s_i^a the average value-added share of firm *i*, and C^a the average CO2 intensity, $(C_2 + C_1)/2$.

The first term on the right-hand side of the equation represents the change in CO2 intensity due to the reallocation of value-added between firms and is defined as the "allocation effect". It is also referred to as the "between effect".

The second term, the "within effect", represents changes in CO2 intensity due to changes in the CO2 intensity of firms. It explains the effects of technological change and/or changes in product mix at the firm level.

The third and fourth terms represent the effect of entry and exit. For example, if new firms have a lower CO2 intensity than the average, the entry effect will be negative.

The allocation (between) effect can be further decomposed into two components:

$$\Sigma_P (s_{i2} - s_{i1})(c^a_i - C^a) = \Sigma_J \Sigma_{Pj} (s_{j2} s_{ij2} - s_{j1} s_{ij1})(c_i^a - C^a)$$

$$= \Sigma_J \Sigma_{Pj} (s_{j2} - s_{j1})(c_i^a - C^a) s_{ij}^a +$$

$$\Sigma_J \Sigma_{Pj} (s_{ij2} - s_{ij1})(c_i^a - C^a) s_j^a$$

$$= \Sigma_J (s_{j2} - s_{j1}) \Sigma_{Pj} (c_i^a - C^a) s_{ij}^a +$$

$$\Sigma_J\, s_i^a\, \Sigma_{Pj}\, (s_{ij2} - s_{ij1})(c_i^a - C^a)$$

$$= \quad \Sigma_J\, (s_{j2} - s_{j1})(c_j^a - C^a) + \qquad \text{Inter-sectoral effect}$$

$$\Sigma_J\, s_j^a\, \Sigma_{Pj}\, (s_{ij2} - s_{ij1})(c_i^a - C^a) \qquad \text{Intra-sectoral effect}$$

where s_{jt} is the value-added share of sector *j* in manufacturing value-added at time *t*, s_{ijt} the value-added share of firm *i* in sector *j* at time *t*. *J* is the set of sectors and *Pj* is the set of firms that operate in both years in sector *j*.

The first term on the last right-hand side of the equation shows the effect of changes in sectoral value-added shares on CO2 intensity at the manufacturing level, while the last term shows the effect of changes in value-added shares of firms within their sectors.

There are basically three components of changes in CO2 intensity: allocation (between) effects, within effects, and entry-exit effects. The allocation effect is further decomposed into two factors, inter-sectoral and intra-sectoral effects.

By applying the decomposition analysis each year, the components of the annual change in CO2 intensity were calculated and these values were cumulated to find their effects over the period 2007-2021. Table 4 summarizes the results of the decomposition analysis for seven variables.

The CO2 intensity of the manufacturing sector decreased from 0.31 kg/TL in 2007 to 0.18 kg/TL in 2021. The cumulative change in CO2 intensity is -0.13 kg/TL. This is the value in the first row and column of Table 4. CO2 is emitted by fuel combustion, electricity generation and IPPU. CO2 emissions from fuel combustion, electricity and IPPU are reduced by 0.058, 0.049 and 0.025 kg/TL, respectively, from 2007 to 2021 (the sum is 0.129 kg/TL).

The first column of Table 4 shows the cumulative contributions of the within, between (allocation) and entry-exit factors. The contribution of the within effect is -24.0%, which shows that, on average, firm-level CO2 emissions increased by about 0.032 kg/TL (-0.133*-24.0%). Since the within effect reflects changes at the firm level, it seems that manufacturing firms, on average, were not able to reduce their CO2 intensity. On the contrary, it increased slightly over the period.

The contribution of the between-effect is about 111.0%, i.e. almost all of the decrease in CO2 intensity is due to a reallocation of value-added to less intensive sectors and firms. Most of this reallocation is between sectors (the inter-industry effect is 83.1%) and about a one fourth is due to the intra-industry effect (27.8%). The entry-exit effect accounts for 13.1% of the decline in CO2 intensity. Apparently, the CO2 intensity of new firms is lower than the average, and they help to reduce the CO2 intensity of the manufacturing sector.

The decomposition analysis shows that although CO2 intensity from fuel combustion, electricity, and IPPU have all declined since 2007, there are significant differences between them in terms of the importance of between- and within-effects. Most of the decrease in CO2 emissions from fuel combustion is due to between effects. Note that the contribution of the within effect to the reduction in CO2 emissions is negative and significant (-41.8%).

In the case of CO2 emission intensity from electricity, the within effect is positive and significant (37.1%). There are two factors driving the within effect in electricity: i) the decline in electricity use and ii) the decline in CO2 intensity of electricity generation. The inter-sectoral and intra-sectoral allocations each account for about 27.2%. The entry-exit effect explains only 8.5%.

The IPPU-induced emissions decreased by -0.025 kg/TL from 2007 to 2021, but the results of the decomposition indicate that the within-effect had an equal but opposite effect on the CO2 intensity. In other words, without the allocation and entry-exit effects, CO2 intensity would increase by about 0.025 kg/TL due to the firm-level increase in IPPU-induced emissions. The main reason why the within-effect is so large is the increase in CO2 intensity in the cement sector, as discussed above. The inter-industry allocation effect is about 200% (or about -0.050 kg/TL), so that on average the IPPU-induced CO2 intensity has decreased by 0.025 kg/TL since 2007 in spite of the negative effect of the within effect.

The decomposition analysis of CO2 intensity shows that firm-level improvements in electricity consumption (efficiency in electricity use) have contributed a small share of the decrease in CO2 intensity in Turkish manufacturing in the period 2007-2021.The bulk of the decrease in CO2 intensity is explained by inter-sectoral allocation, i.e., the decreasing share of dirty industries. The contribution of intra-sectoral allocation, i.e., the declining share of dirty firms within sectors and the entry of "clean" firms, accounts for about one third of the reduction in CO2 intensity.

The decomposition analysis of energy density shows similar results. The energy intensity of the manufacturing sector decreases by almost 40% between 2007 and 2022 (from 0.215 to 0.126). There is a slight decrease in electricity consumption at the firm level, but most of the decrease in energy intensity is explained by intra-sectoral (87.2%) and inter-sectoral (65.4%) allocations. Interestingly, the within effect is negative (-62.5%), driven basically by the increase in fuel intensity.

5. Policies for Climate Change and Decarbonization

Since 1963, Türkiye has been defining its long-term development goals and policies through five-year development plans. Türkiye has joined the United Nations Framework Convention on Climate Change (UNFCCC) in May 2004 as the 189th party, and the first reference to climate change was introduced in the 9th Development Plan in 2006.[24] However, the Plan only states that:

"In the framework of the conditions of Türkiye, and with the participation of the relevant parties, a National Action Plan that sets forth the policies and measures for reducing greenhouse gas emissions will be prepared. Thus, responsibilities concerning UN Framework Convention on Climate Change will be fulfilled."[26] (SPO 2006, 87)

26 The 9th Plan envisages the reduction of the state's share in "coal and other mining" through privatization (SPO 2006, 68). A few years later, the High Planning Council adopts the Electricity Energy Market and Security of Supply Strategy Document in 2009. According to the strategy document, all known lignite and hard coal resources will be utilized for electricity generation by 2023.

In all plans following the 9th one, it was stated in general terms that measures would be taken to address climate change and decarbonization. For example, the 10th plan mentions that:

“Environmental sensitivity and life quality will be improved with practices such as waste and emission reduction, energy, water and resource efficiency, recycling, prevention of noise and visual pollution, usage of environment friendly material in line with sustainable cities approach. Environment friendly practices in production and services such as renewable energy, eco-efficiency and cleaner production technologies will be supported and developing and branding of new environment friendly products will be encouraged.” (Ministry of Development 2014, 137)

Although all these plans have suggestions on adopting “environment friendly” policies, the 10th and 11th plans explicitly called for “increasing reserves by accelerating coal exploration activities” (Ministry of Development 2014, 174) and the “use of indigenous coal resources for electricity generation” (Presidency of Strategy and Budget 2019, 23). The 12th plan also stated that “Within the scope of ensuring energy supply security, the use of domestic coal will continue, taking into account environmental impacts to the maximum extent.” (Presidency of Strategy and Budget 2023, 109)

All three development plans mentioned that R&D activities will be supported “to raise the quality of domestic coals or increase their calorific values” (Ministry of Development 2014, 174), to develop “clean coal technologies” (Presidency of Strategy and Budget 2019, 123) and “to use coal in more environmentally friendly ways such as hydrogen, methanol and ammonia production, and studies will be carried out to utilize our reserves with clean coal technologies.” (Presidency of Strategy and Budget 2023, 109)[27]

Türkiye signed the Paris Agreement in 2016 but postponed its ratification until 2021 due to its objection to be considered as a developed country under the agreement in Annex I. Türkiye's objections were accepted to a certain extent and measures were taken regarding the use of various funds. The Parliament finally ratified the agreement in 2021 (Law No. 7335), but Türkiye declared that it will implement the agreement as a developing country.[28] After ratifying the agreement, Türkiye announced a net-zero emissions target by 2053 and updated the first (2015) Nationally Determined Contribution (NDC) in 2023, declaring that it will reduce its GHG emissions by 41% by 2030 (695 Mt CO2 equivalent in 2030) compared to the business as usual (BAU) scenario in Türkiye's first NDC, taking 2012 as the base year, and intends to peak its emissions by 2038 at the latest.

In referring to the EU's net zero emissions target and CBAM, the 12th Development Plan emphasizes Türkiye's need to “comply with international regulations in areas such as

27 3-year Medium Term Programs are prepared each year to operationalize development plans and guide resource allocation. The first Medium Term Program covers the period 2006-2008 (all Medium Term Programs are available at https://www.sbb.gov.tr/orta-vadeli-programlar/). These programs include climate change and decarbonization targets in line with the development plans.

28 Türkiye’s declaration made upon ratification is as follows:

The Republic of Türkiye, on the basis of “equity, common but differentiated responsibilities and respective capabilities” as clearly and accurately recognized under the United Nations Framework Convention on Climate Change of 9 May 1992 and the Paris Agreement, and by recalling decisions 26/CP.7, 1/CP.16, 2/CP.17, 1/CP.18 and 21/CP.20 adopted by the Conference of the Parties to the Convention, declares that Türkiye will implement the Paris Agreement as a developing country and in the scope of her nationally determined contribution statements, provided that the Agreement and its mechanisms do not prejudice her right to economic and social development. (See United Nations Treaty Collection website, https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-7-d&chapter=27&clang=_en#EndDec]

sectoral capacity building, financial support and carbon pricing mechanisms" and their impact on its "energy balance and coal policies". The plan assigns a critical role to investments in "renewable energy, electrification, energy efficiency, green hydrogen, energy storage" and "new nuclear power plants and domestic small modular reactors (SMRs) in addition to the Akkuyu nuclear power plant" in order to achieve the 2053 net zero emissions target (Presidency of Strategy and Budget 2023, 19, 39, 51).

There are numerous regulations, strategies, and action plans adopted by the government and relevant public organizations (see Table A1 in the Appendix for a list). One of the first and most important regulations is the Energy Efficiency Law (No. 5627), adopted in 2007. The law provided the legal basis for energy efficiency activities and aims at reducing energy and, indirectly, CO2 intensity (the so-called "within effect" discussed above). It introduced "requirements for industrial enterprises of a certain size to commission energy efficiency audits and establish energy management structures". It also allowed companies to benefit from generous incentives (at the level provided for investments in the least developed regions) for energy-saving investments that meet certain criteria (MoENR 2018, 19). A number of secondary regulations have provided additional requirements and incentives for energy efficiency.[29]

After the ratification of the Paris Agreement, Türkiye has restructured the Ministry of Environment and Urbanization as the Ministry of Environment, Urbanization and Climate Change (MoEUCC). The Directorate of Climate Change was established under the MoEUCC to carry out "all necessary work for climate change adaptation and mitigation and raising awareness of climate change in all segments of society with a human and nature-friendly approach"[30] and the Climate Change and Adaptation Coordination Board (CCACB) was reorganized. The Green Deal Action Plan and the National Energy Plan were adopted in 2021 and 2022, respectively.

The Green Deal Action Plan states that the options for a national carbon pricing mechanism will be studied by taking into account "sectoral sensitivities and the CBAM" (MoT 2021, 13). Similarly, the 12th Development Plan, published in 2024, also mentions that "National carbon pricing instruments will be developed to maintain competitiveness by supporting green transformation processes. Legislation and other infrastructure preparations for the establishment of the National Emissions Trading System (ETS) will be finalized and the system will be put into practice." (Presidency of Strategy and Budget 2023, 219) The carbon pricing mechanism is expected to encourage firms to adopt energy-efficient processes (the within effect) and to substitute energy-intensive inputs and products with energy-efficient ones (the between effect).

It is beyond the scope of this paper to analyze the impact of climate change and decarbonization policies (for a comprehensive assessment, see Akçomak et al. 2024). We use the OECD's Environmental Policy Stringency Index (EPS) to compare Türkiye's policies with those of OECD and some non-OECD countries (Kruse et al. 2022). The index is compiled and calculated by the OECD as a composite index. The EPS index has two components, i) market-based policies, which is composed of indices for taxes

29 Some of the regulations concerning energy efficiency and CO2 emissions are as follows: Regulation on Environmentally Responsible Design of Energy-Related Products (2010), Regulation on ohe Display of Energy and Other Resource Consumptions of Products through Labeling and Standard Product Information (2011), Regulation on Increasing Efficiency in the Use of Energy Resources and Energy (2011), Monitoring and Reporting of Greenhouse Gas Emissions (2014), Energy Labelling Framework Regulation (2021).

30 See the Directorate of Climate Change web site, https://iklim.gov.tr/en/about-us-i-75.

(CO2, NOx, SOx, diesel), trading schemes (CO2, renewable energy certificates, energy efficiency certificates), feed-in tariffs and feed-in premiums for renewable energy (wind and solar), and deposit and refund schemes, and ii) non-market-based policies, which is composed of standards (emission limits for NOx, SOx, POx, sulphur content limit) and R&D subsidies (government R&D expenditure on renewable energy). The index takes values between 0 (no policy) and 6 (the most stringent policies).

Figure 19 shows the data for the aggregate market-based policy index for 2020. France, Sweden, Norway, and Denmark have the highest values, while Brazil, Indonesia, Mexico, and South Africa have the lowest values. Türkiye's market-based policy EPS value is 0.67, and it ranks 34th out of 40 countries. Note that Israel, Canada and New Zealand also have similar values.[31]

The data for the aggregate non-market-based policies index for 2020 are shown in Figure 20. Italy has the highest score (6 out of 6), followed by Switzerland, Canada and the US (5.75). Most countries have a score of 5.5 and Türkiye has a score of 5.0. The EPS scores for non-market policies are quite high for most countries, including Türkiye, because of EU standards on emission limits, for example for cars.

There are a few worldwide policy databases that usually indicate that climate change and decarbonization policies in Türkiye are not at the level that can achieve the net zero target. For example, The Climate Policy Database[32] considers the general policy coverage as “Good”, but policies on electricity and heat, and industry have received “fair” and “very poor” assessment, respectively. The “missing” policies on industry are in the following areas: strategy for material efficiency, support scheme for renewables, support scheme for carbon capture and storage (CSS), support scheme for fuel switch, carbon dioxide removal technology development, incentives to reduce CH4 from fuel exploration and production, incentives to reduce landfill CH4, incentives to reduce N2O from industrial processes, overarching carbon pricing scheme or emissions limit and energy and other taxes. The Climate Action Tracker database[33] rates Türkiye’s current policies and action as “Critically insufficient” when compared to its fair share contribution.

A detailed analysis of two main policy tools, carbon pricing and R&D, can provide additional information on how countries address the green transformation in a comparative perspective. Carbon pricing provides incentives for both producers and users of energy towards energy efficiency and renewable energy sources by raising CO2 emission costs. It also facilitates structural change towards clean sectors by imposing a cost penalty on dirty sectors.

A recent OECD study of cement and steel plants in 140 countries shows that higher carbon prices have a significant impact on CO2 emissions (Teusch et al., 2024). Their results indicate that, on average, a \$1/tCO2e increase in carbon prices reduces emissions from cement and steel plants by 1.3%. However, differences in carbon prices between countries lead to carbon leakage through international trade.[34]

The World Bank has compiled a comprehensive database on carbon pricing, the State and Trends of Carbon Pricing Dashboard (CPD).[35] According to the CPD, 30 countries are currently implementing a national carbon tax scheme (CT) and 13 countries a

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31 The scores of countries like Brazil ans New Zealand are low because the index does not include policies on agriculture.

32 See https://climatepolicydatabase.org/countries/Türkiye

33 See https://climateactiontracker.org/countries/Türkiye/policies-action/

34 Two recent studies using firm-level data on Japan, Korea, and China (Le and Azhgaliyeva, 2023) and Sweden (Martinsson et al., 2024) have similar.

35 See https://carbonpricingdashboard.worldbank.org/

national emission trading system (ETS). Most of the countries implementing carbon pricing (CT or ETS) are developed/high-income countries (32 of them) and 11 are developing/middle and low-income countries (Albania, Argentina, China, Colombia, Indonesia, Kazakhstan, Mexico, Montenegro, South Africa, and Ukraine). Most of these 11 countries have introduced carbon pricing in the last decade, although carbon pricing was first introduced by a number of developed European countries in the early 1990s. Moreover, the level of carbon pricing in developing countries is much lower than in developed countries. For example, the average carbon price in the EU was $96.4/tCO2e in 2023, while it was less than $10/tCO2e in almost all developing countries.[36]

Türkiye has stated in various policy documents that an ETS will be established, but no explicit carbon pricing mechanism has yet been put in place. According to the OECD, fuel excise taxes in Türkiye are an implicit form of carbon pricing, covering 31.4% of emissions in 2023, while fossil fuel subsidies cover 16% of emissions.[37] As it is re-iterated in a recent policy document, *Türkiye's 2053 Long-Term Climate Strategy* (MoEUCC, 2024), Türkiye is likely to introduce a carbon pricing scheme (ETS) in the following years, partially as a response to the EU's Carbon Border Adjustment Mechanism (CBAM).[38] The ETS, if rigorously implemented, can force industry to develop and adopt energy-efficient products and processes and help drive the transformation to a green economy.

While financial incentives and penalties such as the ETS provide an impetus for green transformation, they are not sufficient to increase the pace and, more importantly, the direction of technological change. As a result, many countries are actively using targeted R&D policies to achieve net zero emission targets.

The International Energy Agency's (IEA) Energy Technology RD&D Budgets database[39] provides information on public research, development and demonstration (RD&D) expenditures on energy technologies (energy efficiency, renewable energy, nuclear power, fossil fuels, hydrogen and fuel cells, etc.) in IEA member countries since 1974. Figure 22 presents the data on public RD&D as a percentage of GDP in 2022 for a group of countries for which data are available.

There are significant differences in public RD&D intensity between countries. Although the dataset includes only a few developing countries, as shown in the figure, developed countries have a much higher RD&D intensity than developing countries. Public RD&D intensity in Türkiye peaked in 2009 (0.009%), but then gradually declined to 0.002% in 2023.

Türkiye's total public expenditure on energy RD&D in the last 10 years (2014-2023) was 520 million USD (in 2023 prices and exchange rates). "Energy efficiency" accounted for the largest share of RD&D expenditures (36.0%), followed by renewables (29.4%), other power and storage technologies (17.9%) and fossil fuels (8.6%). In contrast, the IEA member countries spent a total of 216,002 million USD on RD&D during the same period

36 Uruguay is an exception with a price of $155.9/tCO2e.
37 OECD, *Pricing Greenhouse Gas Emissions, Country Notes: Carbon Pricing in Türkiye*, 2024, https://www.oecd.org/content/dam/oecd/en/topics/policy-sub-issues/carbon-pricing-and-energy-taxes/carbon-pricing-turkiye.pdf
38 "National carbon pricing mechanisms also present an opportunity to mitigate CBAM's economic impact, accelerate industrial decarbonization, and improve energy efficiency." (MoEUCC, 2024: 25)
39 See https://www.iea.org/data-and-statistics/data-product/energy-technology-rd-and-d-budget-database-2

(23.5% on energy efficiency, 21.1% on nuclear power, 17.5% on other cross-cutting technologies/research, 15.3% on renewables, 8.1% on fossil fuels, and 7.1% on other power and storage technologies).

CO2 and energy intensity at the national economy and industry level in Türkiye have decreased significantly since 2005. In line with the above-mentioned studies on climate change and decarbonization policies, our findings suggest that the decline in CO2 and energy intensity is mainly due to (inter- and intra-industry) reallocation effects, and the contribution of efficiency improvements at the firm level is not sufficient. Although Türkiye has implemented a number of programs to improve energy efficiency since the adoption of the Energy Efficiency Law in 2007, there are two factors that have had a negative impact on the reduction of CO2 intensity.[40]

First, Türkiye is heavily dependent on imports of energy products, and the government has encouraged domestic coal production by the private sector to reduce its dependence on imports.[41] Despite the net zero emission target for 2053, there does not appear to be a radical change in coal policy. A recent study explains that "the announced policies do not include any commitment to phase out coal and state that the development of fossil fuel resources will continue" (SHURA 2024, 10).[42]

Second, Türkiye has pursued a policy of supporting the growth of the construction sector with cheap credit over the past two decades. The construction sector grew rapidly until 2017, with a brief pause right after the global financial crisis (see Figure 21). However, this mode of growth, which was mainly financed by foreign resources and resulted in a significant current account deficit, was not sustainable, and construction output relative to manufacturing and GDP has declined sharply over the past five years. It should be noted that the construction sector is the main consumer of cement, and iron and steel, and these two industries are the main CO2 emitters in Türkiye. Therefore, the rapid growth and recent decline of the construction sector is one of the main drivers of CO2 emissions in Türkiye.

The green transition can provide Türkiye with an opportunity to focus on the efficiency improvements (including energy efficiency) needed to achieve sustainable and equitable growth. To seize this opportunity, Türkiye should abandon short-term policies aimed at temporary solutions to its economic problems and implement long-term and systematic policies.[43] In the industrial sector, climate change and decarbonization policies should have two priorities: i) decarbonization of power generation, and ii) structural change in industry.

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40 For a review of economic policies since 2001, see Taymaz and Voyvoda (2022) and Boratav and Orhangazi (2022).

41 As mentioned in a World Bank study, "subsidizing coal production drives up emissions, has other unintended adverse outcomes, and presents fiscal risks. Subsidies to the state-owned Turkish Hard Coal Enterprises amounted to $200 million in 2018 and to coal-fired power plants amounted to $475 million in 2020." (World Bank Group 2022, 59)

42 Despite the emphasis on domestic coal production, there appears to be no consensus on the volume of domestic coal production. There are three sources of data on coal production in Türkiye. According to TurkStat data, Türkiye's saleable coal production was 74 million tons in 2021. The General Directorate of Energy Affairs (EİGM) of MoENR prepares Türkiye's energy balance tables. The energy balance tables for 2021 show the domestic production as 86.5 million tons of saleable coal. Finally, the General Directorate of Mining and Petroleum Affairs (MAPEG) of MoENR data says Türkiye produced 94 million tons of coal in the same year. Even if the MAPEG value refers to gross production (not saleable), it is not comparable to the previous figures (Tamzok 2023).

43 A recent World Bank study suggests that the 2053 net-zero path requires an investment of $68 billion in 2022-2030, but the benefits ($146 billion for 2022-2040) exceed the costs "through significant avoided energy imports, health gains, and other co-benefits." (World Bank Group 2022, 10)

Decarbonizing power generation is only possible with a radical break from existing energy policies by phasing out (domestic and imported) coal and increasing the share of renewable energy (mainly solar and wind) in generation. Studies on the 2053 net zero target show that Türkiye should significantly reduce the share of coal in power generation by 2030 (Şahin et al. 2022, 52; World Bank Group 2022, 14). Since decarbonization of electricity generation implies the use of domestic and local resources, it will also contribute to reducing the current account deficit, reducing the volatility of energy prices, and reducing transmission losses thanks to the distributed energy network of localized generation.

The main drawback of increasing the share of renewable resources such as wind and solar is their dependence on climatic conditions. To stabilize the electricity supply, efficient energy storage systems (such as batteries and pumped storage) should be developed, and substantial investment in these technologies is needed. Since renewable energy sources are not sufficient to provide a stable electricity supply with current and future technologies, new technologies to capture and store CO2 emitted from fossil fuels will be required to achieve the net-zero target.

There are two main CO2 emitters in Türkiye: iron and steel, and cement industries. About one third of CO2 emissions are due to IPPU, and both industries use fuels for their high-temperature processes. The IPPU emissions are process-specific and can be reduced by changing the production process itself, i.e., new process technologies, if possible, should be innovated and implemented to reduce IPPU emissions. In addition, it is very difficult to reach the temperature levels required by the production processes in these sectors with electrical energy. It does not seem possible for these sectors to use electricity instead of fossil fuels even in the long term without a radical change in production processes. Finally, about 71.6% of crude steel in Türkiye is produced in electric arc furnaces (EAFs) using scrap materials, and Türkiye already has one of the highest EAF rates in the world.[44] EAF production has a lower CO2 emission intensity than blast furnace (BF) and basic oxygen furnace (BOF) production. As EAF is already widely used in Türkiye, the scope for reducing CO2 intensity through EAF diffusion is limited.[45] Decarbonizing iron and steel, and cement industries requires new process and carbon storage technologies. Türkiye, as one of the main producers in the world in both sectors, needs to allocate resources for R&D activities for the development of these technologies.

Since the potential for decarbonizing the most dirty sectors is limited in the short and medium term, the main policy objective should be to promote structural change towards high wage clean activities and sectors that produce new clean technologies and produce energy efficient versions of existing products. Türkiye has accumulated competencies and capabilities in metal-related sectors such as consumer durables, machinery and automobiles, and can use its industrial base to produce “green products” such as wind turbines, batteries, electric cars, energy-efficient consumer durables, and so on. It also has the potential to produce high value-added segments of traditional products such as food and textiles. It should be noted, however, that such a transition to green, energy-efficient and high value-added segments requires competence and innovation in digital technologies. The government should lead the business sector to develop digital and

44 The share of EAF in world steel production in 2023 was only 28.6% (see World Steel Association, https://worldsteel.org/data/world-steel-in-figures-2024/)

45 Türkiye imports scrap for EAF production. As EAF becomes more widespread worldwide to reduce CO2 emissions, the demand for scrap material is increasing worldwide. This is a potential problem for iron and steel production in Türkiye.

green technologies by providing technology-specific support for R&D activities. Since R&D support alone is not sufficient to lead the business sector, the government must complement its R&D policy by creating demand for green and energy-efficient products and technologies through green public procurement and public entrepreneurship.

Another aspect of structural change is to reduce the demand for the output of dirty sectors (namely cement and iron and steel) by changing product design and substituting their use by environmentally friendly materials. For example, there is untapped potential in Türkiye to use renewable materials such as wood as a structural element in construction.[46] The development and use of new materials require additional investment in R&D activities.

The policies discussed so far will facilitate decarbonization mainly by encouraging a group of firms to invest in technological activities and new products. At any given time, many "clean" technologies or options are already available to firms. The government should "push" firms to adopt these options by making CO2 emissions costly, for example through carbon taxes and strict environmental regulations. There are many studies showing the effectiveness of taxes and regulations. For example, Shapiro and Walker conducted a decomposition analysis of air pollution emissions from US manufacturing over the period 1990-2008 and found that emissions fell by 60% over this period, despite a substantial increase in output. They show that the increase in implicit pollution tax explains almost all of the decline in emissions (Shapiro and Walker 2018). Neves, Marques, and Patrício (2020) show that environmental regulation is effective in cutting CO2 emissions in the long-run. The analysis by Brandi et al. (2020) provides evidence on green export promoting effects of environmental provisions in developing countries. A study on Indonesia shows that "the carbon tax and ETS are also likely to promote substitution towards renewable energy" and the "carbon tax which is simpler and more swiftly implementable is the more practical choice compared to the ETS in the short to medium term for developing countries with political economy constraints in their energy and transportation sectors" (Dissanayake, Mahadevan, and Asafu-Adjaye 2020).

Finally, structural change implies a reallocation of resources and a shift in employment from declining to growing activities. For example, about 34,000 people are (formally) employed in coal mining[47], and these workers will lose their jobs as coal production is phased out. The government should provide income support and protection to all those affected by structural change, and encourage firms to invest in training so that the transition will be fair and inclusive to everyone concerned.[48]

46 Linkevičius, Žemaitis, and Aleinikovas (2023) calculates potential CO2 emissions from glue-laminated timber (GLT) and precast reinforced concrete (PRC) framed 2- and 5-floor houses, and find that GLT frames houses have 60% less CO2 emissions. When the carbon storage properties of GLT are taken into account, the reduction in CO2 emission reaches 70%.

47 See TurkStat, *Annual Industry and Services Statistics, 2023* [https://data.tuik.gov.tr/Bulten/Index?p=Yillik-Sanayi-ve-Hizmet-Istatistikleri-2023-53782]

48 The "ILO Guidelines for a Just Transition to Environmentally Sustainable Economies and Societies for All" adopted in 2015 provide detailed guidance in achieving the "just transition". See https://www.ilo.org/publications/guidelines-just-transition-towards-environmentally-sustainable-economies

6. Conclusions

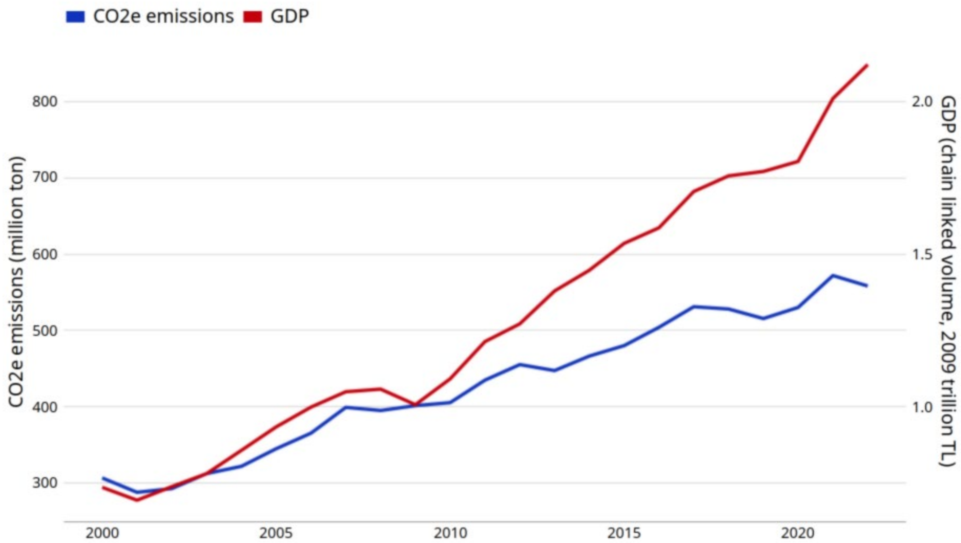
Türkiye ratified the Paris Agreement in 2021 and updated its first Nationally Determined Contribution (NDC), stating that it will reduce its GHG emissions by 41% by 2030 (695 Mt CO2 equivalent in 2030) compared to the business as usual (BAU) scenario in Türkiye's first NDC, taking 2012 as the base year, and will achieve net zero emissions by 2053. In addition, the EU CBAM forces Türkiye and other countries exporting to the EU to reduce carbon emissions.

CO2 intensity at the country level and in the manufacturing sector has been on a downward trend since the early 2000s, but our analysis suggests that this is mainly due to a reallocation of value-added to cleaner firms (intra-industry allocation) and sectors (inter-industry allocation) rather than to efficiency improvements at the firm level. Türkiye has adopted a number of policies to reduce CO2 emissions and improve energy efficiency in recent decades, but its two main priorities, the development of domestic coal resources for electricity generation and the simulation of demand for the construction sector, have had a negative impact on CO2 emissions. Investments in renewable energy sources (wind and solar) over the past decade have helped reduce CO2 emissions from power generation to some extent, but it has not been enough to reduce the volume of emissions.

In the midst of a worsening climate crisis, Türkiye needs to radically change its economic policies. Our analysis shows that Türkiye needs to decarbonize power generation by phasing out coal in power generation and changing the structure of industry towards clean energy technologies and green products. Such a structural change requires substantial investment in R&D to provide the technological base for new activities and sectors. These policies should be supported by increasing the cost of CO2 emissions. Through such a structural change, Türkiye can achieve sustainable growth, create good jobs in industry and services, and provide a healthy and liveable environment for its citizens.

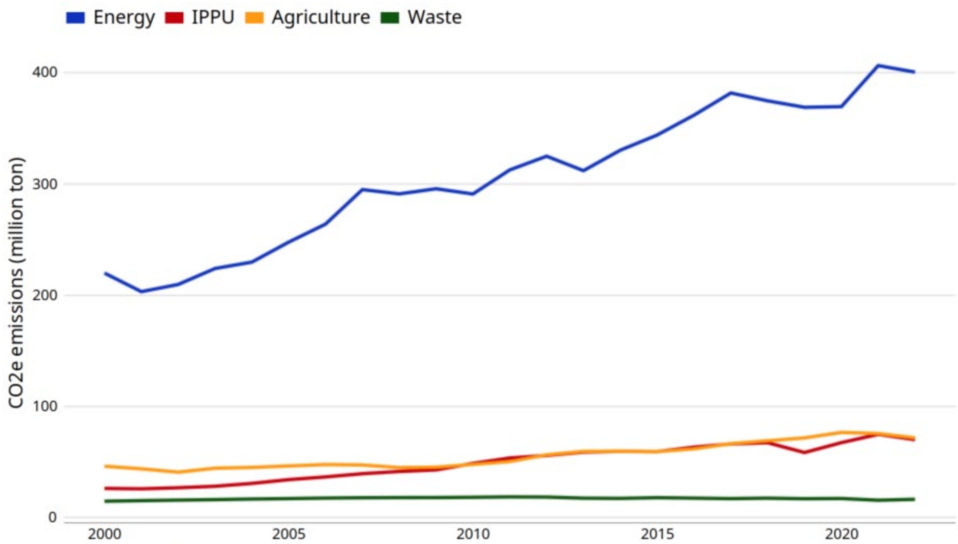
Figures

Figure 1. GDP and greenhouse gas emissions, 2000-2022



Source: TurkStat, Environment Statistics and National Accounts

Figure 2. Greenhouse gas emissions by source, 2000-2022



Source: TurkStat, Environment Statistics

Figure 3. Supply of primary energy sources, 2006-2022

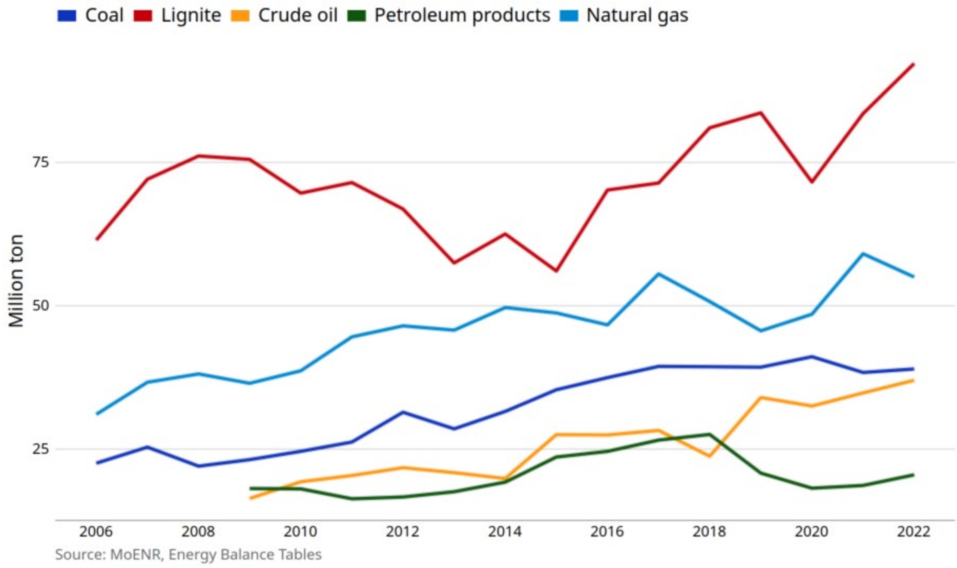


Figure 4. CO2 content of primary energy sources, 2006-2022

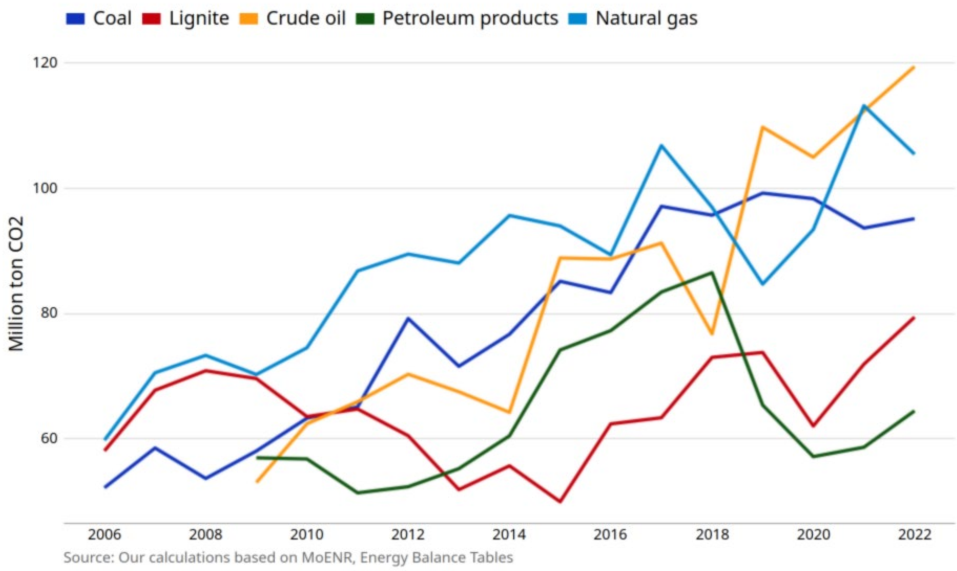


Figure 5. Composition of electricity generation by energy source, 2006-2022

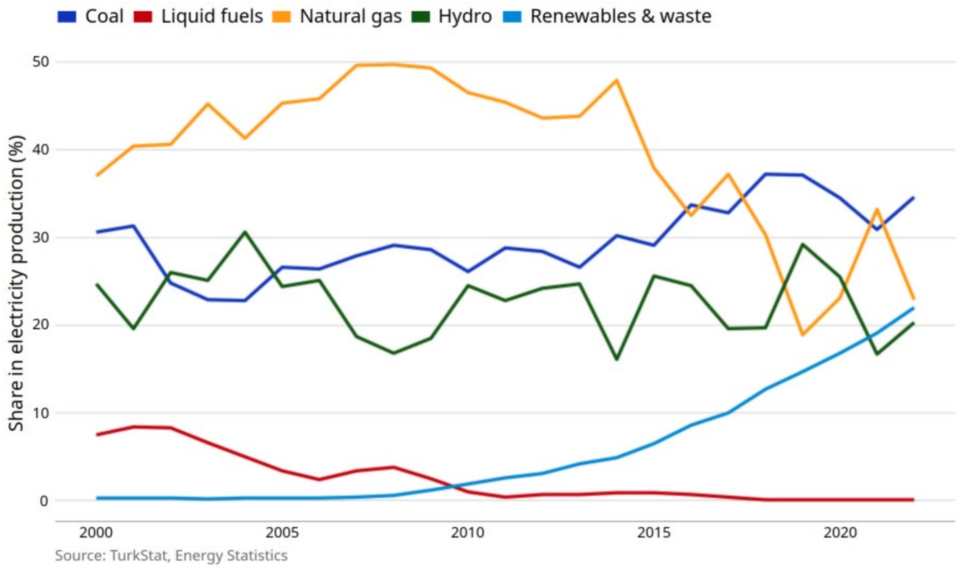


Figure 6. Selected variables on the share of manufacturing, 2007-2021

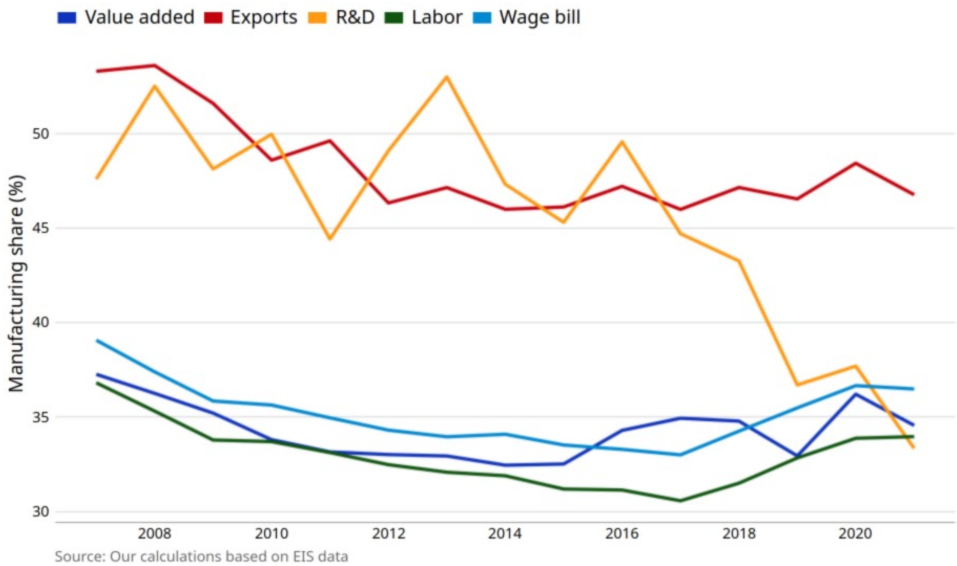
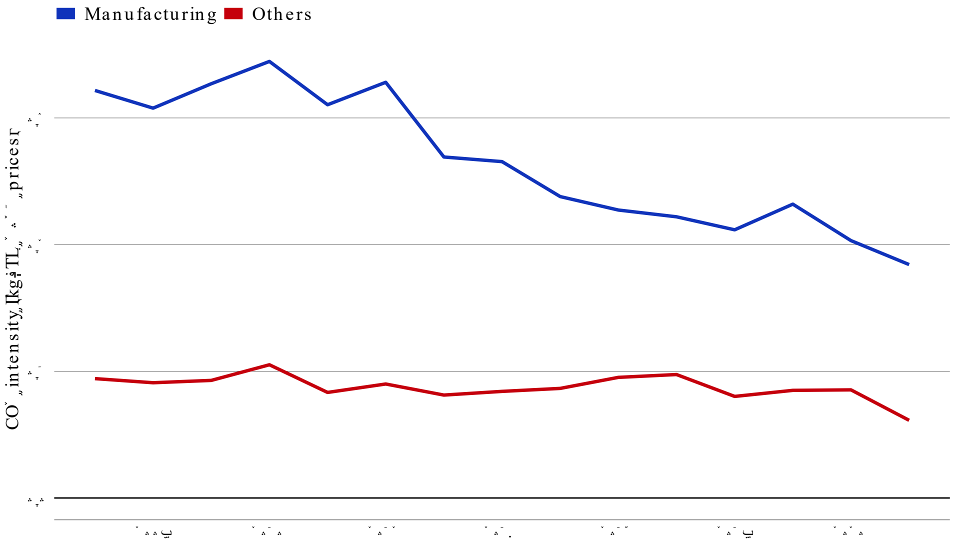
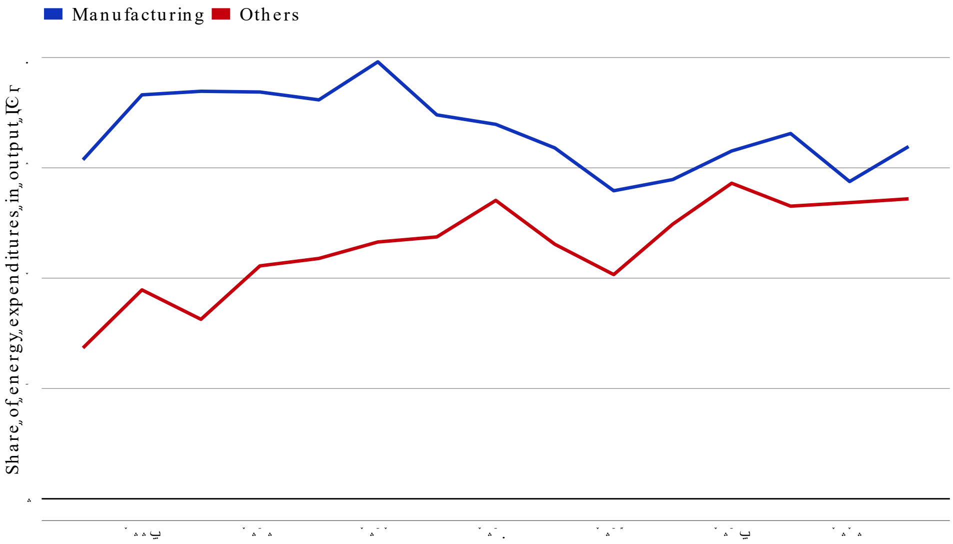


Figure 7. CO2 intensity of manufacturing and other sectors, 2007-2021



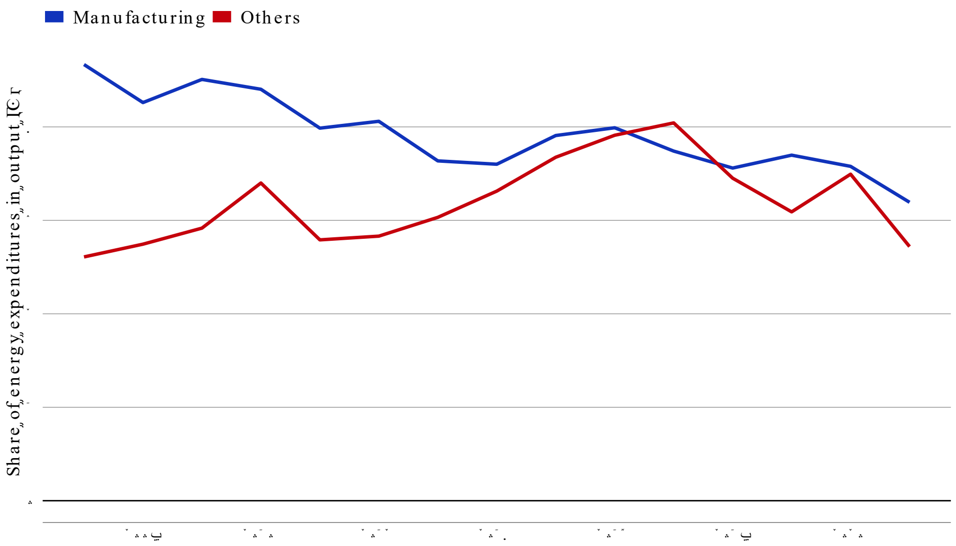
Source: Our calculations based on EIS data

Figure 8. Share of energy expenditures in output, manufacturing and other sectors, 2007-2021



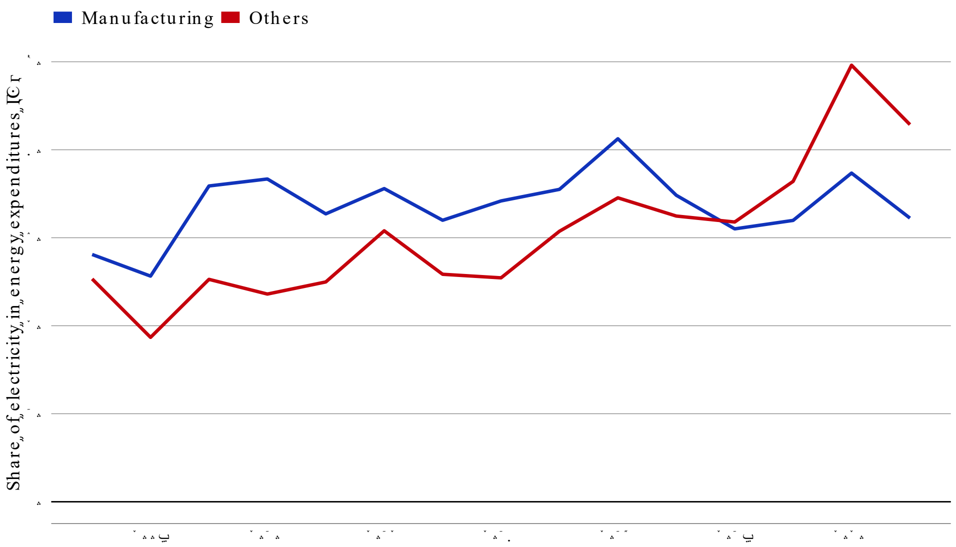
Source: Our calculations based on EIS data

Figure 9. Ratio of real energy expenditures to real output, manufacturing and other sectors, 2007-2021



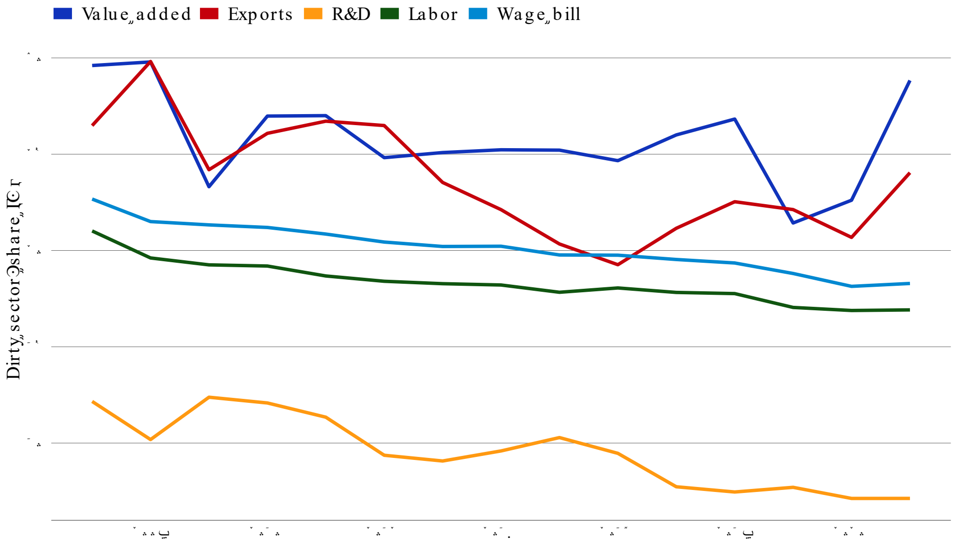
Source: Our calculations based on EIS data

Figure 10. Share of electricity in energy expenditures, manufacturing and other sectors, 2007-2021



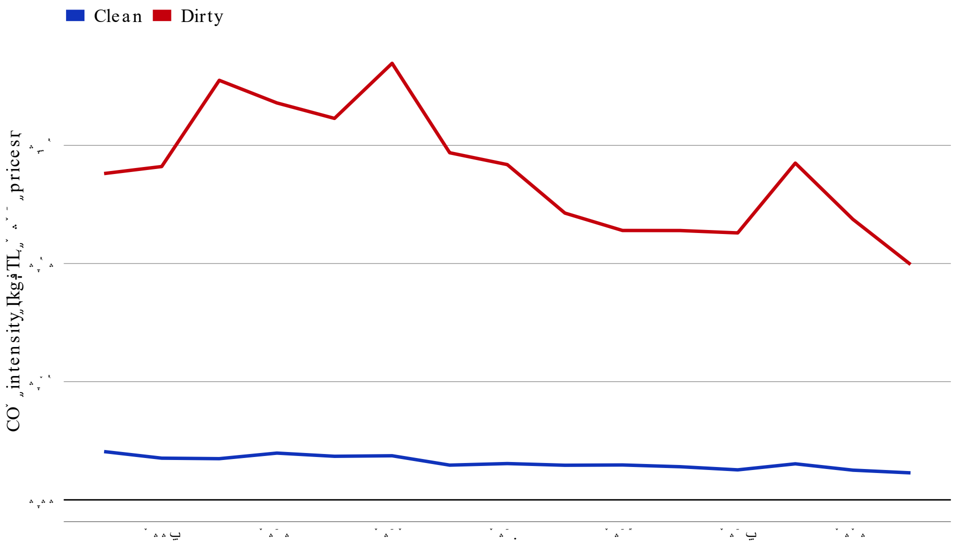
Source: Our calculations based on EIS data

Figure 11. Selected variables on the share of dirty sectors in manufacturing, 2007-2021



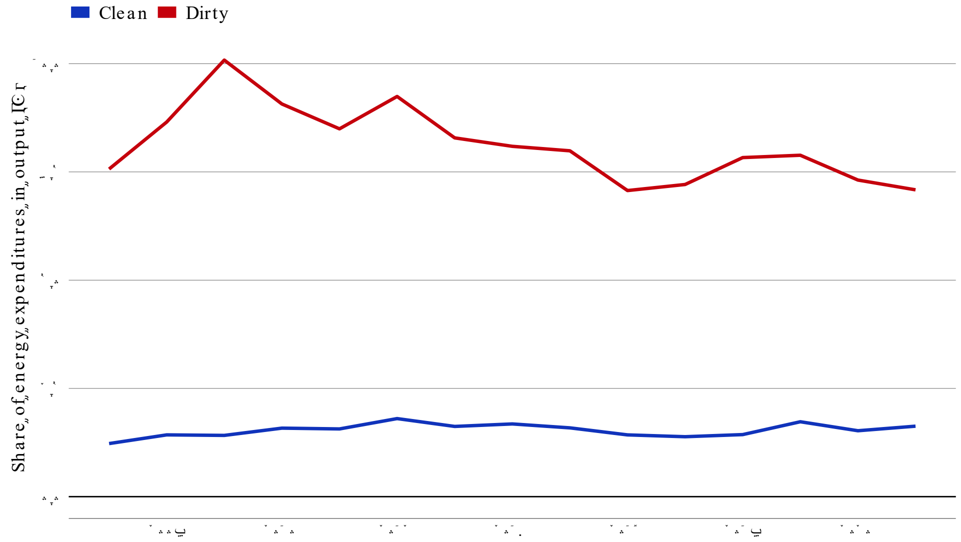
Source: Our calculations based on EIS data

Figure 12. CO2 intensity of dirty and clean manufacturing sectors, 2007-2021



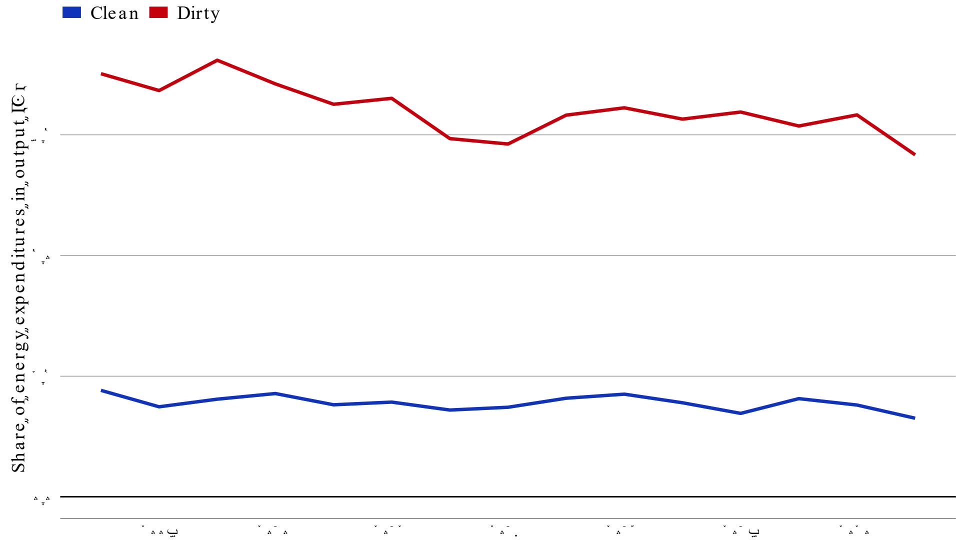
Source: Our calculations based on EIS data

Figure 13. Share of energy expenditures in output, manufacturing and other sectors, 2007-2021



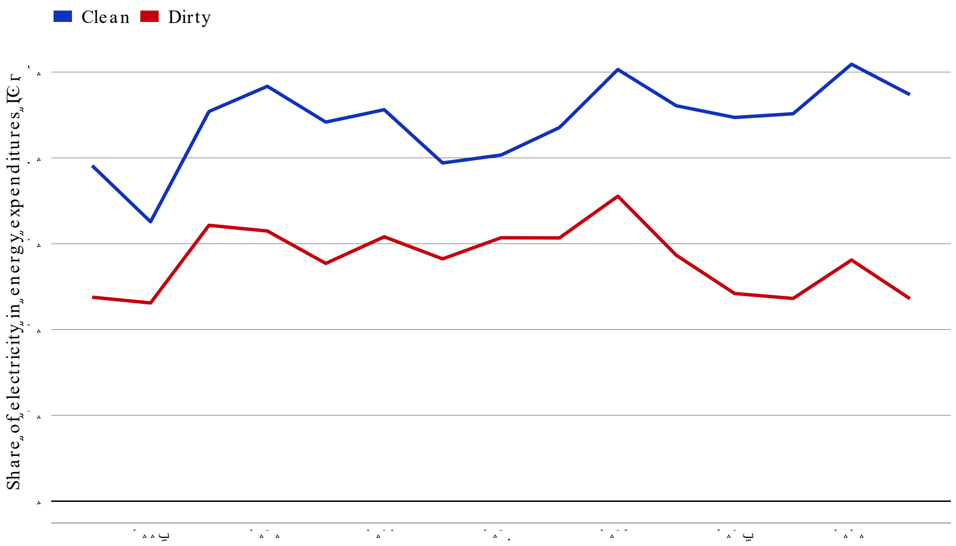
Source: Our calculations based on EIS data

Figure 14. Ratio of real energy expenditures to real output, manufacturing and other sectors, 2007-2021



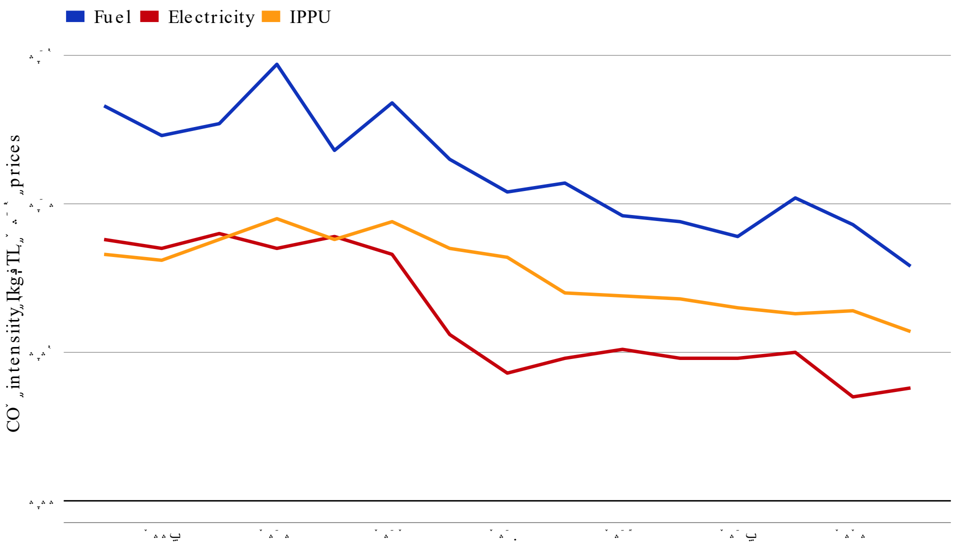
Source: Our calculations based on EIS data

Figure 15. Share of electricity in energy expenditures, manufacturing and other sectors, 2007-2021



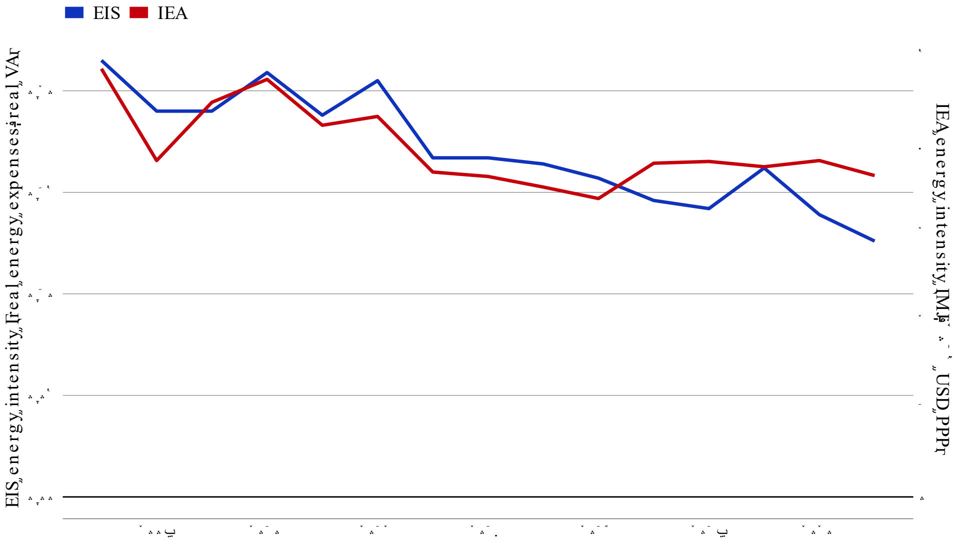
Source: Our calculations based on EIS data

Figure 16. CO2 intensity in Turkish manufacturing by type, 2007-2021



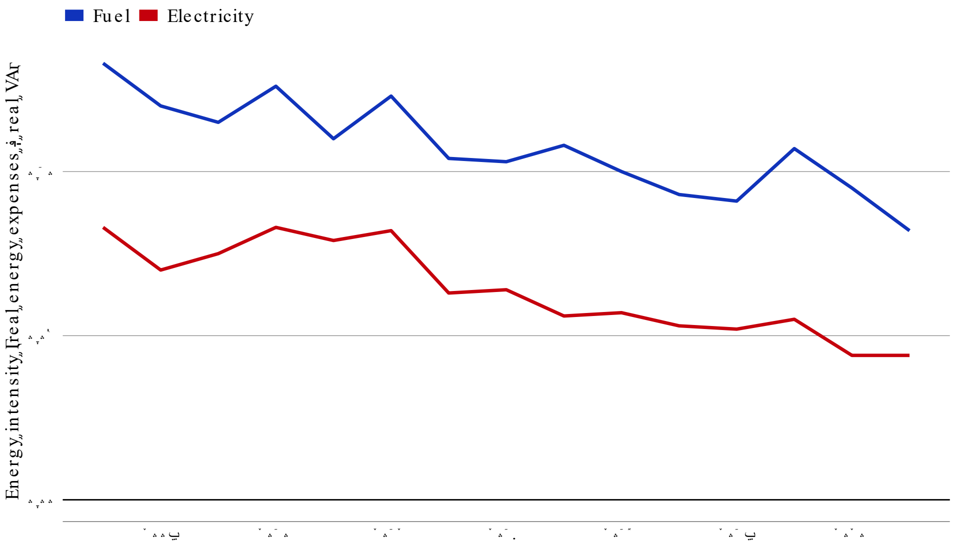
Source: Our calculations based on EIS data

Figure 17. Energy intensity in Turkish manufacturing, 2007-2021



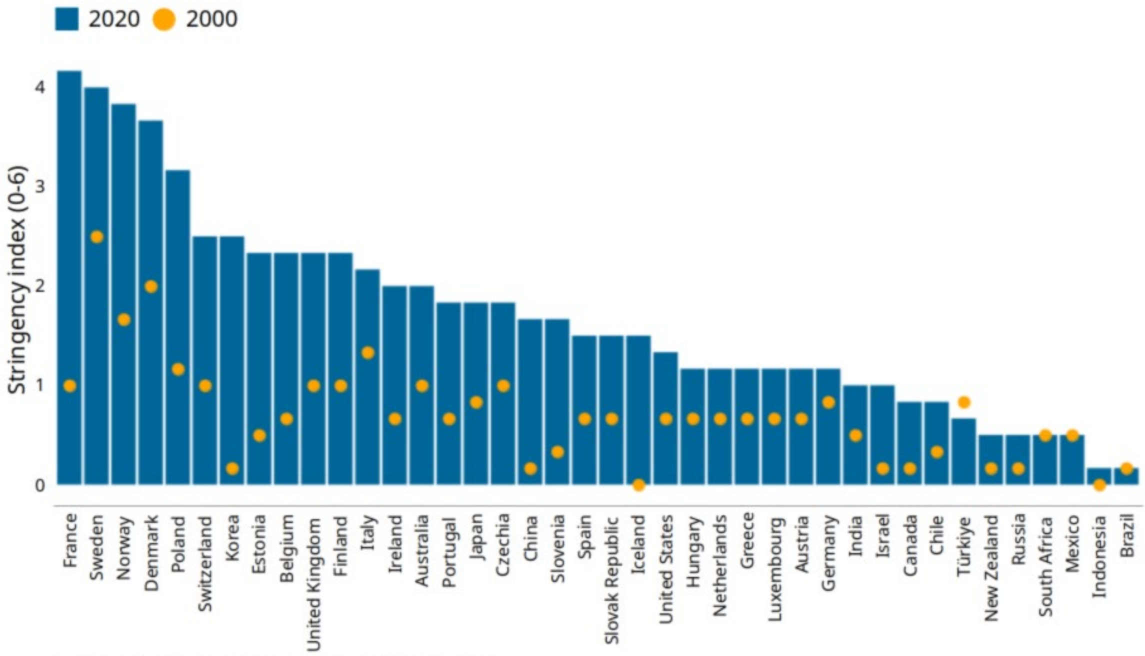
Source: EIA and our calculations based on EIS data

Figure 18. Energy intensity in Turkish manufacturing by type, 2007-2021



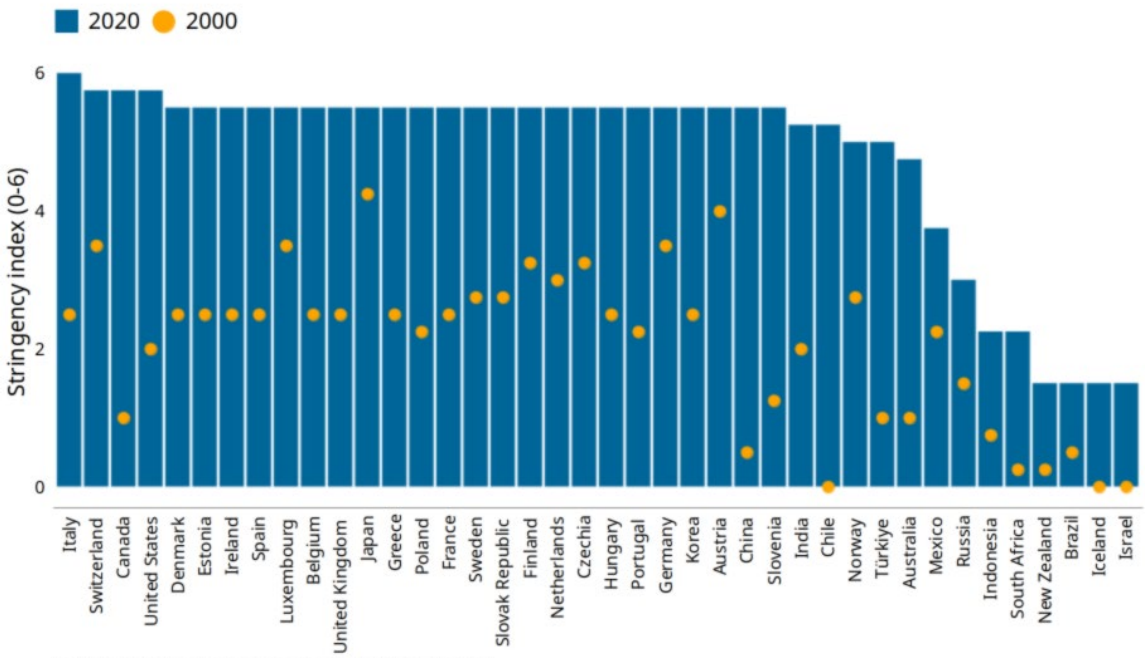
Source: Our calculations based on EIS data

Figure 19. Environmental policy stringency index, market based policies, 2020



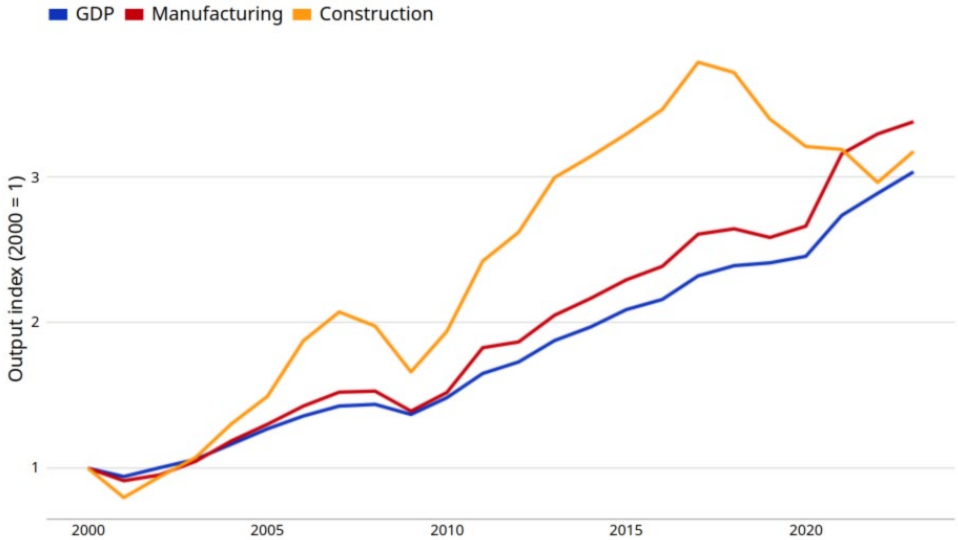
Source: OECD, Environmental Policy Stringency Index

Figure 20. Environmental policy stringency index, non-market based policies, 2020



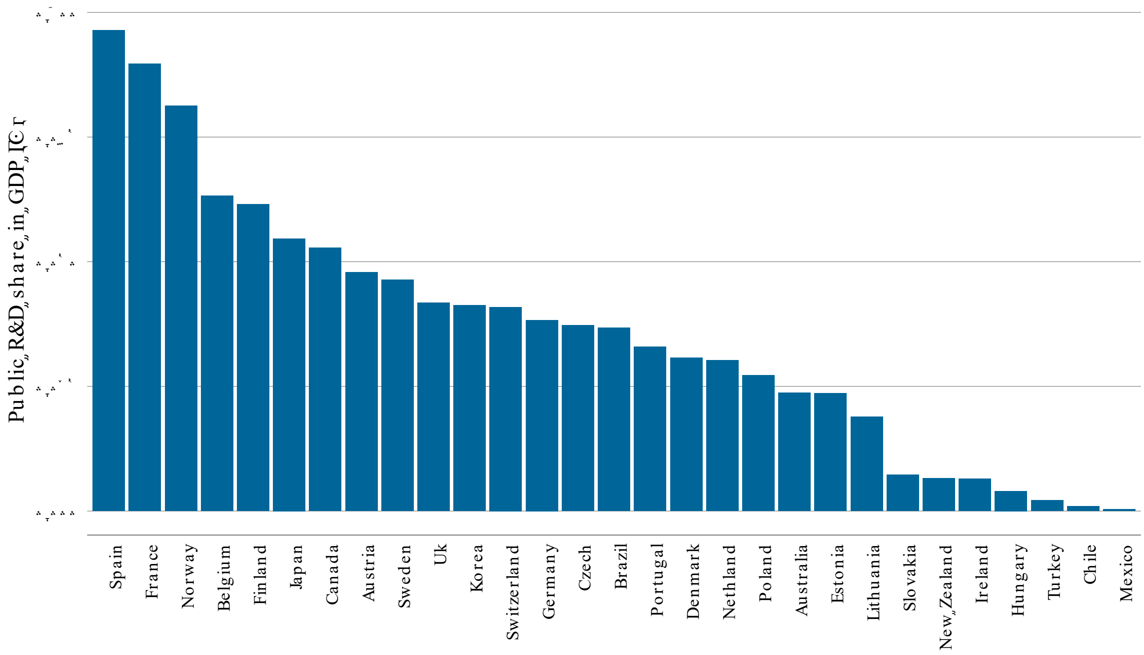
Source: OECD, Environmental Policy Stringency Index

Figure 21. Volume indices of GDP, manufacturing and construction, 2000-2023



Source: TurkStat, National Accounts

Figure 22. Share of public energy technology R&D expenditures in GDP, 2022



Source: IEA Energy Technology RD&D Budgets

Tables

Table 1. CO2 emissions by source, 2000-2022

CO2 sources	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022
Total (million tons)	232.4	267.0	317.6	386.3	404.6	429.4	422.1	404.3	414.4	455.2	441.4
Shares in total (%)											
Energy	89.0	88.0	86.0	86.0	85.5	85.7	85.3	87.0	85.3	85.2	86.6
Fuel combustion	89.0	88.0	85.9	86.0	85.5	85.6	85.3	87.0	85.3	85.2	86.6
Energy industries	34.4	34.6	36.0	35.2	35.4	36.0	37.4	36.8	34.0	34.7	35.1
Manufacturing and construction	24.8	23.5	16.4	15.4	14.8	14.0	14.0	13.8	14.8	15.0	14.7
Transport	15.3	15.4	14.0	19.2	19.8	19.3	19.6	20.0	19.1	19.6	20.4
Other sectors	14.5	14.5	19.5	16.2	15.4	16.4	14.2	16.4	17.4	15.9	16.4
Fugitive emissions from fuels	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carbon dioxide transport and storage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Industrial processes and product use	10.7	11.7	13.8	13.8	14.2	14.0	14.4	12.6	14.3	14.5	13.1
Mineral products	7.9	8.7	10.7	10.4	10.8	10.8	10.9	9.5	11.4	11.2	10.4
Chemical industry	0.1	0.2	0.1	0.3	0.2	0.2	0.4	0.3	0.3	0.5	0.3
Metal production	2.5	2.6	2.9	2.9	3.1	3.0	3.0	2.8	2.6	2.8	2.4
Agriculture (urea application)	0.3	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.3	0.3

Source: TurkStat, Environment Statistics

Table 2. Greenhouse gas emission and energy use by economic activity, 2021

	Greenhouse gas emissions (MT CO2e)	Carbon dioxide (MT CO2)	CO2 share In CO2e (%)	Share in Total CO2 (%)
A Agriculture, forestry and fishing	83.4	11.5	13.8	2.5
B Mining and quarrying	7.7	1.3	17.0	0.3
C Manufacturing	152.0	148.8	97.9	32.9
D Electricity, gas, steam and air conditioning	142.6	139.4	97.8	30.8
E Water supply, sewerage, waste	14.4	0.3	1.9	0.1
F Construction	4.2	4.0	96.0	0.9
G Wholesale and retail trade	11.3	11.2	98.7	2.5
H Transportation and storage	22.9	21.1	92.1	4.7
I Accommodation and food services	2.5	2.5	98.8	0.6
J-T Other services	7.4	7.3	98.8	1.6
Households	108.5	105.3	97.1	23.3
Total Emission	557.0	452.7	81.3	100.0

Note: The "Households" category includes emissions due to households' own activities like transportation and heating.
Source: TurkStat, Environment Statistics

Table 3. Dirty sectors in manufacturing

NACE code	Sector	CO2 emissions in 2021 (million tons) Fuel	Electricity	IPPU	Total
1081	Manufacture of sugar	2.1	0.1	0.0	2.2
1310	Preparation and spinning of textile fibres	0.6	1.7	0.0	2.4
1320	Weaving of textiles	1.0	1.1	0.0	2.1
1330	Finishing of textiles	1.4	0.6	0.0	2.0
1712	Manufacture of paper and paperboard	1.3	0.7	0.0	2.0
1920	Petroleum refineries	10.3	0.1	0.0	10.4
2016	Manufacture of plastics in primary forms	2.4	0.2	0.0	2.6
2331	Manufacture of ceramic tiles and flags	2.4	0.4	1.4	4.3
2332	Manufacture of bricks, tiles and construction products	0.7	0.2	0.3	1.2
2351	Manufacture of cement	13.5	3.9	44.2	61.7
2352	Manufacture of lime and plaster	0.7	0.2	2.8	3.6
2363	Manufacture of ready	1.7	0.4	0.0	2.0
2410	Manufacture of basic iron and steel and of ferro-alloys	30.2	6.4	11.9	48.4

Table 4. Decomposition of changes in CO2 and energy intensity, 2007-2021

	CO2 intensity				Energy intensity		
	Total	Fuel	Electricity	IPPU	Total	Fuel	Electricity
Change (kg/TL or TL/TL)	-0.133	-0.058	-0.049	-0.025	-0.095	-0.057	-0.038
Contributions (%)							
Within	-24.0	-41.8	37.1	-101.8	-32.5	-118.4	20.7
Between	111.0	132.4	54.3	171.6	152.6	208.6	69.1
Inter-industry	83.1	81.0	27.2	196.8	65.4	87.5	32.3
Intra-industry	27.8	51.4	27.2	-25.2	87.2	121.1	36.8
Entry-exit	13.1	9.4	8.5	30.3	10.0	9.8	10.2

CO2 intensity: CO2 emissions/value added (2021 prices, kg/TL)

Energy intensity: Expenditures on energy/value added (2021 prices, TL/TL)

Appendix

Figure A1. CO2 emissions from fuel combustion

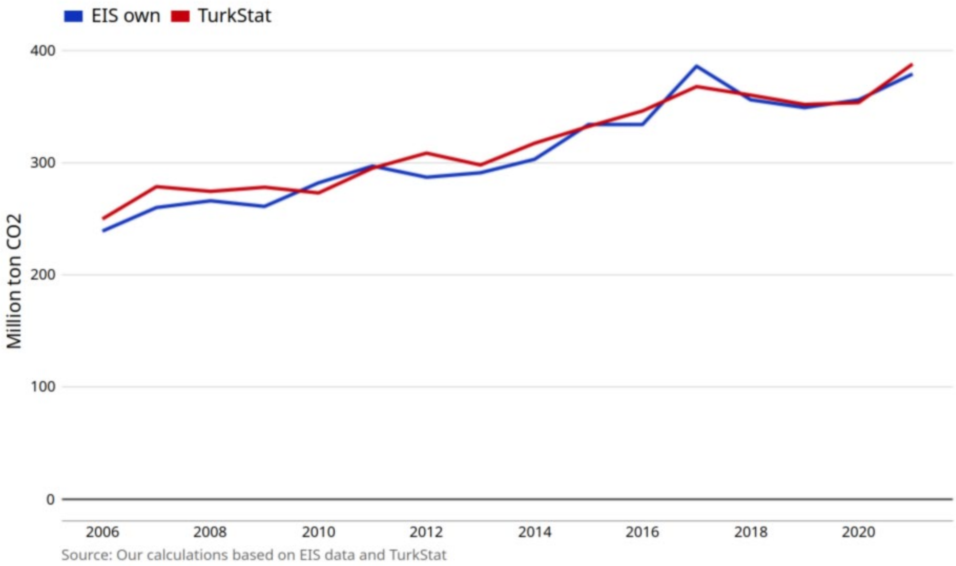


Table A1. Policies for Climate Change and Decarbonization

Main policy documents
- 9th Development Plan (2007-2013)
https://www.sbb.gov.tr/wp-content/uploads/2018/11/Ninth_Development_Plan_2007-2013.pdf
- 10th Development Plan (2014 – 2018)
https://www.sbb.gov.tr/wp-content/uploads/2022/07/Eleventh_Development_Plan_2019-2023.pdf
- 11th Development Plan (2019– 2023)
https://www.sbb.gov.tr/wp-content/uploads/2022/07/Eleventh_Development_Plan_2019-2023.pdf
- 12th Development Plan (2024– 2028)
https://www.sbb.gov.tr/wp-content/uploads/2024/06/Twelfth-Development-Plan_2024-2028.pdf
- Medium Term Programs (since 2006)
https://www.sbb.gov.tr/orta-vadeli-programlar/

Türkiye's 2053 Long-Term Climate Strategy
https://unfccc.int/sites/default/files/resource/Turkiye_Long_Term_Climate_Strategy.pdf

Laws, strategies and action plans
- Energy Efficiency Law No 5627 (2007)
https://www.resmigazete.gov.tr/eskiler/2007/05/20070502-2.htm
- Electricity Energy Market and Security of Supply Strategy Document, 2009
https://ww4.ticaret.edu.tr/enerji/wp-content/uploads/sites/79/2015/11/Elektrik-Enerjisi-Piyasas%C4%B1-Ve-Arz-G%C3%BCvenli%C4%9Fi-Strateji-Belgesi.pdf
- National Climate Change Strategy (2010 – 2023)
https://webdosya.csb.gov.tr/db/iklim/editordosya/iklim_degisikligi_stratejisi_EN(2).pdf
- Türkiye's National Climate Change Adaptation Strategy and Action Plan (2011 – 2023)
https://webdosya.csb.gov.tr/db/iklim/editordosya/uyum_stratejisi_eylem_plani_EN.pdf
- Climate Change Action Plan (2011-2023)
https://webdosya.csb.gov.tr/db/iklim/editordosya/file/eylem%20planlari/iklim_degisikligi_eylem_plani_EN_2014.pdf
- The Energy Efficiency Strategy Document (2012-2023)
https://evcedruzgar.enerji.gov.tr/verimlilik/document/Energy_Efficiency_Strategy_Paper.pdf
- National Energy Efficiency Action Plan, 2017-2023 (NEEAP I)
https://enerji.gov.tr//Media/Dizin/EVCED/tr/EnerjiVerimlili%C4%9Fi/UlusalEnerjiVerimlili%C4%9FiEylemPlan%C4%B1/Belgeler/NEEAP.pdf
- Energy Efficiency 2030 Strategy and 2nd National Energy Efficiency Action Plan (2024-2030) (NEEAP II, 2024)
https://enerji.gov.tr//Media/Dizin/EVCED/tr/EnerjiVerimlili%C4%9Fi/UlusalEnerjiVerimlili%C4%9FiEylemPlan%C4%B1/Belgeler/EnerEffi2030Str2ndNatEnerEffiActPlan2024-2030.pdf
- 2023 Türkiye's Industry and Technology Strategy (2019)
https://www.sanayi.gov.tr/assets/pdf/SanayiStratejiBelgesi2023.pdf
- The Green Deal Action Plan (2021)
https://ticaret.gov.tr/data/60f1200013b876eb28421b23/MUTABAKAT%20YE%C5%9E%C4%B0L.pdf
- National Energy Plan (2022)
https://enerji.gov.tr/Media/Dizin/EIGM/tr/Raporlar/TUEP/T%C3%BCrkiye_National_Energy_Plan.pdf
- 2023 Türkiye Hidrojen Teknolojileri Stratejisi ve Yol Haritası (2019)
https://enerji.gov.tr/Media/Dizin/SGB/tr/Kurumsal_Politikalar/HSP/ETKB_Hidrojen_Stratejik_Plan2023.pdf

Note: For a comprehensive list of policies and measures, see Republic of Türkiye (2023).

Table A2. Actions in industry performed under the 1st NEEAP

With national and international collaborations, studies have been carried out on topics such as process efficiency, energy management, industrial symbiosis, life cycle assessment, and creation of green OIZs. The Energy Saving Potential Map in Industry has been prepared and it has been designated that there is an energy efficiency investment potential with an average payback period of 2 years and a monetary value of more than 5 billion TL.

Türkiye Waste Heat Potential Assessment Project was carried out with the support of the World Bank. According to the project results, it has been designated that there is a waste heat potential of 1,600 kTOE (1,000 TOE) in the industry sector, which requires an investment of approximately 1.37 billion USD, and a cogeneration potential of 2,515 Mwe, which requires an investment of 2 billion USD. It is estimated that by making the necessary investment, a total annual savings of 1.6 billion USD can be achieved in the industry.

Within the scope of VAP support, a total of 450 applications were made in the 2009-2016 period. The number of applications increased by 96% in the 2017-2022 period, reaching 884. The investment amount of the completed and ongoing projects exceeded 1.1 billion TL (approximately 147 million USD, taking into account the relevant year's exchange rates).

Physical space, machinery-equipment infrastructure and technical capacity have been established for Ankara, Bursa, Konya, Kayseri, Gaziantep, Mersin and Izmir Model Factories. Within the scope of learn-transform activities, training was provided to more than 500 businesses.

Cogeneration efficiency certificates were given to 88 industrial facilities within the scope of unlicensed production in the electricity market. Businesses save 25% to 30% from the primary source they use. Energy Management Units were established in 85 OIZs in accordance with the ISO 50001 standard and training on energy management was provided to more than 200 OIZ personnel.

The SME Energy Efficiency Support Program was created, and energy audit expense support of up to 22,500 TL and efficiency-enhancing activity support planned as a result of the survey up to 360,000 TL were provided for the green transition of SMEs.

Projects on Development of National Life Cycle Assessment Database and Promotion of Energy Efficient Engines in SMEs in Türkiye were carried out. The Industrial Internet of Things Project, which Accelerates the Digital Transformation of SMEs, was launched and digitalization road maps for businesses were prepared through studies carried out with 135 SMEs.
Source: MoENR 2024, 32–33.

References

Akbostancı, Elif, Gül İpek Tunç, and Serap Türüt-Aşık. 2011. "CO2 Emissions of Turkish Manufacturing Industry: A Decomposition Analysis." *Applied Energy* 88 (6): 2273–78.

Akbostancı, Elif, Gül İpek Tunç, and Serap Türüt-Aşık. 2018. "Drivers of Fuel Based Carbon Dioxide Emissions: The Case of Türkiye." *Renewable and Sustainable Energy Reviews* 81 (January): 2599–2608.

Akçomak, İbrahim Semih, Beyza Coşkun, Dilara Danacı, Haşim Cihan Demirköprülü, Sinem Erdoğdu, Esra Güler, Ilgın İrem Gündüz, et al. 2024. *Greening Türkiye's Economy: The Policy Perspective*. Ankara: TTGV.

Akyürek, Zuhal. 2020. "LMDI Decomposition Analysis of Energy Consumption of Turkish Manufacturing Industry: 2005–2014." *Energy Efficiency* 13 (4): 649–63.

Boratav, Korkut, and Özgür Orhangazi. 2022. "Neoliberal Framework and External Dependency Versus Political Priorities, 2009–2020." In *Political Economy of Development in Türkiye*, edited by Emre Özçelik and Yonca Özdemir. Singapore: Palgrave Macmillan, 287–314.

Brandi, Clara, Jakob Schwab, Axel Berger, and Jean-Frédéric Morin. 2020. "Do Environmental Provisions in Trade Agreements Make Exports from Developing Countries Greener?" *World Development* 129 (May): 104899.

Dissanayake, Sumali, Renuka Mahadevan, and John Asafu-Adjaye. 2020. "Evaluating the Efficiency of Carbon Emissions Policies in a Large Emitting Developing Country." *Energy Policy* 136 (January): 111080.

İpek Tunç, G., Serap Türüt-Aşık, and Elif Akbostancı. 2009. "A Decomposition Analysis of CO2 Emissions from Energy Use: Turkish Case." *Energy Policy* 37 (11): 4689–99.

Karakaya, Etem, Aziz Bostan, and Mustafa Özçağ. 2019. "Decomposition and Decoupling Analysis of Energy-Related Carbon Emissions in Türkiye." *Environmental Science and Pollution Research* 26 (31): 32080–91.

Kruse, Tobias, Antoine Dechezleprêtre, Rudy Saffar, and Leo Robert. 2022. *Measuring Environmental Policy Stringency in OECD Countries: An Update of the OECD Composite EPS Indicator*. OECD Economics Department Working Papers 1703. OECD. Vol. 1703.

Kumbaroğlu, Gürkan. 2011. “A Sectoral Decomposition Analysis of Turkish CO2 Emissions over 1990–2007.” *Energy* 36 (5): 2419–33.

Le, Hai, and Dina Azhgaliyeva. 2023. “Carbon Pricing and Firms’ GHG Emissions: Firm-Level Empirical Evidence from East Asia.” *Journal of Cleaner Production* 429 (December): 139504.

Linkevičius, Edgaras, Povilas Žemaitis, and Marius Aleinikovas. 2023. “Sustainability Impacts of Wood- and Concrete-Based Frame Buildings.” *Sustainability* 15: 1560.

Lise, Wietze. 2006. “Decomposition of CO2 Emissions over 1980–2003 in Türkiye.” *Energy Policy* 34 (14): 1841–52.

Martinsson, Gustav, László Sajtos, Per Strömberg, and Christian Thomann. 2024. “The Effect of Carbon Pricing on Firm Emissions: Evidence from the Swedish CO2 Tax.” *Review of Financial Studies* 37 (6): 1848–86.

Ministry of Development. 2014. *The Tenth Development Plan, 2014-2018*. Ankara: Ministry of Development.

MoENR. 2018. *National Energy Efficiency Action Plan (NEEAP), 2017-2023*. Ankara: Ministry of Energy and Natural Resources.

MoENR. 2024. *Energy Efficiency 2030 Strategy and 2nd National Energy Efficiency Action Plan, 2024-2030*. Ankara: Ministry of Energy and Natural Resources.

MoEUCC. 2024. *Türkiye’s 2053 Long-Term Climate Strategy*. Ankara: Ministry of Environment, Urbanization and Climate Change.

MoT. 2021. *Yeşil Mutabakat Eylem Planı, 2021*. Ankara: Ministry of Trade.

Neves, Sónia Almeida, António Cardoso Marques, and Margarida Patrício. 2020. “Determinants of CO2 Emissions in European Union Countries: Does Environmental Regulation Reduce Environmental Pollution?” *Economic Analysis and Policy* 68 (December): 114–25.

Ozdemir, Ali Can. 2023. “Decomposition and Decoupling Analysis of Carbon Dioxide Emissions in Electricity Generation by Primary Fossil Fuels in Türkiye.” *Energy* 273 (June): 127264.

Presidency of Strategy and Budget. 2019. *Eleventh Development Plan, 2019-2023*. Ankara: Presidency of Strategy and Budget.

Presidency of Strategy and Budget. 2023. *Twelfth Development Plan, 2024-2028*. Ankara: Presidency of Strategy and Budget.

Reidt, Noe. 2021. “Climate Policies and Labor Markets in Developing Countries.” Application/pdf. ETH Zurich.

Republic of Türkiye (2023), *Republic of Türkiye Updated First Nationally Determined Contribution*. https://unfccc.int/sites/default/files/NDC/2023-04/T%C3%9CRK%C4%B0YE_UPDATED%201st%20NDC_EN.pdf

Şahin, Ümit, Osman Bülent Tör, Bora Kat, Saeed Teimourzadeh, Kemal Demirkol, Arif Künar, Ebru Voyvoda, and Erinç Yeldan. 2022. *Türkiye’nin Karbonsuzlaşma Yol Haritası: 2050’de Net Sıfır*. İstanbul: İstanbul Politikalar Merkezi (IPM).

Shapiro, Joseph S., and Reed Walker. 2018. “Why Is Pollution from US Manufacturing Declining? The Roles of Environmental Regulation, Productivity, and Trade.” *American Economic Review* 108 (12): 3814–54.

SHURA. 2024. *Türkiye Enerji Dönüşümü Görünümü 2023*. İstanbul: Sabancı University.

SPO. 2006. *Ninth Development Plan, 2007-2013*. Ankara: State Planning Organization.

Tamzok, Nejat. 2023. Türkiye’nin Kömür Üretiminde Şüphe [online]. *Enerji Günlüğü*. https://www.enerjigunlugu.net/turkiyenin-komur-uretiminde-suphe-32189yy.htm.

Taymaz, Erol, and Ebru Voyvoda. 2022. “From Domestic to Global Crisis: Türkiye During the 2001–2009 Period.” In *Political Economy of Development in Türkiye*, edited by Emre Özçelik and Yonca Özdemir. The Political Economy of the Middle East. Singapore: Palgrave Macmillan, 257–86.

Teusch, Jonas, Maria Filippo D'Arcangelo, Tobias Kruse, and Mauro Pisu. 2024. *Carbon Prices, Emissions and International Trade in Sectors at Risk of Carbon Leakage: Evidence from 140 Countries*. OECD Economics Department Working Papers 1813.

Wardana, Arief Budi, Mila Indriastuti, and Dhain Adhetiya Safitra. 2022. "Indonesian Carbon Tax: How Newborn Learn to Jump into The Next Step?" *Jurnal Akuntansi Dan Keuangan* 24 (1): 34–45.

World Bank Group. 2022. *Country Climate and Development Report: Türkiye*. CCDR Series. Washington, DC: World Bank.

Yilmaz, M., and M. Atak. 2010. "Decomposition Analysis of Sectoral Energy Consumption in Türkiye." *Energy Sources, Part B: Economics, Planning, and Policy* 5 (2): 224–31.