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"Don't" Take My Breath Away

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Economic Research

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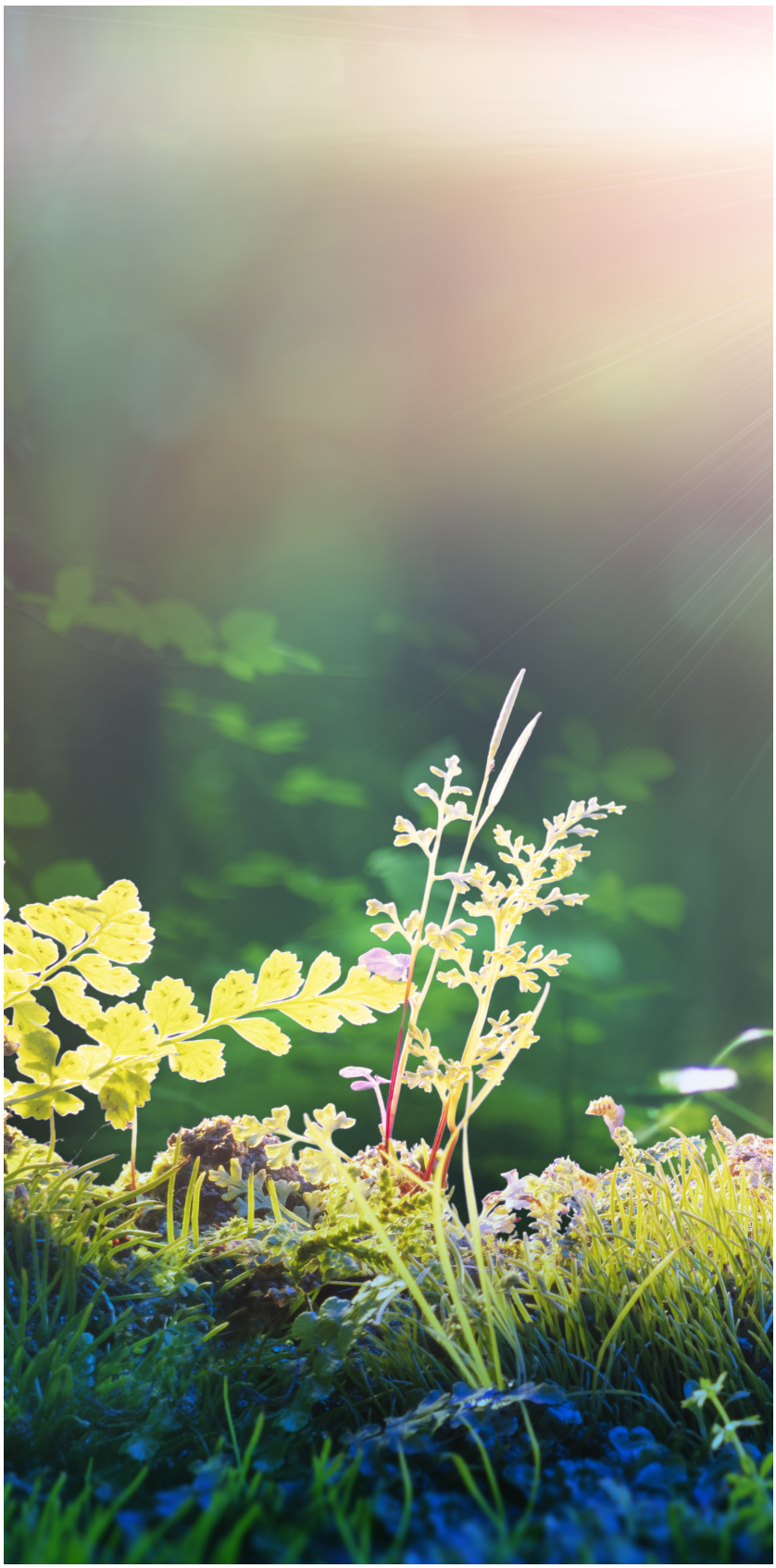
Abbreviations

CAFE: Clean Air for Europe
CAGR: Compound Annual Growth Rate
COP26: 26th Conference of the Parties to the United Nations Framework Convention on Climate Change
COP27: 27th Conference of the Parties to the United Nations Framework Convention on Climate Change
EC: European Commission
EEA: European Environment Agency
EPA: US Environmental Protection Agency
EU: European Union
GDP: Gross Domestic Product
IPCC: Intergovernmental Panel on Climate Change
m^3: Cubic meters
MoEUCC: Ministry of Environment, Urbanisation and Climate Change
NO: Nitrogen oxide
NO_2: Nitrogen dioxide
O_3: Ozone
OECD: Organization for Economic Cooperation and Development
PM: Particulate Matter
RAMAQ: Regulation on Assessment and Management of Air Quality
SDG: Sustainable Development Goals
SO_2: Sulfur dioxide
UN: United Nations
UNECE: United Nations Economic Commission for Europe
UNEP: United Nations Environment Program
UNFCCC: United Nations Framework Convention on Climate Change
USA: United States of America
WHO: World Health Organization
WWF: World Wildlife Fund
µm: Micrometre



In Praise of Action

Air pollution, which claims the lives of more than 7 million people worldwide each year, has been deemed the most important environmental health problem of our time[1]. When we consider that a total of 5.4 million people lost their lives during the COVID-19 pandemic in 2020 and 2021, the threat posed by air pollution is even more apparent.

Although the United Nations (UN) classifies access to clean air as a basic human right, nine out of ten people cannot breathe air that is "clean" according to the World Health Organization (WHO)[2]. It is also important to note that the impact of air pollution varies between country groups and different segments of society. While developing countries are struggling with higher levels of air pollution, the negative effects of air pollution are more tangible for women, children, the elderly and those in low-income groups.

[1] United Nations Environment Program (UNEP). https://www.unep.org/beatpollution/global-response-pollution
[2] https://www.breeze-technologies.de/blog/how-much-does-air-pollution-cost-society/

According to the United Nations Environment Program (UNEP), 300 million children worldwide are exposed to levels of air pollution six times higher than the acceptable limits[3]. As we have seen in the past, when air pollution reaches dangerous levels, it can also negatively affect children and young people by forcing an unplanned pause in their education. The partial and/or full-time school closures during the COVID-19 pandemic are now known to have had a negative impact on learning. According to the World Bank, 70% of 10-year-olds in low- and middle-income countries lack the ability to read basic text[4]. Also referred to as "learning poverty", this situation points to the need to compensate for this loss and the importance of keeping schools open in the coming period. Considering that air pollution is one of the factors which may lead to school closures, it becomes clear that the fight for clean air must start as soon as possible.

Published in 2021, the Intergovernmental Panel on Climate Change (IPCC) report is striking since it indicates a scientific basis for the climate crisis we are facing being the result of human activities. In a similar framework, when evaluating the atmospheric impact of human activities, air pollution stands as an important issue like the climate crisis (Adam D. K. Abelkop, 2017). The fact that many of the factors which cause air pollution also trigger global warming[5] means it is imperative to address the climate crisis and air pollution together.

From the perspective of the climate crisis, it is not possible to offset all of the damage that has been done and which is expected to continue, but it is possible to achieve tangible results, for example in terms of improving air pollution. Moreover, when compared to the policies to be implemented to keep global warming within the 2-degree target set in line with the Paris Agreement, the savings from combating air pollution on health expenditures alone are expected to be between 1.4-2.5 times the cost of the mitigation policies. Of course, all parties have a role to play in such an important struggle, from the public sector and private sector and local governments to individuals. However, there is hope; with an inclusive strategy and a collaborative approach among stakeholders, we can achieve success in the fight against air pollution!

So our message, in praise of action, is clear:

- There are many reasons to tackle air pollution,
- And there is no reason to delay working on the solution!

Because life is one deep breath!

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[3] UNEP. https://www.unep.org/resources/global-environment-outlook-6
[4] UNEP. https://wesr.unep.org/airpollution
[5] World Bank. https://blogs.worldbank.org/voices/reversing-pandemics-education-losses
[6] United Nations Framework Convention on Climate Change (UNFCCC). https://unfccc.int/news/clean-air-is-a-human-right-un-special-rapporteur

1. What is Air Pollution?

"Air pollution", causing 7 million premature deaths every year, is recognized as the most important environmental health problem facing us today[6]. Air pollution is the phenomenon in which air pollutants in the atmosphere exceed certain thresholds as a result of natural and / or human-induced emissions and which have negative impacts on living and non-living beings under certain meteorological conditions[7]. In parallel with the increase in the world population, air pollution caused by factors such as increased energy use, industrial development and urbanisation exacerbates health problems and has negative impacts on living beings. The US Environmental Protection Agency (EPA) defines six different pollutants as "primary air pollutants", taking human health into account. The definitions of primary air pollutant particulate matters (PM_{10}, $PM_{2.5}$), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3) and carbon monoxide (CO) can be found in Annex-1 of our report.

Recognized by UNEP as negatively affecting the enjoyment of basic human rights, including the right to life and the right to health[8], the concept of air pollution has been on and off the agenda of countries for centuries. While air pollution worsened in industrialized countries with the increase in the use of solid fuels during the "Industrial Revolution", especially in the mid-19th century, the use of coal in factories in the UK, the USA and Germany increased air pollution to their highest levels. By the mid-20th century, the effects of air pollution were being felt in countries throughout the world[9]. Donora, Pennsylvania, a hub for steel and zinc production, was affected by severe industrial air pollution, dubbed the "Donora Smog", in 1948. At least 20 people died by poisoning by the smoke and thousands of people fell ill as a result of the smoke that lingered over the city for several days[10].

The **"Great Smog of London"** of 1952 marked a key turning point in the fight against air pollution. In November and December 1952, which was marked by a period of snow and very cold weather in the UK, households in London burned large amounts of coal in their homes to keep warm. Under normal conditions, the smoke should have risen into the atmosphere and dissipated, but a lingering area of high pressure above the area pushed the air downward[11]. As a result, the fumes rising from the chimneys lingered and spread over the city before they could dissipate into the atmosphere. In the same year, between December 5th and 9th, this smoke cloud, which remained over London, caused more than 4,000 deaths. The Great Smog of London thus set the stage for the "Clean Air Act" of 1956, which defined measures to reduce air pollution[12]. In the wake of such incidents, the UK, US and other countries took measures to improve air quality levels with legislation developed to combat air pollution.

[7] UNEP. https://www.unep.org/beatpollution/
[8] Ministry of Environment, Urbanisation and Climate Change (MoEUCC). https://webdosya.csb.gov.tr/db/nigde/webmenu/webmenu16107.pdf
[9] UNEP. https://www.unep.org/news-and-stories/video/human-rights-and-clean-air#:~:text=The%20right%20to%20breathe%20clean,in%20relation%20to%20vulnerable%20groups.
[10] History.com, "Water and Air Pollution". https://www.history.com/topics/natural-disasters-and-envirobbnment/water-and-air-pollution
[11] National Geographic, "Decades ago, this pollution disaster exposed the perils of dirty air". https://www.nationalgeographic.com/history/article/decades-ago-donora-smog-disaster-exposed-perils-dirty-air
[12] Met Office, "The Great Smog of 1952". https://www.metoffice.gov.uk/weather/learn-about/weather/case-studies/great-smog
[13] Smithsonian Magazine, "Air Pollution Goes Back Way Further Than You Think". https://www.smithsonianmag.com/science-nature/air-pollution-goes-back-way-further-you-think-180957716/

2. What are the Causes of Air Pollution?

Although there are many sources of air pollution, these sources are categorized under two main headings: natural and human-made.

Natural causes of air pollutants include volcanic activity, dust storms, wild fires and rising temperatures.

Volcanic eruptions are a major source of natural air pollution. A volcanic eruption produces SO_2 and ash that is released into the atmosphere and can be spread by winds to disperse over large areas[13]. In large areas with little or no vegetation which are arid due to a lack of rainfall, wind creates dust storms. This dust pollutes the air, as it poses a health hazard to living organisms. Wild fires, which are considered a natural cause, on the other hand, usually occur during dry periods and emit smoke and CO, causing air pollution and global warming.

There is no single cause of air pollution from human activities. Factors affecting air pollution include waste management, general energy supply, household energy use, agricultural and industrial practices, transportation activities and practices which trigger dust formation. Activities such as recycling, composting, incineration and landfill, which are considered within the scope of waste management, may affect the health and well-being of those who work directly or indirectly with waste[14]. Landfill sites produce methane gas, which is highly flammable and potentially dangerous if it spreads unchecked. The expansion of landfill sites, especially with urbanisation, leads to an increase in methane gas production. According to the WHO, pollutants emitted by transportation vehicles are also considered one of the main sources of air pollution, as they have a direct impact on respiratory and cardiovascular diseases as well as deaths[15].

[14] Universe Today. https://www.universetoday.com/81977/causes-of-air-pollution/
[15] World Health Organization (WHO). https://www.who.int/publications/i/item/WHO-HEP-ECH-AQH-2021.8
[16] WHO. https://www.euro.who.int/en/health-topics/environment-and-health/Transport-and-health/data-and-statistics/air-pollution-and-climate-change2

3. Impacts of Air Pollution

Air pollution is harmful to health and reduces labour force participation and productivity. Therefore, air pollution is an environmental problem which negatively affects the value of human capital and, therefore, the global economy, as well as the lives of the people who cause it (World Bank, 2018). Air pollution, both pollution which is naturally occurring and the pollution which is caused by human activities, represents a global threat with major impacts on our lives. The impacts of air pollution, which affect every aspect of our lives, can be summarised under several main headings; its impact on human health, its impact on the ecosystem, its impact on the climate and its economic impacts.

3.1 Impacts on Human Health

As time passes, the impact of air pollution on human health is growing more significant, placing it as a health issue which needs to be addressed urgently. Air pollution, which threatens all people including unborn babies, leads to an increased incidence of cardiovascular disease and breathing disorders, especially in the respiratory system and circulatory system[16]. According to the WHO, air pollution kills an estimated seven million people worldwide each year. WHO finds that almost the entire global population (99%) breathes air with high levels of pollutants exceeding WHO reference limits, with low- and middle-income countries being the most affected[17].

PM_{10} and $PM_{2.5}$, known as particulate matter (PM), are two of the most important pollutants affecting human health, and there is a linear relationship between their amounts and the level of adverse health effects[18].

[16] Turkish Thoracic Society. https://toraks.org.tr/site/news/2622
[17] World Health Organization (WHO). https://www.who.int/health-topics/air-pollution#tab=tab_1
[18] Republic of Türkiye, Ministry of Health, General Directorate of Public Health, "Air Pollution and Health Effects". https://hsgm.saglik.gov.tr/tr/cevresagligi-ced/ced-birimi/hava-kirlili%C4%9Fi-ve-sa%C4%9Fl%C4%B1k-etkileri.html

3.2 Impacts on the Ecosystem

Air pollution has a direct impact on the health of people and living beings, as well as on natural ecosystems and biodiversity. Both sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) emissions enter water and soil as "acid rain", with the pollutants increasing their acidity with negative effects on flora and fauna, while acidification affects nutrient cycling and carbon cycling in the ecosystem and water supply[19]. **In this context, ground-level ozone (O_3) leads to USD 11-18 billion worth of crop losses every year (S. Avnery, 2011).**

Air pollution also has an impact on the quality of water in the ecosystem. Pollutants may enter drinking water directly, especially through groundwater seepage, adversely affecting the vegetation which helps filter water and leading to a deterioration in water quality. Another effect of increased air pollution on the ecosystem is eutrophication (phosphate pollution). Eutrophication refers to the excessive proliferation of plankton and algae in large aquatic ecosystems following a sharp increase in nutrients, especially coming from the land[20] as a result of various causes related to air pollution[21]. **Accordingly, the mucilage problem which occurred in the Marmara Sea in 2021 may in fact be the result of an increase in eutrophication, an indirect outcome of air pollution** (Eren, 2021)**.**

3.3 Impacts on the Climate

In parallel with all recent studies, the sixth Assessment Report published by the Intergovernmental Panel on Climate Change (IPCC) in August 2021 emphasizes that major climate change is inevitable and irreversible, and refers to air pollution as an important issue. Under all five scenarios studied in the report, the global average temperature is projected to rise by 1.5°C by 2050. The report states that the increase in CO_2 emissions will stabilize, peaking towards the middle of the century, before gradually declining in the second half of the century[22].

While there is a complex relationship between air pollution and climate change, this relationship has been dubbed the "two sides of the same coin"[23]. Air pollution affects climate change and climate change triggers air pollution. Active volcanoes and dust storms are among the natural causes of air pollution. In addition to natural causes, the increase in production and consumption since the Industrial Revolution has led to increased emissions of greenhouse gases and chemicals, including **"black carbon"** and the production of air pollutants in the form of PM.

Black carbon, which may remain airborne in the atmosphere for up to a week, is an efficient absorbent of solar radiation. Caused especially by the burning of solid fuels indoors and agricultural waste in open areas[24], black carbon contributes to global warming, with studies estimating that black carbon is responsible for around 15% of the rise in global temperatures (European Commission, Directorate-General for Environment, 2010).

On the other hand, certain extreme weather events, which are increasing in frequency and intensity due to climate change, cause a rise in concentrations of O_3 and PM, while some other extreme weather events, including heat waves and drought, result in increased air pollution. These extreme weather events cause more severe negative impacts on air quality and human health than the wider global or regional climate change, greater destruction to infrastructure and the economy and more loss of life (Zhang, Yang, Gao, Leung, & Bell, 2020). For example, according to the EPA, the incidence of wild fires, which has been increasing due to climate change, exacerbates air pollution in surrounding areas and affects regional air quality[25].

[19] UNECE, "Air Pollution, Ecosystems and Biodiversity". https://unece.org/air-pollution-ecosystems-and-biodiversity
[20] Van Yüzüncü Yıl University. http://www.biyolojiegitim.yyu.edu.tr/kf/tootrfksyn/index.htm
[21] World Wildlife Fund (WWF). https://www.wwf.org.tr/?9081/5-haziran-cevre-gunu-aciklamasi-hava-kirliligi-tehlikeli-boyutlara-ulasti
[22] Intergovernmental Panel on Climate Change (IPCC). https://www.ipcc.ch/2021/08/09/ar6-wg1-20210809-pr/
[23] UNEP, "Air pollution and climate change: two sides of the same coin". https://www.unep.org/news-and-stories/story/air-pollution-and-climate-change-two-sides-same-coin?__cf_chl_managed_tk__=pmd_JfvaeX5zl2tuGtYWUOMc4bz38MCJ8oFV3hAtKw61wdE-1633691370-0-gqNtZGzNA3ujcnBszQjR
[24] Climate and Clean Air Coalition. https://www.ccacoalition.org/en/activity/open-agricultural-burning#:~:text=Responsible%20for%20more%20than%20a,regions%20of%20snow%20and%20ice).
[25] US Environmental Protection Agency (EPA). https://www.epa.gov/air-research/wildland-fire-research-health-effects-research

3.4 Economic Impacts

The risks posed by air pollution are not limited to health and the environment; air pollution directly and indirectly affects the economy, too. The OECD estimates that the total annual cost of environmental air pollution, taking all factors into account, will rise from 0.3% of global gross domestic product (GDP) in 2015 to 1% of global GDP by 2060 (OECD, 2016). According to the same report, not taking action to tackle air pollution brings with it both market and non-market costs. A breakdown of market costs takes into account health expenditures, labour productivity and agricultural production. It is worth noting that when non-market costs are examined, it becomes apparent that premature deaths and disease caused by air pollution affect public welfare.

Increased air pollution takes a toll on welfare as it increases the incidence of disease and premature deaths. According to a study published by the OECD in December 2019, a 1 μg/m^3 increase in the annual average $PM_{2.5}$ concentration reduced Europe's GDP by 0.8%[26], corresponding to a decrease of USD 273 per capita GDP in 2020[27]. According to the World Bank, annual labour income losses resulting from premature deaths caused by air pollution in the world reached around USD 179 billion in 2015, up from USD 47 billion in 1995 (World Bank, 2016). A related study conducted by the WHO and OECD in 2015 estimated that the economic price of premature death and disability caused by air pollution in Europe was close to USD 1.6 trillion[28].

Source: OECD

The UNEP states that the monetary value of welfare losses caused by air pollution in 2013 was USD 5.1 trillion (or 6.6% of global output)[29]. The negative impacts of environmental air pollution are also examined in terms of harm to human health and shortened life expectancy. To this end, while people were unwilling to pay more than USD 500 per person per year in 2015 to prevent loss of health or shortening in life expectancy due to air pollution, this figure is projected to rise to USD 2,800 by 2060 (OECD, 2016). **The report estimated that the losses to welfare resulting from premature deaths caused by environmental air pollution would increase from USD 3.16 trillion in 2015[30] to USD 18.3-25.3 trillion in 2060.**

The health problems caused by air pollution requires increased treatment and intervention, placing pressure on overall budgets. In this framework, health expenditures related to global air pollution are projected to increase from USD 21 billion in 2015 to USD 176 billion in 2060 (OECD, 2016). Moreover, according to a study conducted in November 2018, each percentage point increase in the $PM_{2.5}$ concentration leads to a 2.94% increase in household health expenditures (Jing Yang, 2018). According to a 2020 study covering countries in the Middle East and North Africa (MENA), each percentage point increase in the $PM_{2.5}$ per capita leads to a 1.13% increase in total per capita health expenditure (Özocaklı D., 2020).

We also know that air pollution increases the number of diseases, which in turn affects labour productivity. **In this framework, it is estimated that the annual working day losses due to air pollution, which totalled 1.2 billion days in 2010, will increase to 3.7 billion days by 2060**. Additionally, the number of days of restricted activity due to increased disease is expected to rise from a total of 4.9 billion days in 2010 to 14.9 billion days in 2060 (OECD, 2016).

[26] OECD (2019). https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=ECO/WKP(2019)54&docLanguage=En
[27] World Bank. https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=EU
[28] WHO. https://www.euro.who.int/en/media-centre/sections/press-releases/2015/04/air-pollution-costs-european-economies-us$-1.6-trillion-a-year-in-diseases-and-deaths,-new-who-study-says
[29] UNEP, Global Environment Outlook 6. https://www.unep.org/resources/global-environment-outlook-6#:~:text=The%20United%20Nations%20Environment%20Programme's,the%20global%20environment%20since%20202012.&text=GEO%2D6%20shows%20that%20a,prosperity%20a,prosperity%202C%20human%20health%20and%20wellbeing.
[30] Adjusted for 2010 purchasing power parity.

There are a number of studies which examine the impact of industrial air pollution on agricultural production. Air pollution causes reductions to agricultural yields, which depend on air quality. In recent years, many developing countries have been suffering from the negative effects of industrial developments and increasing urbanisation on agriculture. In China, a lack of atmospheric O_3 is expected to reduce summer wheat yields by 6-12% and soybean yields by 21-25% each year (Wang, 2004).

In addition to these economic impacts, the impact of air pollution on education should also be interpreted from an economic perspective. Research indicates that high concentrations of pollutants affect children's learning process by exacerbating respiratory diseases, fatigue, school absence and attention problems (Miller & Vela, 2013). Greater exposure to air pollution is associated with a higher likelihood of getting sick, in turn increasing the likelihood of children being absent from school. In this context, the increase in children's school absence due to air pollution indirectly affects the labour force participation and productivity of the children's parents.

Focus 1: Energy Supply Security and Air Pollution

According to the 2016 report on "Energy and Air Pollution" published by the International Energy Agency (IEA), securing access to modern and affordable energy and guaranteeing clean and healthy air are two complementary goals[31]. Investments by countries in energy efficiency and renewable energy are effective both in ensuring energy supply security and decarbonizing their economies. In this context, while increasing energy diversity (with a preference for renewable energy resources) will pave the way for energy to be obtained from a wider range of sources, their combined use with storage technologies will increase the security of energy supply. At the same time, the shift towards renewable energy sources will reduce dependence on energy production from conventional fuels, thus reducing air pollution. Additionally, low-carbon technologies and improvements in energy efficiency may help further advance the energy supply security goals of countries and regions by promoting a more reliable, resilient and diversified energy portfolio.

[31] IEA, "Energy and Air Pollution" (2016). http://pure.iiasa.ac.at/id/eprint/13467/1/WorldEnergyOutlookSpecialReport2016EnergyandAirPollution.pdf

4. Limits Used in Air Quality Measurement

Air pollution is a major environmental problem affecting everyone in low, middle and high-income countries. As the impacts of air pollution on health and the environment as well as the economy continue to increase, countries and organizations are working to improve air quality and reduce the public health burden and costs associated with air pollution.

Following fatal air pollution incidents in both the UK and the US in the 1950s, the WHO first started discussing limit values for air quality in 1958. The first version of the limits for air pollutants published by WHO was drafted in 1987[32]. Since 1987, several updated versions have been developed with the first version released globally in 2005 (WHO, 2005). In September 2021, WHO updated these limits, which entered force in 2005[33]. Following the WHO update, European Union (EU) countries pledged to follow the new guidelines for policies to reduce air pollution with the target of a 55% reduction in the number of premature deaths arising from air pollution by 2030[34].

Table 1: WHO Limit Values

Pollutant	Average Period	2005 Limits	2021 Limits
PM_{10} (µg/m³)	Annual	20	15
	24-Hourly	50	45
$PM_{2.5}$ (µg/m³)	Annual	10	5
	24-Hourly	25	15
NO_2 (µg/m³)	Annual	40	10
	24-Hourly		25
O_3 (µg/m³)	Peak Season		60
	8-Hourly	100	100
SO_2 (µg/m³)	24-Hourly	20	40
CO (mg/m³)	24-Hourly		4

Source:WHO, TSKB Economic Research

When we look at the European side, it is seen that the air quality policy created by the European Commission (EC) while determining the critical values aims to develop and implement appropriate tools to improve air quality[35]. The EC based these limits on directives published in 2004[36] and 2008[37]. The European Environment Agency (EEA) highlights that EU member states (including the UK) have set the annual average limit value for $PM_{2.5}$ at 25 µg/m³ from 2015[38].

[32] WHO. https://apps.who.int/iris/bitstream/handle/10665/107335/9789289013581-eng.pdf?sequence=1&isAllowed=y
[33] WHO (2021). https://www.who.int/news-room/feature-stories/detail/what-are-the-who-air-quality-guidelines
[34] Reuters. https://www.reuters.com/business/environment/eu-tighten-pollution-laws-clean-up-air-water-2021-05-12/
[35] European Commission (EC). https://ec.europa.eu/environment/air/quality/
[36] EC (2004). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32004L0107&qid=1633959496784
[37] EC (2008). https://ec.europa.eu/commission/presscorner/detail/en/IP_08_570
[38] European Environment Agency. https://www.eea.europa.eu/themes/air/air-quality-concentrations/air-quality-standards

According to EC guidelines, the limit value for 24-hourly PM_{10} concentration of 50 µg/m³ may be exceeded 35 days in a year.

Table 2: EC Limit Values

Pollutant	Average Period	Limit Value	Annual Exceedance Amount[39]
PM_{10} (µg/m³)	Annual	40	
	24-Hourly	50	35 days/year
$PM_{2,5}$ (µg/m³)	Annual	25	
NO_2 (µg/m³)	Annual	40	
	24-Hourly		
O_3 (µg/m³)	8-Hourly	120	25 days/year (averaged over three years)
SO_2 (µg/m³)	Hourly	350	24 hours/year
	24-Hourly	125	3 days/year
CO (mg/m3)	8-Hourly	10	

Source: EC, TSKB Economic Research

Türkiye plans to adopt the EU guidelines as a basis for its own limits, which will be reached gradually. The Regulation on Assessment and Management of Air Quality (RAMAQ), published in the Official Gazette on June 6, 2008, aims to define and establish air quality objectives to prevent or reduce the harmful effects of air pollution on environmental and human health, to assess air quality based on defined methods and criteria, to maintain current levels where air quality is good and to improve air quality in other cases, to collect sufficient information on air quality and to inform the public through warning thresholds[40]. Additionally, the Ministry of Environment, Urbanisation and Climate Change published the Regulation on Outdoor Air Quality Management on May 17, 2021.

Table 3: Limit Values Used for Türkiye[41]

Pollutant	Average Period	2017 Limit	2018 Limit	2019 Limit	2020 Limit	2021 Limit	2022 Limit	2023 Limit	2024 Limit
PM_{10} (µg/m³)	Annual	48	44	40	40	40	40	40	40
	Winter Period	60	50	40	40	40	40	40	40
	24-Hourly	70	60	50	50	50	50	50	50
$PM_{2,5}$ (µg/m³)	Annual[42]					30	29	29	28
NO_2 (µg/m³)	Annual	54	52	50	48	46	44	42	40
	24-Hourly	270	260	250	240	230	220	210	200
O_3 (µg/m³)	8-Hourly	target value[43]					120	120	120
SO_2 (µg/m³)	Hourly	410	380	350	350	350	350	350	350
	24-Hourly	175	150	125	125	125	125	125	125
CO (mg/m³)	8-Hourly	10	10	10	10	10	10	10	10

Source: Official Gazette, MoEUCC, TSKB Economic Research

$PM_{2.5}$ concentration measurements are still not sufficiently widespread in Türkiye. As can be seen in Table 3, limits for average $PM_{2.5}$ concentration have been included in the regulations since 2021. The steps expected to be taken in this regard in the coming period will be of critical importance.

[39] Annual excess refers the number of times that the limit is exceeded each year. It refers to the number of times limits may be exceeded at the maximum frequency within a year.
[40] Official Gazette. https://www.resmigazete.gov.tr/eskiler/2008/06/20080606-6.htm
[41] The values marked in grey in the table indicate the years when the limits in Türkiye converge with EC limits.
[42] The Ministry of Environment, Urbanization and Climate Change of the Republic of Türkiye, "Regulation on Outdoor Air Quality Management", 2021.
[43] A target value is the level that should be achieved, where feasible, by the end of the prescribed period, to avoid, prevent or reduce long-term harmful effects on the environment and/or human health. The target value varies by region.

5. Air Pollution in the World

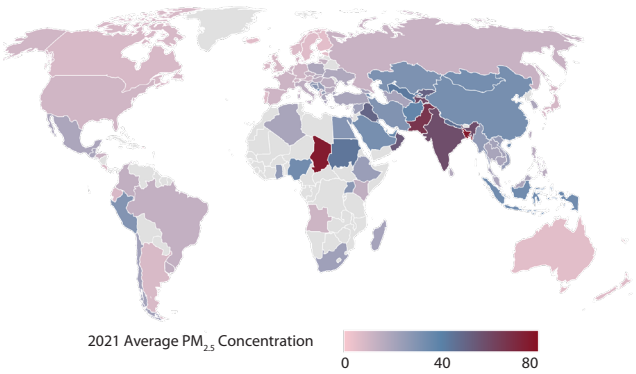
According to calculations carried out by IQAir using data for 2021, only 222 of the 6,475 cities worldwide where average $PM_{2.5}$ concentrations were measured in 2021 were found to have levels lower than the WHO limit of 5 µg/m³ (IQ Air, 2021).

The "World Air Quality Report 2021" prepared by IQAir found Bangladesh to be the country with the highest average $PM_{2.5}$ concentration, at 76.9 µg/m³, followed by Chad (75.9 µg/m³) and Pakistan (66.8 µg/m³). An analysis of country values found that thirteen of the fifteen countries with the highest average $PM_{2.5}$ concentrations were in Asia. The country with the 16th highest average $PM_{2.5}$ concentration was Montenegro, a European country.

With a $PM_{2.5}$ concentration of 20.0 µg/m³, Türkiye ranks 46th among 117 countries, with island countries having the lowest values. The country with the lowest $PM_{2.5}$ concentration among OECD countries is Finland, with a a $PM_{2.5}$ concentration of 5.5 µg/m³.

In a comparison of OECD countries, Türkiye's average $PM_{2.5}$ concentration in 2021 was second only to Chile (21.7 µg/m³). Greece and Italy, other countries which may be considered to be in the same category as Türkiye in terms of climate and geography, were found to have average $PM_{2.5}$ concentrations of 19 µg/m³ and 15.2 µg/m³, respectively in 2021[44].

Figure 1: Average $PM_{2.5}$ Concentration (2021)*



Source: IQAir, TSKB Economic Research

*A darker color means that the $PM_{2.5}$ concentration is high.

Focus 2: Air Pollution and COVID-19

Air pollution has a bidirectional relationship with the COVID-19 pandemic which has affected the whole world. The pandemic, which first emerged in the Wuhan province of China in early 2020 before gradually spreading around the entire world, forced countries to implement restrictions and impose lockdowns on their populations. The pandemic restrictions led to a fall in both regional and global reductions in 2020, along with reduced mobility and a contraction in the global economy. According to a study conducted by WHO, $PM_{2.5}$ concentrations decreased by 30-40% when much of the world was in full lockdown in 2020, when compared to the same periods in 2015-2019[45].

On the flip side, the health effects of COVID-19 are more severe in areas suffering from high air pollution. Air pollution is known to cause diseases which increase mortality, such as heart attacks, strokes and high blood pressure. A study published in November 2020 found that prolonged exposure to air pollution can exacerbate the effects of COVID-19 (Wu, Sabath, Nethery, Braun, & Dominici, 2020) while a study carried out with data gathered from Italy, Spain, France and Germany found that prolonged exposure to nitrogen dioxide (NO_2) concentrations may be one of the most important contributors to deaths caused by COVID-19 in the said regions (Ogen, 2020). According to the results of a study conducted in the UK, each 1 µg/m³ increase in concentrations of NO_2 and $PM_{2.5}$ raises mortality rates due to COVID-19 by 0.5% and 1.4%, respectively (Konstantinoudis, et al., 2021).

We have seen that air pollution decreased in many areas around the globe in 2020. Though the decline in mobility and contraction in the global economy led to a common decrease in air pollution, there were still some regions with higher air pollution, demonstrating that air pollution is not only caused by economic activity and mobility.

[44] It is worth noting that in 2021, the average $PM_{2.5}$ concentration recorded a year-on-year decrease in 38 countries and increased in 59 countries. Türkiye's average $PM_{2.5}$ concentration grew by 7%, while among OECD countries, 24 countries recorded an increase and 10 countries recorded a decline in their $PM_{2.5}$ concentration. Among OECD countries, the sharpest increase was recorded in Sweden (32%), while the deepest contraction was in Australia, with a 25% decrease.
[45] United Nations (2021). https://news.un.org/en/story/2021/09/1099092

6. Air Pollution in Türkiye

As in the rest of the world, air pollution is a key cause of many health problems in Türkiye. According to data published by the Institute for Health Metrics and Evaluation at the University of Washington, air pollution is one of the risk factors which combine to cause the most deaths and disabilities in Türkiye. It is noteworthy that air pollution, which ranked 6th in 2009 in the risk ranking, rose to 5th place in 2019[46]. The "Country Climate and Development Report" on Türkiye, published by the World Bank in 2022, states that while Türkiye has achieved progress in reducing air pollution, its health costs are higher than in high-income countries[47]. The report states that PM_{10} and NO_2 concentrations are decreasing in parallel with the country's economic growth and that the economic cost of $PM_{2.5}$ concentrations in Türkiye could amount to more than 5% of GDP.

In this context, the measurement of PM_{10}, NO_2 and $PM_{2,5}$ concentrations, in particular, becomes more important than ever in Türkiye. We hope that our study, which we will present in this section, will contribute to air pollution research from a development perspective.

6.1 Sources of Data and Methods Used

The air pollution pollutant parameter data used in our study are obtained from the "Download Station Data" section of the National Air Quality Monitoring Network Website of the Ministry of Environment, Urbanisation and Climate Change (MoEUCC)[48]. A city-based comparison of PM_{10}, NO_2 and $PM_{2.5}$ concentrations, among pollutants published across Türkiye, was made the studied. Particulate matter (PM_{10} and $PM_{2.5}$) are the most hazardous air pollutants for health, while nitrogen dioxide (NO_2) is included in the study since it is produced by combustion at high temperatures, such as in wild fires, and is also produced by motor vehicles. Data collected from a total of 343 stations between 2015 and 2021 were analysed and the annual averages of the daily data of these stations were used in the calculations. In order for the data to be used properly in air pollution calculations for each station, it was taken as a criterion that the station has collected data for at least 75% of the days in the year, i.e. at least 274 days (275 days in leap years). Therefore, stations that recorded data on 74% or less of the days in a year were excluded from the calculations. Since having at least two stations in air pollution calculations for each city is important in the data refinement process, cities with at least two stations that meet the previously mentioned criteria were included in our study.

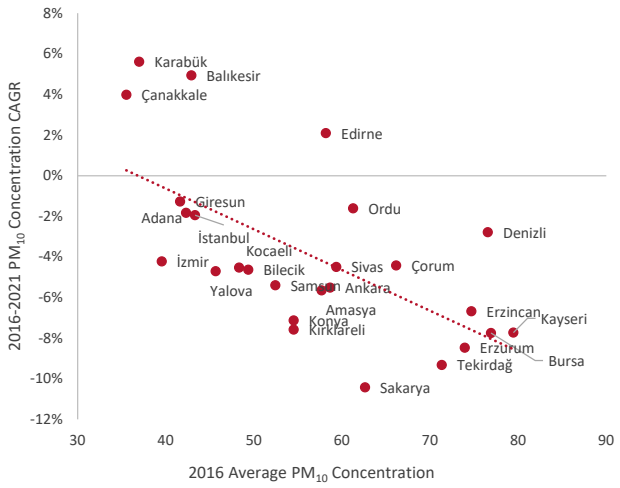
[46] Institute for Health Metrics and Evaluation. http://www.healthdata.org/turkey
[47] World Bank (2022). "Turkey – Country Climate and Development Report". https://openknowledge.worldbank.org/handle/10986/37521
[48] Ministry of Environment, Urbanisation and Climate Change. https://sim.csb.gov.tr/STN/STN_Report/DataBank

6.2 PM_{10} Concentration

At the end of the data refinement process, we conducted a study covering 26 cities[49] that met the data criteria for particulate matter (PM_{10}) pollutants of less than 10 µg/m^3 and compared their average concentrations for 2016 and 2021.

Among the cities examined in the study, there was an increase in average PM_{10} values in Balıkesir, Çanakkale, Edirne and Karabük between 2016-2021. The sharpest increase in average PM_{10} concentrations between 2016 and 2021 was found in Karabük, with a compound annual growth rate (CAGR) of 5.6%, followed by Balıkesir (4.9%), Çanakkale (4.0%) and Edirne (2.1%). The average PM_{10} concentrations in the other 22 cities included in this part of the study were found to have improved during the period.

Graph 1: Changes in Cities' Average PM_{10} Concentration in the 2016-2021 Period



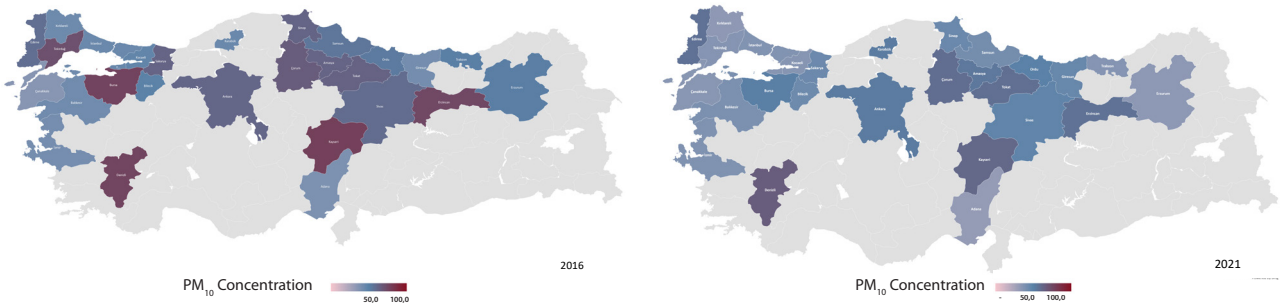
Source: Ministry of the Environment, Urbanisation and Climate Change (MoEUCC), TSKB Economic Research

According to the results of the study, which found steeper declines in cities with higher average PM_{10} concentrations in the baseline year, more than half of the cities included in the study recorded a sharper than average reduction. In the 5-year period starting from 2016, Sakarya achieved the strongest improvement with a 10.4% decline in PM_{10} concentrations, followed by Tekirdağ with a fall of 9.3%. On the other hand, cities such as Erzurum, Bursa, Kayseri, Kırklareli and Konya recorded declines of more than 7% in their average PM_{10} concentrations.

A total of 16 cities had an average PM_{10} concentration which exceeded the limit determined by Türkiye in 2016, while in 2021 this number had declined to 15. In 2016, Balıkesir, Çanakkale and Karabük had average PM_{10} concentrations within the limits set for Türkiye, while in 2021 the average exceeded the limit. The PM_{10} concentrations in Kırklareli, Konya, Sakarya and Samsun all exceeded the limits set by Türkiye in 2016, but where lower in 2021.

Air pollution increases in parallel with urbanisation, transportation and industrialization, which theoretically increase in tandem with population growth. According to the WHO, industrial and vehicle emissions are deemed to be the main source of PM_{10}. In this context, the study examined the relationship between the change in real industrial production and changes in average PM_{10} concentrations between 2016 and 2019.

Figure 2: Average PM_{10} Concentration (2016 and 2021)

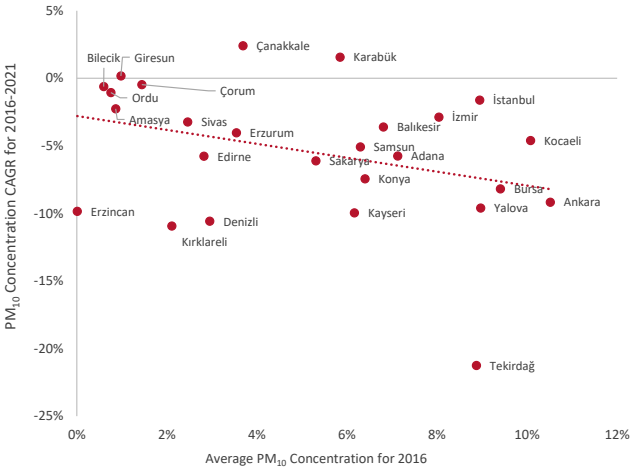


Source: MoEUCC, TSKB Economic Research

[49] Adana, Amasya, Ankara, Balıkesir, Bilecik, Bursa, Çanakkale, Çorum, Denizli, Edirne, Erzincan, Erzurum, Giresun, İstanbul, İzmir, Karabük, Kayseri, Kırklareli, Kocaeli, Konya, Ordu, Sakarya, Samsun, Sivas, Tekirdağ, Yalova.

As seen in Graph 2, while real industrial production increased in all cities included in the study, average PM_{10} concentration decreased in all cities with the exception of Çanakkale, Giresun and Karabük. **Therefore, the available dataset does not imply a direct relationship between production and indicators of air pollution. This suggests that an increase in production can be achieved without increasing air pollution[50].**

Graph 2: Relationship Between PM_{10} Concentration and Real Production[51] (2016-2019)*

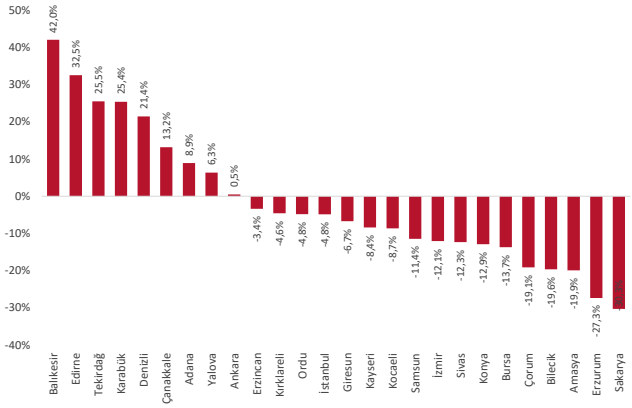


Source: MoEUCC, TurkStat, TSKB Economic Research

*** Since there is no city-based production data for 2021, the period of 2016-2019 has been taken into account. The year 2020 has not been considered due to its Covid-19 shutdown effect.**

As presented in Graph 3, when the average PM_{10} concentration in 2021 is compared to 2019, it is seen that there was an increase in 9 cities and a decrease in 17 cities. The strongest average PM_{10} concentration growth in 2021 compared to 2019 was in Balıkesir with 42%, followed by Edirne with 32.5% and Tekirdağ with 25.5%. In the meantine, the biggest decrease in average PM_{10} concentration was recorded in Sakarya with 30.3%, followed by Erzurum with a 27.3% decrease and Amasya with a 19.9% decrease.

Graph 3: Average PM_{10} Concentration Comparison Between 2019 and 2021*



Source: MoEUCC, TSKB Economic Research

*** The year 2020 has not been considered due to its Covid-19 shutdown effect.**

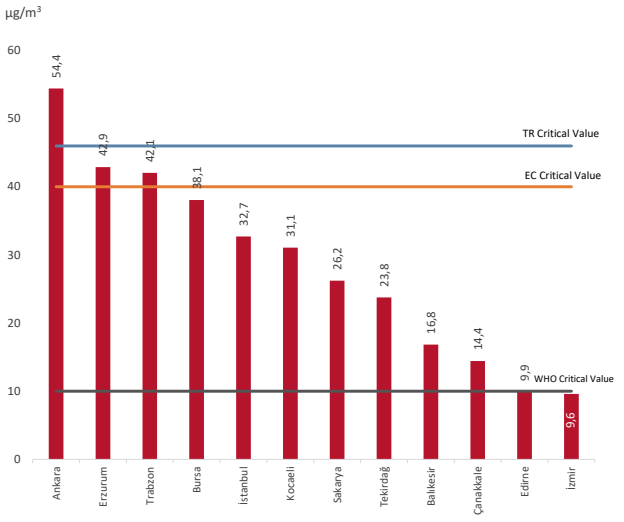
6.3 NO_2 Concentration

The study examined nitrogen dioxide (NO_2) concentrations between 2016 and 2021 in 12 cities[52].

As seen in Graph 4, Ankara, Erzurum and Trabzon were found to suffer the highest average NO_2 concentrations among the cities included in the study, with the average NO_2 concentrations in these cities exceeding WHO/EC limits in 2021.

The annual average NO_2 concentrations in all of the cities were found to be within the limits determined in Türkiye in 2016. However, the average NO_2 concentration in Ankara exceeded the limit determined for Türkiye in 2019, 2020 and 2021.

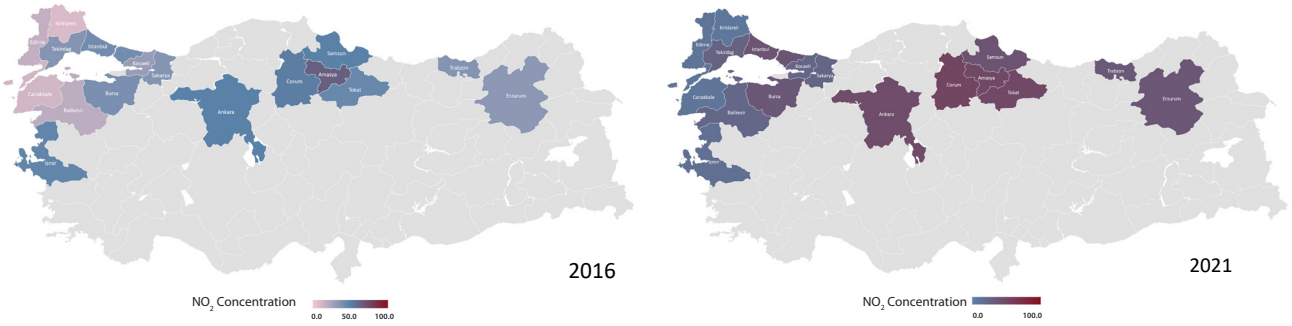
Graph 4: Average NO_2 Concentration for 2021



Source: MoEUCC, TSKB Economic Research

[50] The graph of 2020 calculations using real production data is presented in Annex-2.
[51] To determine the relationship between the change in real production and the change in average PM10 concentration between 2016 and 2019, production value data by economic activity and size groups published by TurkStat and regional size, dominance and specialization data from the Entrepreneurship Information System of the Ministry of Industry and Technology were used. After materializing these data, the compound annual growth rates were compared with the compound annual growth rate of the annual average PM10 concentration published by the MoEUCC.
[52] Ankara, Balıkesir, Bursa, Çanakkale, Edirne, Erzurum, İstanbul, İzmir, Kocaeli, Sakarya, Tekirdağ, Trabzon.

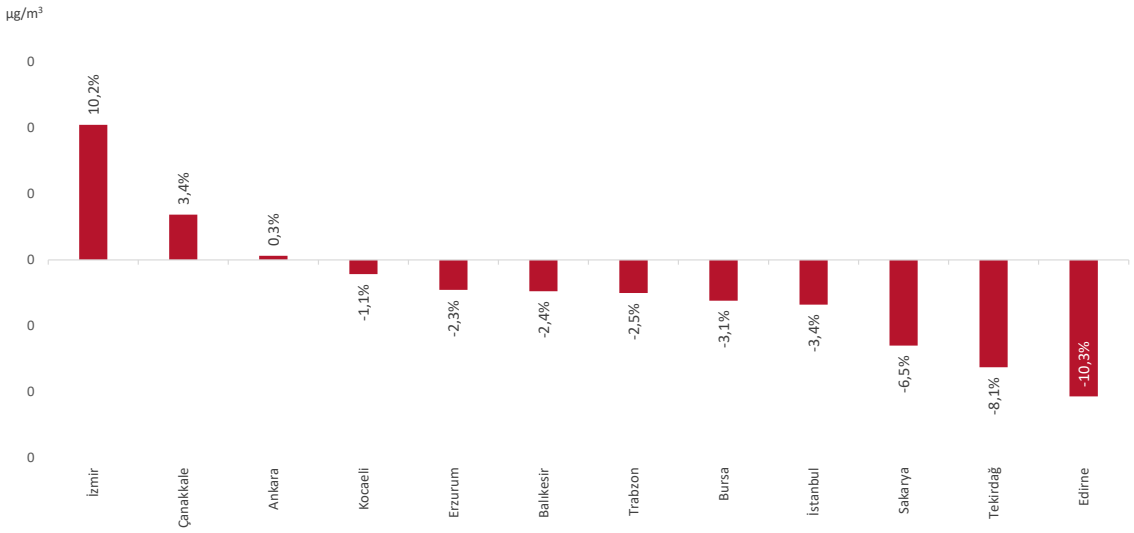
Figure 3: Average NO_2 Concentration (2016 and 2021)



Source: MoEUCC, TSKB Economic Research

The average CAGR of the 12 cities included in the study was calculated as -2.1%. As seen in Graph 5, the most rapid compounded annual growth rate in NO_2 concentration between 2016 and 2021 was recorded in İzmir, at 10.2%, followed by Çanakkale (3.4%) and Ankara (0.3%). On the other hand, among the cities included in the study, the steepest compounded annual decline in average NO_2 concentrations was realised in Edirne at 10.3%, followed by Tekirdağ (8.1%) and Sakarya (6.5%).

Graph 5: Average NO_2 Concentration CAGR for the 2016-2021 Period



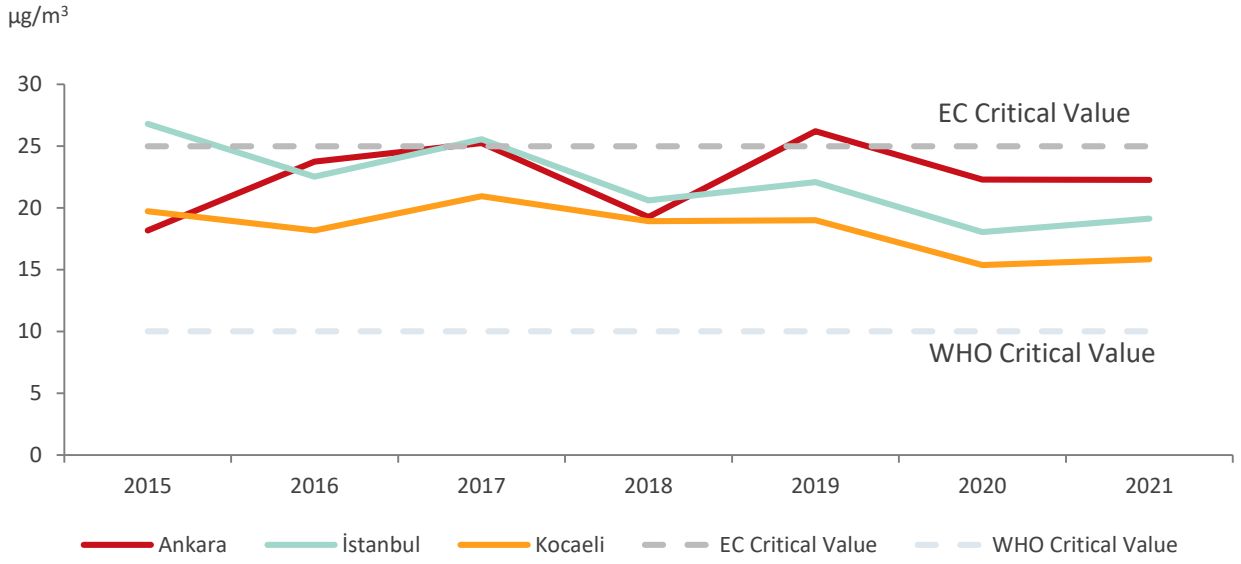
Source: MoEUCC, TSKB Economic Research

6.4 $PM_{2.5}$ Concentration

The pollutant of particulate matter smaller than 2.5 µg/m³ ($PM_{2.5}$), deemed to include the most dangerous particulate matter, has become even more critical in recent years. Not enough measurements for the $PM_{2.5}$ pollutant, which is closely linked to lung diseases, have been carried out in Türkiye. This study analyses the average $PM_{2.5}$ concentration for only three cities (Ankara, İstanbul, Kocaeli) which met the data criteria for the period of 2016-2021.

The average $PM_{2.5}$ concentration values for all of the cities included in the study were found to exceed the WHO limits but to be lower than the EC limits in terms of average $PM_{2.5}$ concentration in 2020 and 2021. The average $PM_{2.5}$ concentration in Ankara, which was recorded as 22.29 µg/m³ in 2020, stood at 22.23 µg/m³ in 2021, marking an annual decrease of 0.1%. Despite average $PM_{2.5}$ concentration values for 2021 being within the EC limits, Kocaeli and İstanbul recorded annual increases of 3.0% and 6.1% in their annual concentration of $PM_{2.5}$ respectively. Additionally, the average concentration values for these cities in 2021 were lower than the $PM_{2.5}$ limit determined within the scope of the Regulation on Outdoor Air Quality Management published by the Ministry of Environment, Urbanisation and Climate Change (MoEUCC) on May 17, 2021.

Graph 6: Change in Average $PM_{2.5}$ Concentration in Cities in the 2016-2021 Period



Source: MoEUCC, TSKB Economic Research

7. Regulation on Air Pollution

Air pollution, which has become a particularly important problem in recent years, directly and indirectly affects the environment and economy, especially health. In addition to its impact on human health, pollution is one of the main causes of biodiversity loss and reduces the ability of ecosystems to sequester carbon. While natural causes contribute significantly to local air pollution in arid regions more prone to wild fires and dust storms, the contribution from human activity remains far outweighs the contribution from natural causes.

Since the Industrial Revolution, the quality of the air we breathe has deteriorated significantly, mainly as a result of human activity. Rising industrial and energy production and a dramatic increase in road, air and sea traffic have contributed to the rise in air pollution and continue to do so. The "Convention on Long-Range Transboundary Air Pollution"[53] signed by 32 countries in 1979 and the "Gothenburg Protocol"[54], signed in 1999, have served as the guiding documents in tackling air pollution. In its report, "The Declaration on Clean Air for 2020-2030 and Beyond" published in December 2019, UNECE states that air pollution was a high-impact problem given that it can spread over long distances, while emphasising that local air pollution is greatly affected by transboundary air pollution. UNECE went on to endorse cooperation at different levels of government in the UNECE region[55]. In this context, on May 12, 2021, the EC adopted the EU Action Plan: "Towards a Zero Pollution for Air, Water and Soil" under the European Green Deal[56]. The EC's vision of zero emissions by 2050 is to reduce air, water and soil pollution to levels not harmful to human health and ecosystems, thus creating a non-toxic environment. In this context, 2030 targets have been set to accelerate the reduction of pollution at source, including improving air quality to achieve a 55% reduction in the number of premature deaths caused by air pollution and a 25% reduction in the number of ecosystems where air pollution threatens biodiversity.

A regulation on air pollution and published in the Official Gazette of June 6, 2008, the Regulation on Assessment and Management of Air Quality aims to define and establish air quality objectives to prevent or reduce the harmful effects of air pollution on the environment and human health, to assess air quality based on defined methods and criteria, to maintain the current situation where air quality is good and to improve it in other cases, to collect sufficient information on air quality and to inform the public through warning thresholds.

[53] UNECE. https://unece.org/sites/default/files/2021-05/1979%20CLRTAP.e.pdf
[54] UNECE. https://unece.org/gothenburg-protocol
[55] UNECE. https://unece.org/fileadmin/DAM/env/documents/2019/AIR/EB/Declaration.pdf
[56] EC. https://ec.europa.eu/environment/strategy/zero-pollution-action-plan_en

8. Latest Developments in Tackling Air Pollution

Many of the gases driving climate change are also common air pollutants which affect our health and the environment. Combating air pollution, one of the biggest threats to health today, supports efforts to mitigate climate change. As in many countries around the world, air pollution directly affects human and environmental health in many cities throughout Türkiye and is at the forefront of the agenda both globally and in terms of Türkiye's steps to tackle climate change. In its 2007 report, the IPCC, an international organization which was established to assess climate change, predicted a decrease in air quality in cities in the future due to climate change (Intergovernmental Panel on Climate Change, 2007).

It would appear that the solution to the problem of air pollution, which has many origins, will or should be multi-stakeholder based. The United Nations Environment Assembly, held in Nairobi in 2017 with participants from 170 countries, took an important step by publishing a declaration[57] at the ministerial level on combating pollution. In the implementation plan that followed, participants included ministries, policy makers, businesses, industry, NGOs, local governments and citizens, confirming that the solution should have a multi-stakeholder basis.

Improving waste management for both industrial plants and cities is crucial to the solution. Energy efficiency should not be limited to industry; green buildings, accessible public transportation services, bicycle lanes and pedestrian-friendly green cities are listed as both important and urgent actions. Of course, other management areas include preventing wild fires, supporting natural vegetation and balancing the relationship between agricultural activities and forestry.

Adopting electric end-use technologies instead of fossil-fuelled alternatives, known as electrification, is an important economy-wide decarbonization strategy that also reduces criteria pollutant emissions and improves air quality[58]. According to a study conducted in the USA, electrification significantly reduces carbon dioxide, while improving air quality.

In particular, electrification efforts in the transport sector are changing ozone and $PM_{2.5}$ concentrations[59].

At the 26th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP26), which took place in Glasgow in 2021, more than 40 countries pledged to commit to phase out the use of coal, while the inclusion of the phrase "phase down" in the Final Declaration was noted to be a noteworthy effort in the context of the measures taken to address the climate crisis[60]. At COP27, which took place in Egypt in November 2022, air pollution was discussed under the "Health" day. It was stated that the steps taken in the fight against air pollution are also effective in the fight against climate change. In the meantime, the report titled "Health and Climate Change Country Profile 2022 - Türkiye" published by WHO in the same period indicates that 37,000 premature deaths occur in Türkiye every year due to air pollution[61].

In this context, we need to accept the fact that both the world and Türkiye have a long way to go when it comes to tackling air pollution. The addition of financing opportunities to be developed within the scope of combating air pollution to the steps that the public sector, municipalities, companies in the private sector and individuals will carry out together by taking responsibility will support the process of improving air quality throughout the world and in Türkiye.

[57] UNEP. https://wedocs.unep.org/bitstream/handle/20.500.11822/31015/k1800398.english.pdf?sequence=3&isAllowed=y
[58] https://www.nature.com/articles/s41467-022-33902-9
[59] https://pubmed.ncbi.nlm.nih.gov/36335099/
[60] COP26 Glasgow Climate Agreement. https://ukcop26.org/wp-content/uploads/2021/11/COP26-Presidency-Outcomes-The-Climate-Pact.pdf
[61] WHO, "Health and Climate Change Country Profile 2022". https://apps.who.int/iris/bitstream/handle/10665/353977/WHO-HEP-ECH-CCH-22.01.05-eng.pdf?sequence=1&isAllowed=y

9. Sustainable Development Goals and Air Pollution

Tackling air pollution is closely related to almost all Sustainable Development Goals (SDGs) because of its direct relationship with a wide range of development themes such as climate, water and natural resources. It refers directly to Goal 3 - "Good Health and Well-Being", Goal 6 - "Clean Water and Sanitation", Goal 7 - "Affordable and Clean Energy", Goal 8 - "Decent Work and Economic Growth", Goal 11 - "Sustainable Cities and Communities", Goal 12 - "Responsible Consumption and Production", Goal 13 - "Climate Action", Goal 14 - "Life Below Water" and Goal 15 - "Life on Land".

"Good Health and Well-Being" aims to ensure healthy living and promote happiness at every age. Under this objective, the goal is to reduce the incidence of illness and death caused by harmful chemicals and air pollution by 2030. Target 3.9 is to significantly reduce the incidence of death and illness caused by air, water and soil pollution and contamination with hazardous chemicals by 2030.

The "Clean Water and Sanitation" objective is also affected by air pollution. The goal prioritizes access to water and sanitation for all and aims to protect aquatic ecosystems and biodiversity. Air pollutants, the concentration of which is affected by climatic conditions, pollute water and lead to deterioration in water quality. Some rivers, lakes or coastal areas may appear clean but may still be polluted by acid precipitation from rain, snow and particulate matter[62]. Therefore, every step taken to combat air pollution indirectly contributes to the efforts to tackle water pollution.

[62] Canadian Department of Environment and Natural Resources. https://www.canada.ca/en/environment-climate-change/services/air-pollution/quality-environment-economy/ecosystem/effects-soil-water.html

Air pollution is inseparable from energy production and consumption. Therefore, the production and use of "Affordable and Clean Energy", covered under SDG 7, is directly linked to air pollution. Shifting the composition of electricity generation towards renewable energy sources contributes positively both to achieving clean energy target and to reducing air pollution.

The link between air pollution and Goal 8 - "Decent Work and Economic Growth", which aims to progressively increase global resource efficiency in consumption and production and to decouple economic growth from environmental degradation, is an important issue when it comes to the health and productivity of employees. Improved employee health and well-being along with workplaces free of pollution leads to increased productivity and efficiency and economic growth.

SDG 11 - "Sustainable Cities and Communities" includes a target to reduce the negative per capita environmental impact of cities by 2030, with special attention on air quality. In particular, target 11.6 prioritizes reducing the negative environmental impacts of cities, including outdoor air pollution, while indicator 11.6.2 measures the extent to which air quality (in particular, annual average particulate matter) affects people living in urbanized areas[63]. Therefore, this target directly contributes positively to the efforts to tackle air pollution.

Goal 12 - "Responsible Consumption and Production" is based on the goal of sustainable production and consumption of natural resources. One of the targets under this objective was to ensure that, by 2020, chemicals and all wastes would be managed in an environmentally sound manner in accordance with agreed rules throughout their life cycle. Another goal is to gradually reduce waste generation through prevention, reduction, recycling and reuse by 2030. In this context, reducing waste generation and combating air pollution are two concepts that speak are closely intertwined with each other.

Climate change is caused by human activity and threatens the future of the world and its population. Greenhouse gas emissions from human activities are triggering climate change and an increase in global warming. The use of conventional fuels has increased the level of air pollution and thus greenhouse gas emissions, and is one of the most important activities driving global warming. Therefore, most of the actions to reduce air pollution also leads to a reduction in greenhouse gas emissions. For this reason, SDG 13 - "Climate Action" is one of the goals directly linked to air pollution.

Goal 14 - "Life Below Water", highlights the adverse impact of air pollutants on water quality and life below water through their deposition in waterways. Eutrophication in the sea and bodies of fresh water, with the effect of air pollution, can reach levels which can destroy life and ecosystems underwater.

Goal 15 - "Life on Land" states that thriving ecosystems require clean soil and water resources, and that tackling air pollution is necessary to protect life on land. Emissions from the combustion of conventional fuels that which react with rainfall cause acid rain, posing a major threat to forests and the ecosystem[64]. Therefore, every step to tackle air pollution will directly affect SDG 15.

[63] World Bank. https://datatopics.worldbank.org/sdgatlas/goal-11-sustainable-cities-and-communities/
[64] https://medium.com/climatewed/cleanairforall-air-pollution-and-impacts-on-sustainable-development-goals-79a90e1473f9

References

-Mosley, S. (2014). Environmental History of Air Pollution and Protection. In N. S. Agnoletti M., The Basic Environmental History. Environmental History, vol 4 (pp. 143-169). Springer, Cham.
-Right to Clean Air Platform. (2020). Kara Rapor 2020 Hava Kirliliği ve Sağlık Etkileri (Dark Report 2020: Air Pollution and Health Effects). Istanbul.
-S. Avnery, D. M. (2011, April). Global Crop Yiled Reductions due to Surface Ozon Exposure: 1. Year 2000 Crop Production Losses and Economic Damage. Atmospheric Environment, pp. 2284-2296.
-Greenpeace. (2020). Toxic Air: The Price of Fossil Fuels.
-Wang, X. a. (2004). Characterizing Distributions of Surface Ozone and Its Impact on Grain Production in China, Japan and South Korea: 1990 and 2020. Atmospheric Environment.
-Jing Yang, B. Z. (2018). Air pollution and healthcare expenditure: Implications for the benefit of air pollution control in China. Environment International, 443-455.
-World Bank. (2016). The Cost of Air Pollution Strengthenin the Economic Case for Action. Washington.
-World Bank. (2018). Air Pollution: Impact on Human Health and Wealth. In W. B. Group, The Changing Wealth of Nations 2018 Building a Sustainable Future (pp. 171-188). Washington.
-Intergovernmental Panel on Climate Change. (2007). Climate Change 2007: Synthesis Report. Geneva.
-Lopez R., I. A. (2013). Government Spending and Air Pollution in the US. Retrieved from United States Department of Agriculture Research, Education & Economics Information System: https://reeis.usda.gov/web/crisprojectpages/0218802-government-expenditure-and-air-pollution-in-the-us.html
-Özocaklı D., A. Ö. (2020). The Effect of Air Quality and Prevalence of Smoking on Different Categories of Health Expenditures: Empirical Evidence From MENA Countries. Eurasian Journal of Researches in Social and Economics, 85-103.
-Adam D. K. Abelkop, J. D. (2017). Persistent, Bioaccumulative, and Toxic (PBT) Chemicals Technical Aspects, Policies, and Practices. CRC Press.
-Zhang, Y., Yang, P., Gao, Y., Leung, R., & Bell, M. (2020). Health and economic impacts of air pollution induced by weather extremes over the continental U.S. Environment International.
-McCollum, D., Krey, V., Riahi, K., Klop, P., Grubler, A., Makowski, M., & Nekicenovic, N. (2013). Climate Policies Can Help Resolve Energy Security and Air Pollution Challenges. Climate Change, 479-494.
-IQAir. (2020). 2020 World Air Quality Report Region & City PM2.5 Ranking.
-Urrutia-Pereira, M., Mello-da-Silva, C., & Sole, D. (2020). COVID-19 and air pollution: A dangerous association? Allergologia et immunopathologia, 496-499.
-Wu, X., Sabath, M. B., Nethery, R. C., Braun, D., & Dominici, F. (2020). Air pollution and COVID-19 mortality in the United States: Strengths and limitations of an ecological regression analysis. Science Advances.
-Ogen, Y. (2020). Assessing nitrogen dioxide (NO2) levels as a contributing factor to coronavirus (COVID-19) fatality. Science of The Total Environment.
-Konstantinoudis, G., Padellini, T., Bennett, J., Davies, B., Ezzati, M., & Blangiardo, M. (2021). Long-term exposure to air-pollution and COVID-19 mortality in England: A hierarchical spatial analysis. Environment International.
-Colvile, R., Hutchinson, E., Mindell, J., & Warren, R. (2001). The Transport Sector as a Source of Air Pollution. Atmospheric Environment, 1537-1565.
-Eren, Z. (2021). Zararlı Alg Patlaması ve Marmara Denizindeki Müsilaj Problemi İlişkisi. Journal of Environmental and Natural Studies, 182-192.
-OECD. (2016, December). The Economic Consequences of Outdoor Air Pollution. Paris.
-Miller, S., & Vela, M. (2013). The Effects of Air Pollution on Edocational Outcomes: Evidence from Chile. Inter-American Development Bank Working Paper Series.
-Right to Clean Air Platform. (2021). Kara Rapor 2021 Hava Kirliliği ve Sağlık Etkileri (Dark Report 2021: Air Pollution and Health Effects).
-IQAir. (2021). World Air Quality Report.
-WHO. (2006). Air Quality Guidelines Global Update 2005. Copenhagen.
-European Commission, Directorate-General for Environment. (2010, November). Reducing Black Carbon Emissions Benefits Both Climate and Health. Science for Environment Policy, p. 4.

Annex-1

Particulate Matter (PM)

PM is an air pollutant consisting of a mixture of solid particles and liquid droplets in the air. Some particles such as dust, dirt, soot or smoke can be large enough to be visible to the eye[65]. The most harmful components of air pollution are particulate matter with a diameter of 10 micrometres (µm) or less (PM_{10} and $PM_{2.5}$). $PM_{2.5}$ consists of particles finer than PM_{10}, including organic compounds and some metals.

PM_{10}, like $PM_{2.5}$ consists of solid particles such as dust and pollen. These particles arise from human activities through road and rail transport, shipping, industry and solid fuel combustion, or from naturally occurring phenomena such as sand and sea salt. PM_{10} particles can stay in the air for hours, while $PM_{2.5}$ particles can stay in the air for up to weeks.

Sulphur Dioxide (SO_2)

SO_2 is a colourless gas which is produced when a sulphur-containing material or fuel is burned. SO_2 is emitted from fires and volcanoes, which are among the natural causes of SO_2. The gas may remain in the air for around 40 days[66].

Nitrogen Dioxide (NO_2)

Nitrogen dioxide (No_2) is a colourless and odourless gas produced as a result of the combustion process under high temperature. It occurs in all forms of combustion. Nitrogen dioxide (NO_2), a form of NO, is anthropogenic and produced from sources such as fertilization and transportation vehicles. NO_2, which remains in the air for about one day, generally originates from exhaust gases, fuels and organic substances.

Ozone (O_3)

O_3 is a colourless gas formed by the combination of three oxygen atoms. It is found in the upper layers of the atmosphere and protects the Earth from the sun's harmful ultraviolet rays. Nevertheless, at ground level it is known to be a very harmful air pollutant. O_3 is formed by chemical reactions between emissions from industrial plants, vehicle exhaust and chemical solvents in sunlight. It also occurs in areas where pollutants are concentrated, when NO and volatile organic compounds react in the presence of sunlight.

Carbon Monoxide (CO)

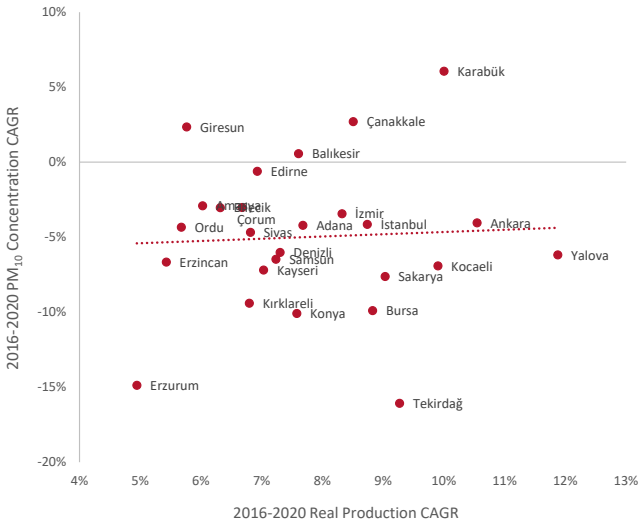
CO, a colourless gas, is produced when carbon-containing fuels do not burn completely. A gas that can kill within minutes, it can remain in the air for more than two months. In recent years, CO has mainly been produced in road transport, especially in gasoline powered vehicles.

[65] US Environmental Protection Agency (EPA). https://www.epa.gov/pm-pollution/particulate-matter-pm-basics#PM
[66] Sakarya University, "Air Pollution and Pollutants". http://www.sahakk.sakarya.edu.tr/documents/hava_kirliligi_ve_kirleticiler_rapor1.pdf

Annex-2

Between 2016 and 2020, when the relationship between the change in real industrial production and the change in average PM_{10} concentration was analysed, real industrial production increased in all cities included in the study, while average PM_{10} concentration decreased in all cities except Çanakkale, Giresun, Balıkesir and Karabük.

Graph 7: Relationship Between Average PM_{10} Concentration and Real Production



Source: MoEUCC, TurkStat, TSKB Economic Research

Notes

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