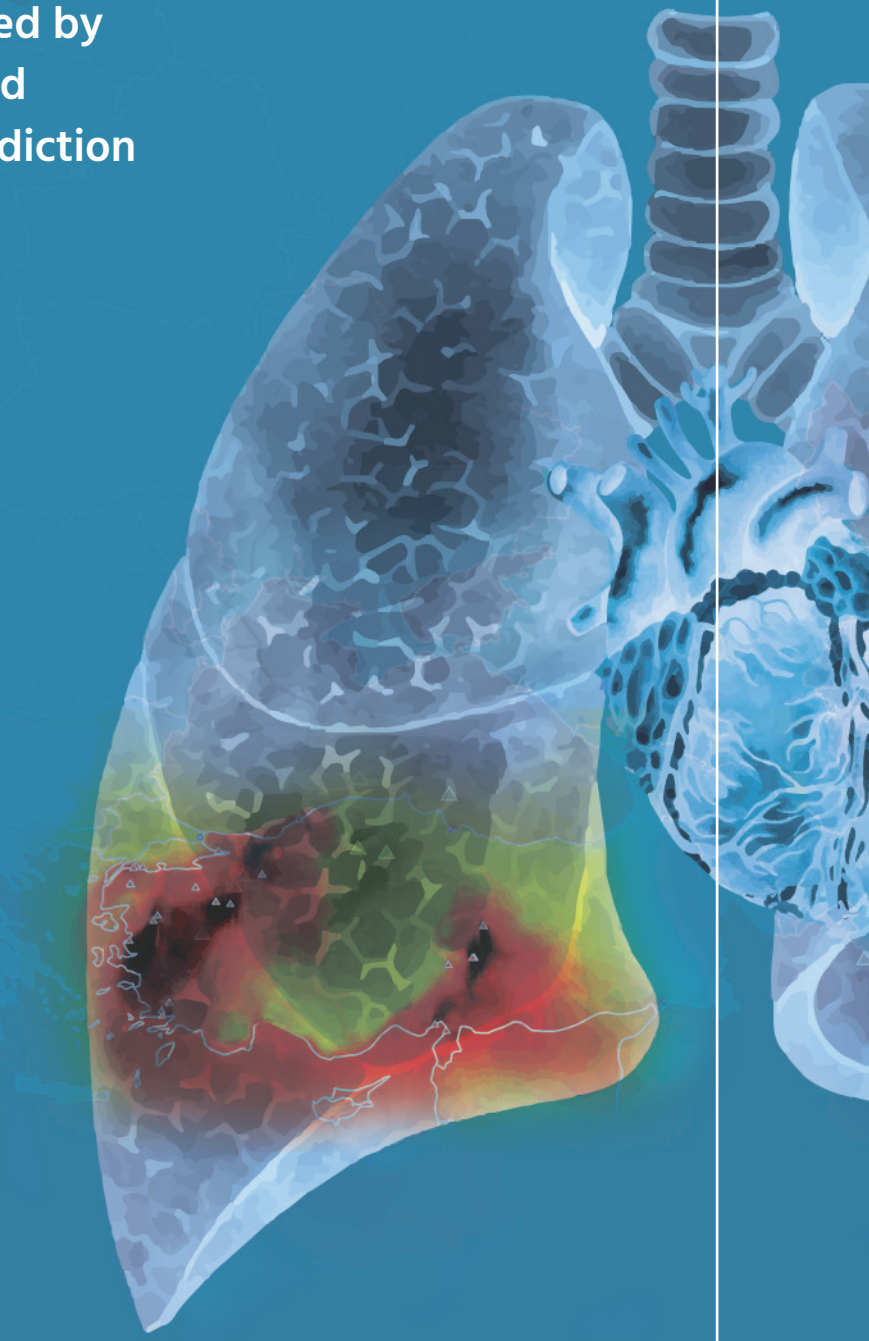
Chronic coal pollution Turkey

The health burden caused by coal power in Turkey and how to stop the coal addiction



HEAL
HEALTH AND ENVIRONMENT ALLIANCE

EUROPE BEYOND COAL

ABOUT

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The health impact methodology used in this report is guided by recommendations from the World Health Organization (WHO) 'Health risks of air pollution in Europe' (HRAPIE) project on health impact assessments for air pollution, as implemented in the Europe's Dark Cloud report. It includes atmospheric modelling with the European Monitoring and Evaluation Programme Meteorological Synthesizing Centre - West (EMEP MSC-W) computer model, which is also used by the European Environment Agency for European Commission assessments of health impacts from air pollution in Europe. The assessments are based on publicly available, relevant data known by the authors; this data may not be exhaustive and there may exist further or updated information they were not aware of at the time of writing.

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LIST OF ABBREVIATIONS

de-SOx	Technologies designed to remove sulphur oxides
de-NOx	Technologies designed to remove nitrogen oxides
EU	European Union countries
EUR	Euro currency
GW	Gigawatts
GWh	Gigawatt-hour
MW	Megawatt
NO2	Nitrogen dioxide
NOx	Nitrogen oxides
PM	Particulate matter
PM2.5	Particulate matter size 2.5 micrometers or less
PM10	Particulate matter size 10 micrometers or less
RES	Renewable energy sources
SO2	Sulphur dioxide
SOx	Sulphur oxides
TRY	Turkish lira
TWh	Terawatt-hour
USD	US dollar
VOCs	Volatile organic compounds
WHO	World Health Organization

CONTENTS

EXECUTIVE SUMMARY

In Europe, coal power is playing an increasingly diminished role in the electricity market which is reinforced by political decisions on phase outs across the region, and the implementation of the Paris Climate Agreement.

In contrast, Turkey continues to rely on coal power generation, and the government has plans for a significant increase, which would more than double the current 19 GW coal power capacity. Thirty new coal power plants are in the pipeline (permitted, announced or at pre-permit stage) totalling 33 GW. This expansion is a public health threat given that existing coal power generation already causes an unacceptably high health burden in Turkey from the massive amount of air pollution released.

This report aims to quantify the health burden of Turkey's 28 large coal power plants that operated in 2019, which burn lignite, hard coal or asphaltite. These plants are responsible for generating approximately 37% of Turkey's electricity. The analysis is a detailed update of HEAL's 2015 Unpaid Health Bill report.

The report also includes a special focus on four coal hotspots where a huge increase in coal capacity is planned; the cities of Çanakkale, Adana and Hatay, Muğla, and Eskişehir.

KEY FINDINGS

In 2019, emissions from coal power plants in Turkey led to:

- **4,818** premature deaths,
- **3,070** cases of preterm births ,
- **26,500** cases of bronchitis in children,
- **3,230** new cases of chronic bronchitis in adults,
- **5,664** hospital admissions,
- **237,037** days of asthma and bronchitis symptoms in asthmatic children,
- **1,480,000** lost working days,
- **11,300,000** sickness days and
- **8,850** lost IQ points due to mercury exposure.

The annual economic cost of these health impacts in Turkey and across the region are 47.41 - 99.37 billion Turkish Lira, or 5.20 - 10.90 billion EUR.

The health costs of coal power generation in Turkey alone are 26.07 - 53.60 billion TRY (2.86 - 5.88 EUR), which is equivalent to 13 - 27% of Turkey's each year health expenditure (201.03 billion TRY, calculation based on health care expenditure by private and public sector data from TurkStat, 2019).

Health impacts and costs from climate change have not been considered, which are fuelled by CO_2 releases of coal plants and further add to the health and economic impact from coal power.

This huge health (economic) burden and measures to reduce it are currently not taken into account in any policy considerations and decisions.

Gap in transparency: emissions data not publicly available

The report is a major endeavour to fill data gaps on emissions of existing coal plants. While EU member states are legally required to report emissions at plant level to a publicly accessible database (E-PRTR), Turkey does not share power plant or sectoral emission data. Instead, it reports merged data for electricity generation and the heating sector, under international commitments.

This makes it challenging to pinpoint emissions coming only from coal powered energy sources, or even from the electricity sector as a whole. Furthermore, there is a lack of studies and data about the effects of air pollution on health in Turkey. To overcome data limitations, this report is based on extensive research and collaboration. The technical details of the coal plants which influence air pollution levels were studied, alongside real time electricity generation. Filtration systems, which can reduce but not eliminate pollution, were also studied.

Coal phase out as a triple win for health, clean air and the climate

The Turkish health sector recommends a full coal phase out, involving the closure of existing coal plants, an end to building new ones, and health and environmental impact assessments to allow informed energy choices.

In addition, the Turkish government should also increase their climate commitment, with e.g. adopting an ambitious 2030 greenhouse emissions reduction target as well as ratifying the Paris Agreement.

Doctors, nurses, asthma patients and groups of people affected by air pollution have a unique role to play and can add a long neglected perspective to the debate about Turkey's energy future. The report recommends that the capacity of health and medical organisations should be increased for further engagement in debates on the health impacts and costs of coal and energy production. It also recommends health professionals to highlight the true costs of coal power generation in economic and public health deliberations and decisions.

Furthermore, health ministries should have a place at the table in energy, climate and clean air decisions.

1.

The reliance on coal power generation in Turkey

Turkey, with a population of 82 million, has experienced the highest rate of increase in energy demand among OECD countries over the last 15 years[1]. 56% of its electricity is generated by burning fossil fuels, with coal accounting for 37%[2]. Over the last three years, the share of lignite, which is a domestic resource, has increased as a result of Turkey's energy policy.

As of December 2020, Turkey has 29 large[3] coal power plants that have a total installed capacity of 19,122 megawatt (MW). The majority of the plants rely on nationally mined coal (especially lignite), while ten plants are fuelled with imported coal. One third of the country's coal power plants are over 30 years old and all of these were installed by the government and have since been privatised in the 2000s and 2010s.

There are currently no coal plant retirement plans, and Turkey does not envisage an exit from coal.

While some new coal projects have been shelved in recent years, there are still over 30 new large coal power plants in the pipeline (permitted, announced or at pre-permit stage) totalling 33 GW[5] demonstrating that Turkey plans to rely on coal powered energy for decades to come[6].

Incentives in the form of subsidies or international cooperation are still a priority in Turkey's energy strategy. As a member of the Chinese Belt and Road Initiative, the government is actively seeking foreign investment in new coal plants especially from Chinese investors, including for the Hunutlu coal power plant in Adana city, Iskenderun Bay.

Fig. 1 Overview of installed large coal power plants (100 MW capacity) by fuel use and operator type[4], for 2019.

Uses domestic coal & operated by private sector

Uses domestic coal & state-owned

Uses imported coal & operated by private sector

Uses domestic coal & privatised since 2000

2.

The science: coal power, air pollution and health

Air pollution: the top environmental threat to people's health

According to the World Health Organization (WHO), air pollution is the largest environmental threat to people's health across the globe, in Europe and also in Turkey. Worldwide, air pollution, both ambient and indoor, leads to 7 million premature deaths each year[7].

In 2016, 37,000 premature deaths were attributed to ambient pollution in Turkey. Since then, the number of premature deaths and the health burden attributed to air pollution has continuously increased. According to a recent study based on WHO's calculation tool AirQ+, 45,398 premature adult deaths could have been prevented if ambient air pollution measured in Turkey in 2019 had been within WHO air quality guideline values[8].

The WHO says that no level of air pollution can be considered 'safe'[9] and the link between air pollution and respiratory and cardiovascular diseases is well established[9,10,11].

Breathing in particulate matter, even at low levels, can lead to physiological changes in the body that damage health. Poor air quality is also linked to chronic and acute respiratory diseases, which significantly degrades quality of life, such as bronchitis and the aggravation of asthma.

Scientists continue to identify new ways that air pollution can harm our health. For example, there is increasing evidence linking air pollution to dementia[12] and new evidence has shown that particles of air pollution travel through the lungs of pregnant women and lodge in their placentas, harming babies before they are born[13].

How air pollution from coal-fired power plants damages health

Each coal power plant emits huge amounts of hazardous air pollutants every year and has an average lifetime of at least 40 years. Allowing new coal power plants to be built would thus lock-in hazardous emissions for many years. It would also counterbalance short-term reductions in air pollutants achieved in other sectors.

When burning coal to generate electricity, four main health-harming pollutants are released into the air:

- **Particulate Matter** is the term used to describe small particles in the air. The number next to the abbreviation PM indicates the size of the particle; PM_{10} is 10 micrometers or less, while $PM_{2.5}$ is 2.5 micrometers or less. When inhaled, particles travel into the bloodstream and cause harm to our lungs and heart. They can cause stroke and lead to premature death. New studies also link PM with harm to the healthy development of children, and diseases such as obesity and Alzheimer's.

- **Sulphur dioxide (SO_2)** is classified as very toxic for humans when inhaled. It can cause severe irritation of the nose and throat. High concentrations can cause a life-threatening accumulation of fluid in the lungs (pulmonary edema). Symptoms may include coughing, shortness of breath, difficult breathing and tightness in the chest. Even a single exposure to a high concentration can cause a long-lasting condition like asthma. It can react in the atmosphere to form PM, called 'secondary PM'.

- **Nitrogen oxides (NO_x)** are gases that cause inflammation of the airways. They are oxidisers which means they cause oxidative stress which can disrupt normal cell mechanisms and cause damage to tissues, reducing the immune abilities of the body. They can react in the atmosphere to form PM, called 'secondary PM'.

- **Mercury (Hg)** is a neuro-toxic heavy metal that can cause both chronic and acute poisoning. Coal combustion is the second largest anthropogenic source of mercury emissions in the world. An EU study has shown that more than 1.8 million children are born every year with methylmercury (MeHg) exposures above the limit of 0.58 microgram per gram (µg/g), considered to be safe. About 200,000 of these babies were found to exceed the stricter WHO recommendation of limit of 2.5 µg/g. Preventing exposure was estimated to save a potential of more than 600,000 IQ points annually, corresponding to a total economic benefit of between 8-9 billion EUR per year[14].

Turkey has tightened its air pollutant standards for some pollutants, such as PM_{10}, SO_2 and NO_2, to align with EU limits (which are still higher than WHO's recommendations - See Annex 3). But, as of December 2020, neither a standard nor comprehensive monitoring for fine particulate matter, $PM_{2.5}$, has been defined - a crucial necessity to assess health burdens and pollution sources.

Table 1 Air pollution limits for selected pollutants (in µg/m³)

Pollutant	Period	WHO Air Quality Guidelines	EU Directive (2008/50/EC)	Turkey's Regulation (2019-2023)
PM_{10}	24-hour mean	50	50	50
	Annual mean	20	40	40
$PM_{2.5}$	1 hour	25	-	-
	Annual mean	10	25	-
SO_2	1 hour	-	350	350
	24 hour-mean	-	125	125
NO_2	1 hour	200	200	250 200*
	Annual mean	40	40	40

WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide – Global update 2005 – Summary of risk assessment. The guidelines are currently under revision with an expected update in 2021. https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

EU Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0050&from=en

* Turkey's limits are based on "Air Quality Assessment and Management Regulation". For NO_2 250 ug/m³ limit is set for 2019-2023 when the 200 ug/m3 limit is set for 2024 and beyond. https://www.mevzuat.gov.tr/mevzuat?MevzuatNo=12188&MevzuatTur=7&MevzuatTertip=5

How air pollution from coal-fired power plants damages health

Brain

- Increased cerebrovascular ischemia
- Dementia

Blood

- Altered rheology
- Increased coagulability
- Translocated particles
- Peripheral thrombosis
- Reduced oxygen saturation

Cells

- Bladder cancer
- Skin cancer
- Obesity
- Diabetes

Lungs

- Inflammation
- Oxidative stress
- Accelerated progression and exacerbation of COPD
- Increased respiratory symptoms
- Effected pulmonary reflexes
- Reduced lung function
- Higher lung cancer risk

Heart

- Altered cardiac autonomic function
- Oxidative stress
- Increased dysrhythmic susceptibility
- Altered cardiac repolarisaion
- Increased myocardial ischemia

Children

- Pre-eclampsia of the pregnant mother
- Pre-term birth
- Reduced birth weight
- Pollutants can reach the placenta
- Increased asthma risk, and increased frequency of attacks for already asthmatic children
- ADHD

Vasculature

- Atherosclerosis, accelerated progression and destabilisation of plaques
- Endothelial dysfunction
- Vasoconstriction and hypertension

Source: Adapted from APHEKOM project 2012; and Pope&Dockery 2006, as well as REVIHAAP 2013.

3.

Gap in transparency: emissions data not publicly available

Air pollutant and greenhouse gas emissions from large combustion plants in Turkey, including coal power plants, are not shared with the public at utility level. This lack of transparency is contrary to the practice in e.g. the European Union, where member states are legally obliged to report air pollutant emissions at plant scale annually, under the European Pollutant Release and Transfer Register Regulation (E-PRTR)[15].

Turkey's Ministry of Environment and Urbanization monitors large combustion plants, including coal power plants, and applies penalties when stack emission limits are exceeded. However, this real time data belongs to the Ministry and is not shared with the public.

Turkey is a signatory of the Convention on Long-Range Transboundary Air Pollution (CLRTAP) and the European Monitoring and Evaluation Programme (EMEP)[16]. The government is therefore required to submit data on annual emissions[17].

But as emissions from electricity and heating sectors are reported together, it is impossible to deduct emissions solely from coal power generation, or even from the electricity sector as a whole[18]. Furthermore, Turkey has not signed other important technical agreements to limit and cooperate on other pollutants[19].

The lack of transparency prevents a rational and informed debate about improving air quality and health in the country.

4.

Results: assessing the health economic cost of existing coal in Turkey

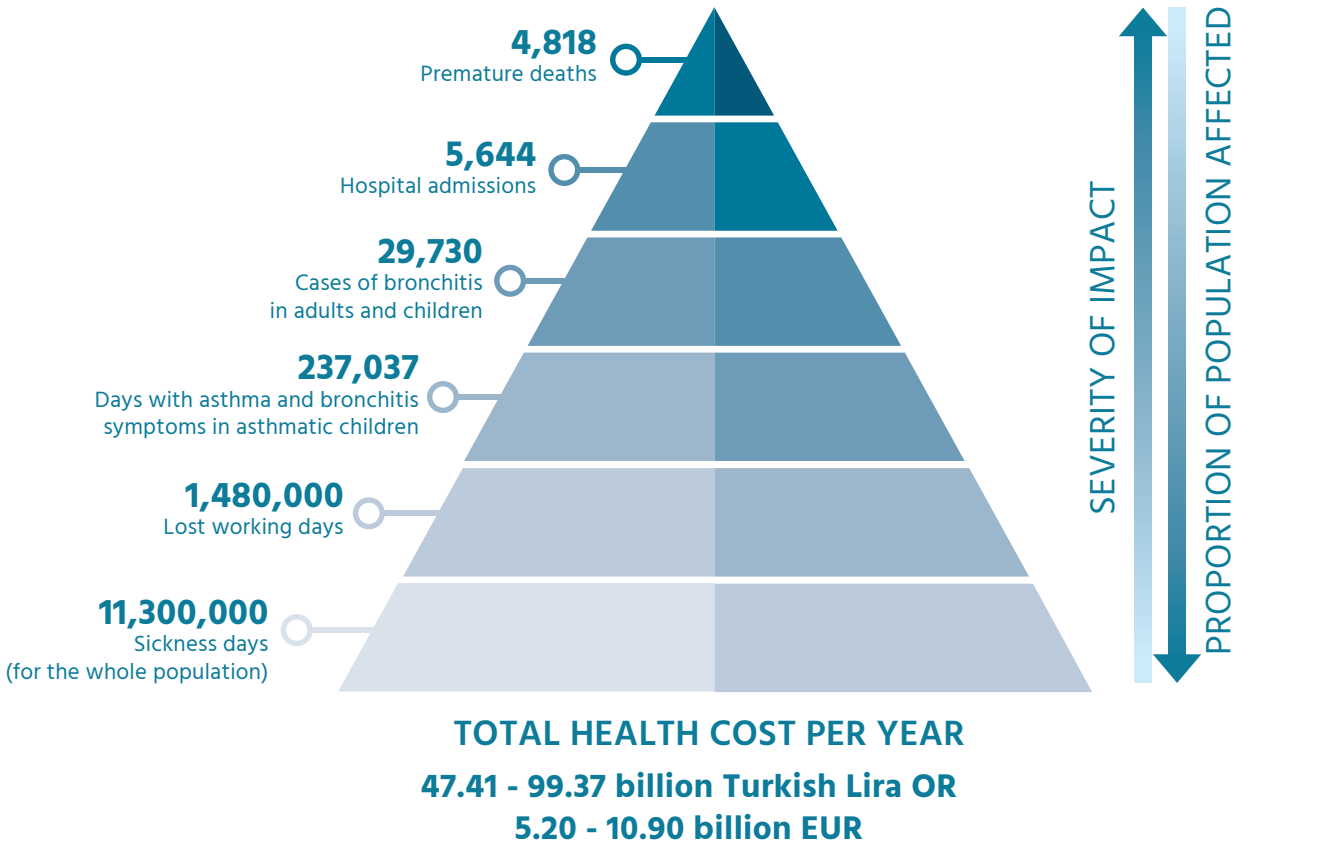
The current health burden

In 2019, 28 of the 29 installed coal power plants were operational, emitting air pollution and impacting health near and far.

For 2019 alone, health impacts include 4,818 premature deaths[20], 3,070 cases of preterm births, 26,500 cases of bronchitis in children, 3,230 new cases of chronic bronchitis in adults, 5,664 hospital admissions due to respiratory and cardiovascular symptoms, 237,037 asthma and bronchitis symptoms in asthmatic children, 1,480,000 lost working days, 11,300,000 sickness days and 8,850 lost IQ points (details can be found in Annex 1).

The economic cost of these health impacts in Turkey and across the region are 47.41 - 99.37 billion Turkish Lira, or 5.20 - 10.90 billion EUR[21]. The health costs of coal power generation in Turkey alone amount to 26.07 - 53.60 billion TRY (2.86 - 5.88 EUR), which is equivalent to 13 - 27% of Turkey's health expenditure (201.03 billion TRY or 22.05 billion EUR)[22, 23].

Fig. 2 Estimated health impacts of air pollutant emissions from coal-fired power plants in Turkey in 2019



Specific impacts on children's health

Children are particularly vulnerable to air pollution as their bodies are still developing. Exposure to air pollutants may increase their risk to develop disease much later in life. It is not (yet) possible to quantify and monetise this health risk over a lifetime. However, children's vulnerability as a whole should be considered in policy deliberations.

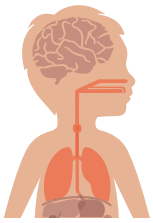
Mercury is a pollutant of particular concern to children's health, preventing them from developing their full potential. Mercury is a highly toxic substance, and combustion is the second-largest source of human-made mercury emissions worldwide. Mercury from coal plants enters the water cycle, and travels up the food chain. The main exposure to Europeans is in its neurologically damaging form, methylmercury, which happens through fish consumption. Contaminated fish is especially worrying for pregnant women and small children. An analysis from 2013 showed that in the EU, more than 1.8 million children are born every year with mercury exposure above a threshold that is considered safe.[14]

This harmful mercury exposure may reduce children's IQ and consequently decrease their educational and working achievements over a lifetime, with implications for society and the economy overall. Thus the damage from mercury is permanent.

In this report, the health impacts of mercury emissions were calculated following the health impacts per kilogram of emissions (see Annex 4 for details).

Fig. 3 Selected impacts on children's health from chronic coal pollution in Turkey, in 2019

27
Deaths of children up to 1 year, per year



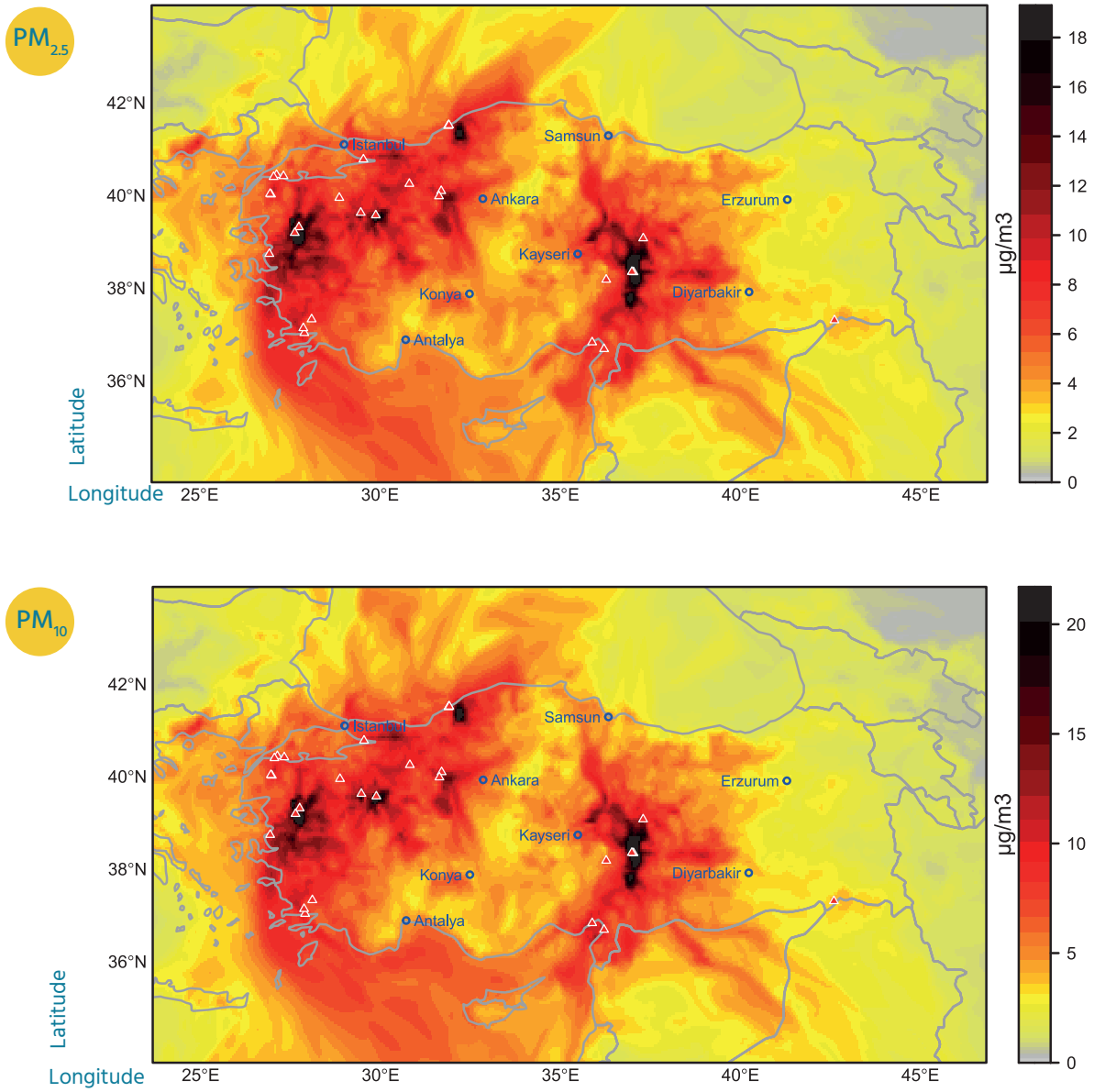
237,037
Days of asthmatic and bronchitis symptoms in asthmatic children per year

26,500
New cases of bronchitis in children per year

3,070
Preterm births per year

8,850
Lost IQ points per year

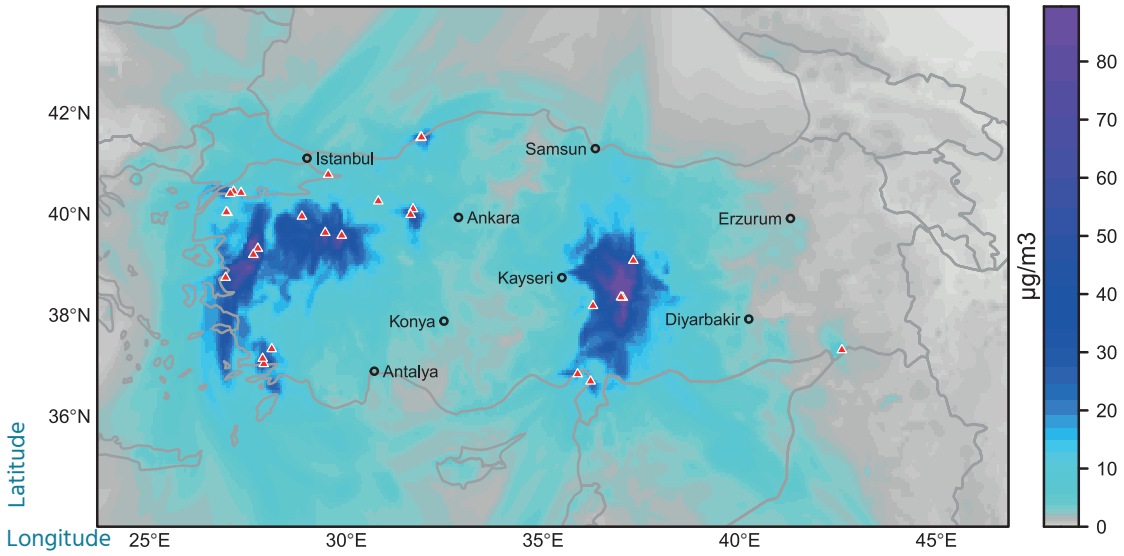
Fig. 4 Modelled pollutant dispersion of particulate matter ($PM_{2.5}$ and PM_{10}) from the 28 operating large coal plants in Turkey, operating in 2019, 24 hours max concentration



Legend: µg/m³ = concentration of the pollutant; triangle = coal plants.
The maps only reflect the additional pollution from the plants.

The most heavily affected areas are the Afsin-Elbistan region and the "coal belt" between Zonguldak, Çanakkale and Milas-Muğla. Most major cities, including Istanbul, Ankara and İzmir are substantially affected, as is the entire Mediterranean seaboard and the part of the Black Sea coast stretching from Zonguldak to Istanbul. The dispersion shows the effect of prevailing northerly winds on the western coast around Canakkale, easterly (winter) and westerly (summer) winds in Afsin and Adana, and north-north westerly winds in Zonguldak. The mountainous terrain of Koroğlu and Eastern Taurus reduces dispersion to the east and northeast of the country, making these areas less affected. Overall, on 24 hour basis, Manisa, Kütahya and Maraş are the most polluted provinces in terms of PM emissions.

Fig. 5 Modelled pollutant dispersion of sulphur dioxide (SO_2) from the 28 operating large coal plants in Turkey, operating in 2019, 24 hours max concentration

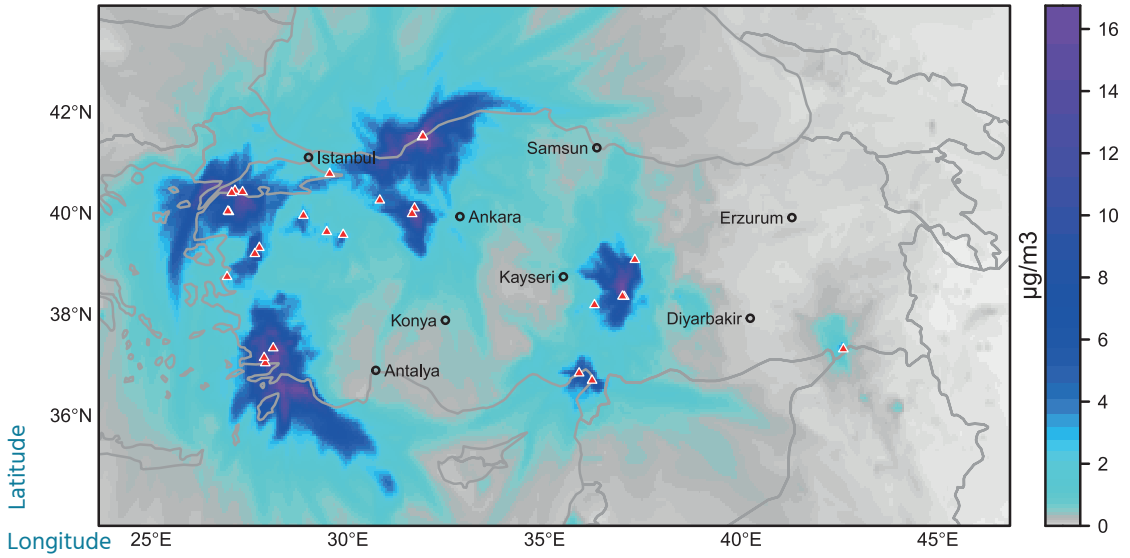


Legend: µg/m³ = concentration of the pollutant; triangle = coal plants.
The maps only reflect the additional pollution from the plants.

Even though there are no direct health impacts from SO_2 included in this report (in accordance with the recommendations of the HRAPIE study by WHO), SO_2 is a key pollutant to be considered and regulated, given that it contributes to PM formation (secondary PM), which in turn harms health.

According to Turkey's national dataset reported under CLRTAP, "public electricity and heat production" alone is the leading factor behind Turkey's emissions of sulphur oxides (the group of pollutants which include SO_2) similar to global trends. Energy has accounted for more than half of the SOx emissions since the first inventory in 1990 and since 2013 it has gone up from 60% to 70% in 2018. Over the last 20 years, the power plants that have been privatised and do not use filter technology for SO_x ($DeSO_x$ infrastructure), are the major contributor to Turkey's increasing SO_x pollution (these plants are the top 5 plants in term of SO_2 pollution).

Fig. 6 Modelled pollutant dispersion of nitrogen dioxide (NO_2) from the 28 operating large coal plants in Turkey, operating in 2019, 24 hours max concentration



Legend: µg/m³ = concentration of the pollutant; triangle = coal plants.
The maps only reflect the additional pollution from the plants.

Compared to PM, NO_2 hotspots are smaller in scale; the south-north axis of the Muğla region, the south western part of Çanakkale region and sea parallel axis of Zonguldak region are particularly affected.

The top existing polluters

The tables below show the top 10 polluting plants according to their estimated annual emissions of PM ($PM_{2.5}$ and PM_{10}), SO_2 and NO_x.

The model for this report's calculations takes boiler type, filtration type and efficiency, previous air pollution monitoring (if there is any) and coal specific data such as calorific value, sulfur and dust content of the coal into account. All these elements affect the stack emissions of PM, SO_2 and NO_x shown in figure 7,8 and 9 (below).

Fig. 7 Top 10 polluting plants in Turkey by PM emissions in 2019 (in tonnes/year)

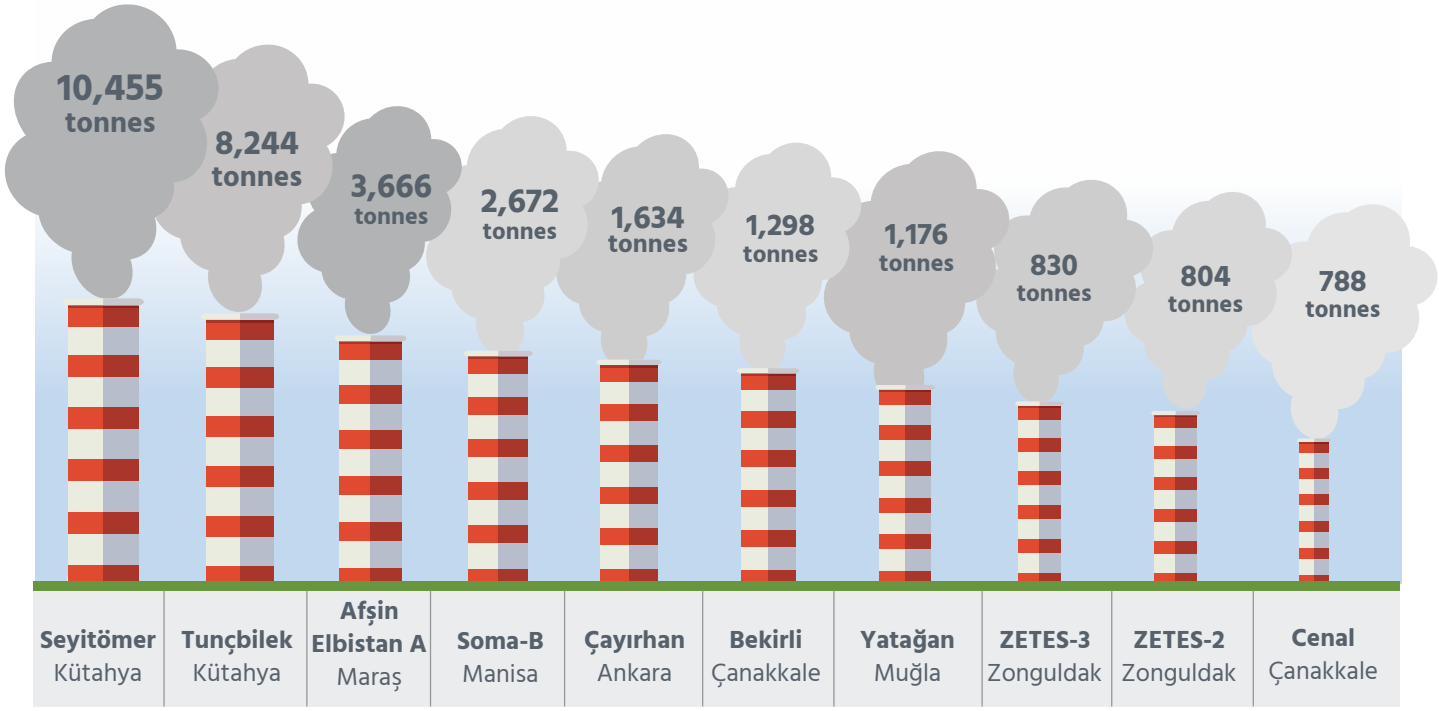


Fig. 8 Top 10 polluting plants in Turkey by SO_2 emissions in 2019 (in tonnes/year)

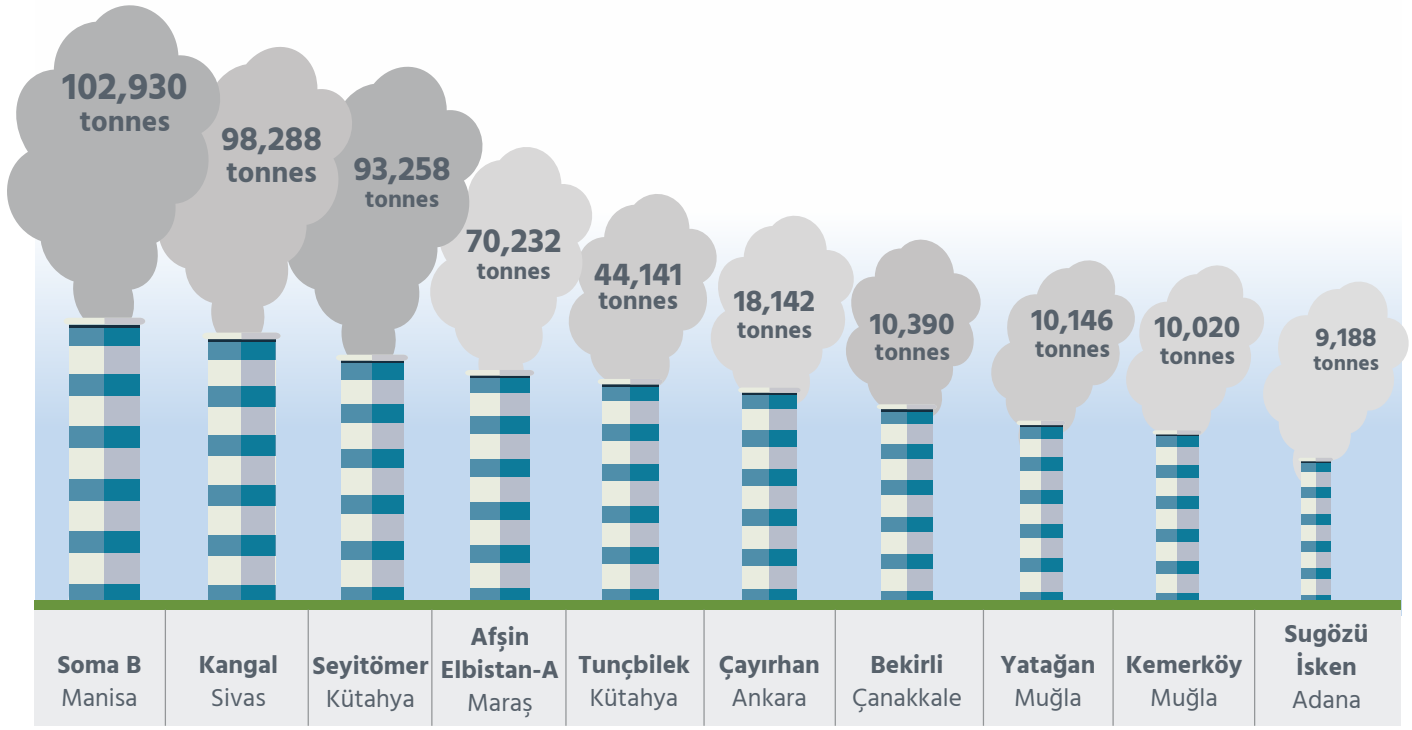
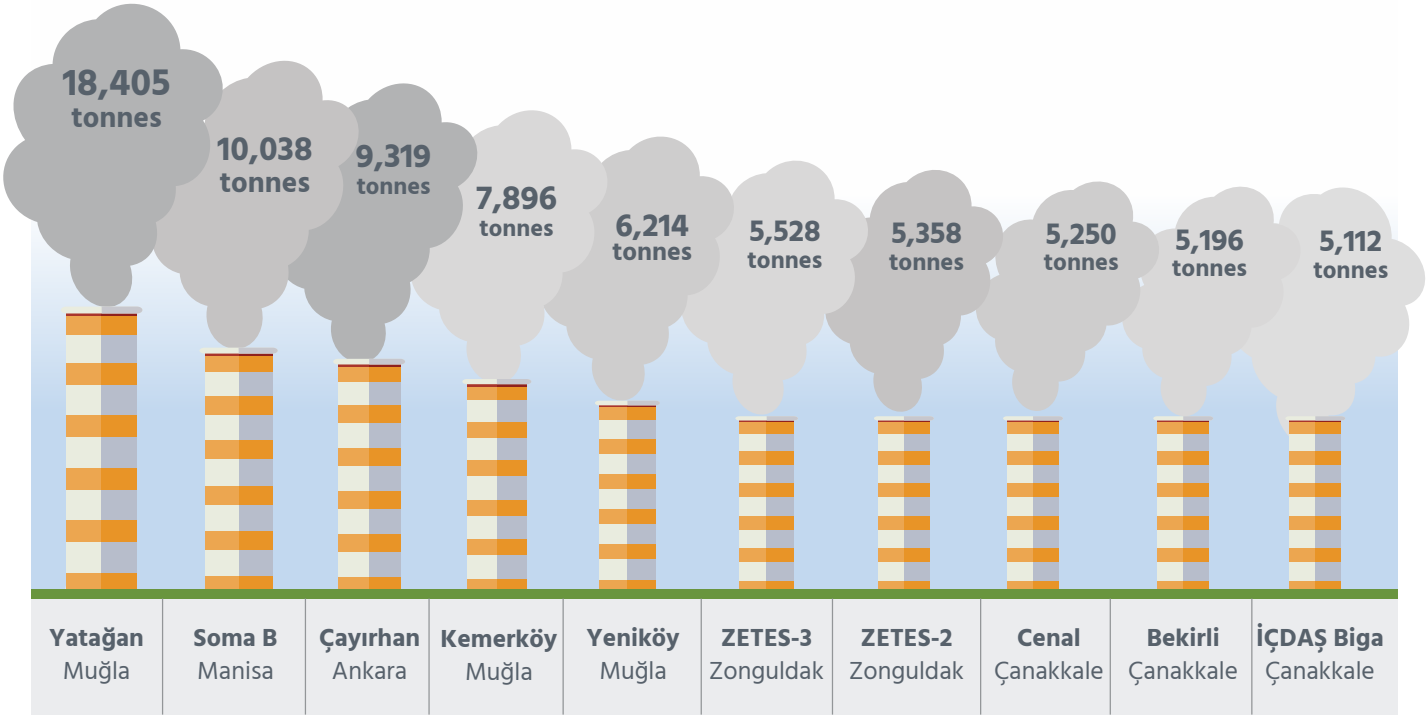


Fig. 9 Top 10 polluting plants in Turkey by NO_x emissions in 2019 (in tonnes/year)



Methodology

This report quantified the air pollution emissions from operating coal power plants and calculated the health impacts and costs those emissions cause. It analyses the coal plants' filtration systems, coal index and burning technologies, which are key factors in controlling air pollution, alongside real time electricity generation data to bring some transparency to the air pollutant emissions from coal power plants.

In 2015, HEAL published the "Unpaid Health Bill" report[24,25], which calculates the health burden from air pollution based on a top down model that considers Turkey's report to CLRTAP, on heating and electricity production, and a Global Burden of Disease Approach[26].

This report adopted a more detailed methodology that calculates stack emission by plant by paying attention to plant design such as type and efficiency of boilers, dust, NO_x and SO_x filters, sulfur, dust and moisture content of the coal, real time electricity generation in 2019. This information was obtained through research, data from previous EU twinning projects, operators' reports, websites and presentations, and official requests for plant specific information from Directorates of the Ministry of Environment and Urbanisation at city levels. 2020 was not studied as several plants were not in operation for a period of time during the year due to the installation of air pollution filtration systems.

The methodology to calculate the health impacts and costs is scientifically agreed, and has been developed and used by the EU Commission and WHO.

The methodology in four steps is detailed in Annex 4 of this report.

5.

Focus on coal hotspots: Çanakkale, Adana and Hatay, Eskişehir and Muğla

Çanakkale: Highest planned increase in coal power plant capacity

With a population of 520,000, Çanakkale is one of the provinces with the highest rural population in the Marmara Region and in Turkey as a whole. Air pollution from coal plants is the most critical environmental problem in the province, according to the 2016 report from the Turkish Ministry of Environment and Urbanisation[27].

The province's industrial sectors are mainly dependent on agriculture and forestry, however environmentally hazardous sectors such as coal power plants, the iron, steel and cement industries and mining are still expanding[28].

There are five operating coal plants in Çanakkale city, some of which are already among the top 10 polluters in the country. According to this report's assessment, the Bekirli plant ranks as the 7th most polluting plant in terms of both SO_2 and PM emissions in Turkey, and the Cenal plant ranks as the 10th most polluting plant in terms of PM emissions.

Moreover, five new plants with a total capacity of 4,360 MW, are in the pipeline. Three have received permits and two are at the pre-permit stage[6].

The city and region can expect a significant increase in pollution, with dire health consequences.

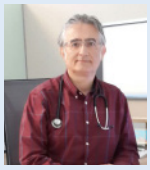
5 new plants
in the pipeline

Table 2 Air pollutant emissions from large coal power plants in Çanakkale

	Emissions (tonnes/year)						
	PM	SO_2	NO_x	Capacity (MWe)	Coal type	Filters installed	Year first unit operated
Bekirli	1,298	10,390	5,196	1,200	Imported hard coal	PM ✔ SO_x ✔ NO_x ✔	2011
Cenal	788	5,250	5,250	1,320	Imported hard coal	PM ✔ SO_x ✔ NO_x ✔	2017
İÇDAŞ Biga	510	4,089	5,112	405	Imported hard coal	PM ✔ SO_x - NO_x -	2005
18 Mart Çan	70	5,918	1,268	320	Lignite	PM ✔ SO_x - (2019) NO_x -	2005
Çan-2	157	1,045	1,045	330	Lignite	PM ✔ SO_x ✔ NO_x ✔	2018

In 2017, the Ministry of Environment and Urbanisation published the "Action Plan for Clean Air in Çanakkale" report. To improve air quality, the report lists actions such as decreasing coal use in domestic heating and decreasing personal electricity consumption. However, the report does not suggest measures for coal power plants. The report also flags sulfur pollution as a problem.

Both the 18 Mart Çan and Çan-2 coal power plants are using locally mined lignite coal. According to HEAL's analysis, SO_2 pollution from the 18 Mart Çan coal power plant is higher than Çan-2 as it delayed the installation of a $DeSO_x$ system until 2020 (table 2).



"The fundamental principle of the medical mission is to protect human health which means tackling the causes of the illness before it occurs. The protection of human health and the reduction of the health burden in Çanakkale city is only possible by controlling the use of coal for heating purposes and by ending the new coal-fired power plant projects in Çanakkale".

Haluk Çalışır
Associate Professor of the Turkish Thoracic Society

"Five coal power plants in Çanakkale city are already operating and more are being planned, despite the pollution they create. The Cenal coal power plant in Çanakkale city continues to operate even though lawsuits against its impact evaluation reports are ongoing. Turkey urgently must ratify the Paris Agreement and abandon coal-based energy production that worsens the climate crisis, threatens our health and environment."

Eftal Yıldırım
President of Çanakkale Chamber of Medicine

Adana and Hatay (İskenderun Bay)

Iskenderun Bay, in the south-east Mediterranean region of Turkey, is a densely populated area with three metropolitan cities - Adana, Mersin and Hatay. The total population of the region is almost six million and is expected to grow from migration from within Turkey and Syria.

The region's major economic activity is agriculture, with a large population of seasonal agricultural workers. It is also one of the major industrial regions of Turkey, hosting a considerable number of heavy, energy-intensive industrial facilities.

By the end of 2020, the region had three operating coal power plants (Tufanbeyli and Sugözü İsken in Adana and Atlas in Hatay provinces) with a total capacity of 2,860 MW. There are also five coal power plants planned in Adana province with a total capacity of 5,445 MW[6]. Three are at pre-permit stage, one is permitted, and the Hunutlu plant is currently under construction despite objections from health and environmental NGOs in the area, especially as there is an important and protected sea turtle nesting area where the power plant is being constructed[30].

According to this analysis, Sugözü İsken plant in Adana ranks as the 10th most polluting plant in terms of SO_2 emissions in Turkey. It is also the oldest in Iskenderun bay (table 3). Air quality in Adana city centre is already very poor[31].

Table 3 Air pollutant emissions from large coal power plants in Adana and Hatay

	Emissions (tonnes/year)						
	PM	SO_2	NO_x	Capacity (MWe)	Coal type	Filters installed	Year first unit operated
Sugözü İsken	690	9,188	4,594	1,210	Imported hard coal	PM ✔ SO_x ✔ NO_x ✔	2003
Atlas	256	5,102	5,102	1,200	Imported hard coal	PM ✔ SO_x ✔ NO_x ✔	2014
Tufanbeyli Enerjisa	393	2,613	2,613	450	Lignite	PM ✔ SO_x ✔ NO_x -	2016

In a previous assessment, HEAL estimated that 2,072 adult deaths could have been prevented in 2019, in Adana, if air quality concentrations were improved in-line with WHO recommendations. The assessment showed that air pollution was a factor in the deaths of one-fifth of people over the age of 30 in 2019[32].

Furthermore, an increase in the number and types of cancer incidents has already been observed in settlements around both operating coal plants in Iskenderun Bay[32].

According to research carried out in 2020, the three operating coal power plants are projected to be responsible for 5,350 premature deaths in their lifetime and the Hunutlu coal power plant, which is currently under construction, is projected to cause 2,080 premature deaths in its 40 year lifetime[32].

Concern about new coal plants has grown, especially in the case of Hunutlu, and in particular from health professionals, the Adana Chamber of Medicines, Adana Baro and civil society organisations. The Hunutlu coal power plant is China's biggest foreign direct investment in Turkey and a key project in both the Belt and Road Initiative (BRI).

In June 2020, more than 20 international and national civil society organisations sent a letter to several Chinese banks - the China Development Bank, ICBC and Bank of China - calling on them to withdraw their financial support for Hunutlu. They stated that it does not comply with the regulations in Turkey and international agreements in addition to the controversies that the project poses to China's green finance policies. Hunutlu is currently being built around the Sugözü beach, which is a protected nesting site under a 2009/10 memorandum issued by the General Directorate of Nature Conservation and National Parks. Construction of a power plant in this area would pose a threat to nesting sites and violate the Bern Convention and Convention on Biological Diversity of which both Turkey and China are signatories[32].

"An investment of this scale needs to benefit both China and Turkey, most importantly the local communities who will bear the impacts of the coal plant. We do not believe that the project that will operate on imported coal will provide any benefit to our communities and our country due to the negative impacts on the environment, climate and biodiversity. We demand support for clean sectors such as solar and wind which would benefit stakeholders in Turkey and China and we ask the Chinese banks to act on the basis of sustainable development and comply with China's green financing policies."

Sadun Bölükbaşı, M.D.
President of Adana Environment and Consumer Protection Association

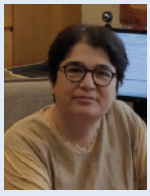
Eskişehir

Eskişehir is in the north western of Turkey with a population of 887,000. Both Eskişehir and its neighbouring Ankara (capital of Turkey) and Kütahya provinces have lignite mines and lignite powered coal plants. There is currently one large coal power plant, Yunus Emre, with a capacity of 145 MW, in Eskisehir city, installed in 2016 but it is not operating and has not been considered in the calculations used for this report as it did not operate regularly in 2019.

The planned Alpu 1,080 MW coal power plant is currently at pre-development stage.

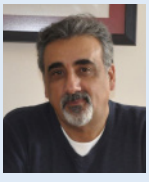
In 2018, health groups raised concerns about Alpu and both health and environmental groups have been calling for an official health impact assessment[34]. In 2020, health and environment groups published the Alpu Health Impact Assessment - the first time a health impact assessment has been carried out for for an individual coal power plant in Turkey[35].

1 new plant
in the pipeline



"The Alpu coal power plant and its effects on air pollution and public health should be re-evaluated and the tender process of the plant should be cancelled. The Alpu plant is designed to burn 7.8 million tonnes of coal annually, which is more than 156 times the amount used in homes for heating purposes. In addition, each 10µg/m³ increase of air pollutant emissions means a 15-27% increase in the premature death rates due to lung cancer".

Associate Prof. Dr. Çiğdem Çağlayan
HASUDER (The Assocation of Public Health Specialists in Turkey)



"In 2013, the World Health Organization classified outdoor air pollution as a "group-I" carcinogen, meaning "carcinogenic to humans". Eskişehir is one of the five cities in Turkey with the highest cancer death rates. If the planned Alpu coal power plant begins to operate, the number of cancer-related deaths in Eskişehir would significantly increase in the next 35 years."

Mehmet Akif Aladağ
President of Eskişehir-Bilecik Chamber of Medicine Management Board

Muğla

Muğla city is in south-west Turkey on the Aegean coast. It is the administrative capital of a province with a population of around 1 million people which is also home to internationally well-known tourist resorts.

For the past 38 years, coal has played a major role in the province of Muğla. There are three operating coal power plants, which are all older than 27 years and operate with lignite. Currently two new plants are in the pipeline at announcement and pre-permit stages, with a total capacity of 460 MW[6]. The region is also home to several lignite mines that feed the three plants. The construction of these mines destroyed agricultural land and eight villages[36].

According to HEAL's analysis, the Yatağan plant ranks as the 7th most polluting plant in terms of PM and 8th for SO_2 emission in Turkey when, the Kemerköy plant ranks as the 9th most polluting plant in terms of SO_2 emissions. All three plants operating in the region have $DeSO_x$ systems that reduce SO_2 emissions but still it is uncertain for the public whether these filters are in operation 24/7 or if they are regularly maintained given their age. Overall, filters cannot achieve zero pollution. According to recent research by CAN Europe, the three coal power plants are estimated to cause 280 premature deaths annually[36].

Table 4 Air pollutant emissions from large coal power plants in Muğla

	Emissions (tonnes/year)						
	PM	SO_2	NO_x	Capacity (MWe)	Coal type	Filters installed	Year first unit operated
Yatağan	1,176	10,146	18,405	630	Lignite	PM ✔ SO_x ✔ NO_x -	1982
Kemerköy	336	10,020	7,896	630	Lignite	PM ✔ SO_x ✔ NO_x -	1993
Yeniköy	278	8,488	6,214	420	Lignite	PM ✔ SO_x ✔ NO_x -	1986

"While air pollution and the climate crisis are being discussed all over the world, and it is announced by scientists that we have very little time to end this crisis, three coal power plants in the Muğla region continue to operate despite the complaints of the locals. The planned capacity increase and expansion of mining areas means destroying villages and forests. As a citizen and physician, based on information from residents, I am concerned that these power plants are not run under the necessary environmental precautions. Moreover, for more than a year, there is no information about the air quality in Yatağan due to the failure of the measurement device. We don't know what we breathe in such a risky zone."

Prof. Dr. Sebahat Genç
Chest Disease Specialist, Turkish Thoracic Society

6.
The cure: invest in healthy energy

COVID-19 has exposed the vulnerability of our health, our healthcare systems and our societies, and the need to ensure greater resilience. Globally, urgent action to reduce environmental pollution, climate change and the associated health consequences is needed more than ever.

To reduce the large health burden of fossil fuel powered energy generation, Turkey has to take into account the real external costs of different forms of energy production. Once these costs are considered, the only possible outcome is divesting from fossil fuels, and the phase out of coal power generation.

The real health and environmental costs of fossil fuels are still not being taken into account in the decision making process on electricity generation. According to a recent study, health costs caused by fossil fuels are 10 times higher than the costs of quantifiable subsidies allocated to fossil fuels[37]. The amount spent on both subsidies and external health and environment costs could be allocated to the health system.

Pollution filters will not solve the problem

Coal power plants have three types of filtration systems to capture dust (particulate matter - PM), SO_x (sulfur oxides) and NO_x (nitrogen oxides). They aim to reduce emissions from coal power station stacks to limits set by national legislation. In Turkey, some coal plants have all three types of filtration systems, however, a lack of data means it is impossible to determine whether all plants are comply with emission limits.

Even the best filtration systems are not a solution to chronic air pollution since they can only limit air pollutants emitted from stacks to a point, and there are concerns around efficiency of aged filters. Filters also do not prevent the release of CO_2 meaning that they do not reduce coal's role in driving climate change.

In addition to filters, the type and energy content of the coal, as well as the boiler technology, affect the air pollutant emissions released from stacks. Meanwhile, the stack design, such as its diameter and height, influences the distribution of this pollution.

All of these technical details are decided during the environmental permission stage and are designed to meet national legislation. In Turkey, there are two main regulations to limit industrial pollution: the "Air Quality Assessment and Management Regulation" on measured air pollution and the "Regulation on the Control of Industrial Air Pollution" on air pollution from industrial sources including coal power plants.

In 2013, air pollution limits stated in the Air Quality Assessment and Management Regulation were tightened (for 2019), and to adopt EU limits. In 2014, the Regulation on the Control of Industrial Air Pollution was also revised. However, all these limits are still higher than EU standards[39].

Public health win for better filtration systems

Between 2000 to 2015, 11 of the 19 plants fuelled by lignite and hard coal mined in Turkey were privatised. In 2013 and again in 2016, a series of incentives/exemptions were granted to private operators of coal power plants, which gave private operators a longer deadline of 31st December 2019 to comply with new requirements for filter technologies[38].

However, most of the new operators did not take any steps for better filters. In the beginning of 2019, the Turkish parliament discussed extending the deadline to comply with requirements for two more years, but following massive concerns from civil society, including from health groups, this extension of the exemption was cancelled.

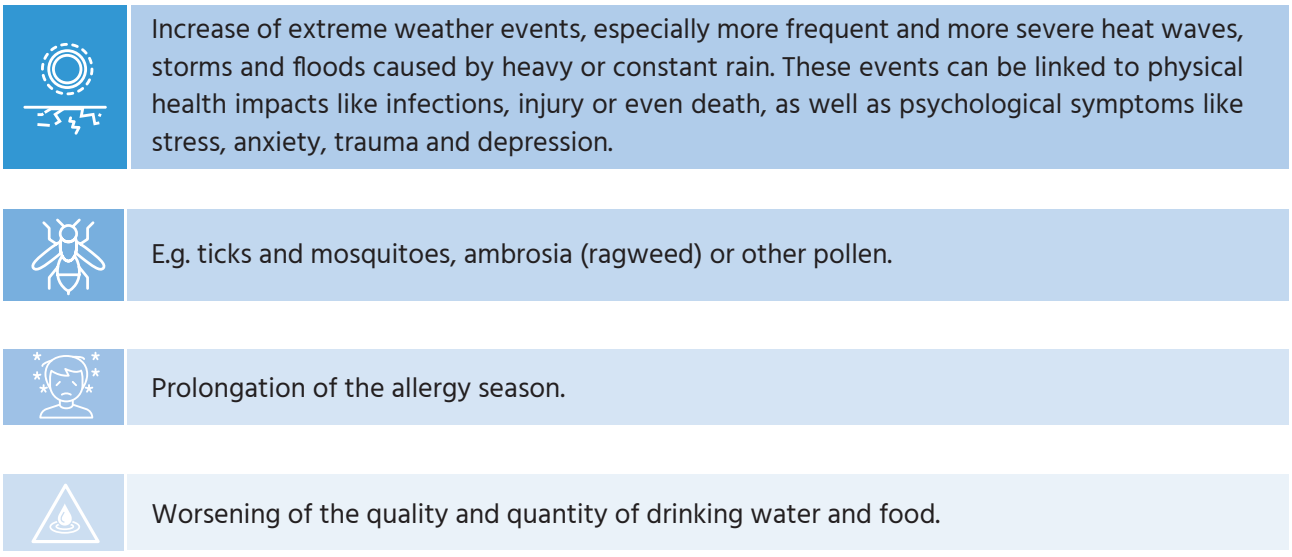
As a result, thirteen coal plants (eleven privatised and two public) were investigated: six were closed for the first half of 2020 and required to fully install filtration systems, four were given temporary environmental permits and required to apply for environment permits in 2020, and three were given permanent environment permits (for further details on filters see Annex 2).

Coal phase out a triple win: climate, clean air, health

Coal-fired power stations are not only a health concern because of the air pollution they emit. Burning coal for electricity also leads to the release of large amounts of CO_2, which fuels climate change, that in turn impacts our health in many ways.

The Lancet Countdown 2020 report has underlined that no continent, country or community is immune to the health impacts of climate change. Climate change affects many of the social and environmental determinants of health – clean air, safe drinking water, sufficient food and secure shelter.

Fig. 10 Health impacts from climate change[40]

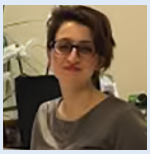


In 2015, recognising the importance of taking action to tackle climate change, world leaders adopted the Paris Climate Agreement. Its goal is to limit global warming to well below 2°C, preferably to 1.5°C, compared to pre-industrial levels.

Turkey is now the only G20 country which has not formally backed the Paris Agreement, and one of seven parties out of 197 that have not done so[41]. The CO_2 reduction goal it has set for 2030 is considered critically insufficient by independent assessments[42].

"Tackling global climate change is not a problem that can be postponed. If we do not take immediate action, we will be severely impacted by extreme weather events. Heat waves can cause death, as can infectious diseases, and food and water-borne diseases which could spread from other regions of the world. We will struggle with water scarcity, drought, insufficient nutrients and the pressures of mass migrations. This cannot be the future we want for our children. To stop climate change, we need to implement all measures, in particular we must phase out fossil fuels."

Prof. Dr. Çiğdem Çağlayan
Public Health Expert,
HASUDER, Right to Clean Air Platform-Turkey



"Defending the citizens' right to live in a clean environment is a fundamental duty for physicians. Therefore, to protect citizens and their right to live in a healthy environment, we demand the abandonment of fossil fuel-based energy generation."

Assoc. Prof. Dr. Gamze Varol
Turkish Medical Association, Right to Clean Air Platform-Turkey,
Head of the Public Health Department at Namık Kemal University

7.

Recommendations and health sector engagement to end the coal addiction

Recommendations for Turkish policy-makers

- Close all existing and ageing coal-fired plants as soon as possible and do not build new ones.
- Make informed energy choices based on health and environment impact assessments, and economic cost and benefits analyses that include short and long term local and transboundary impacts.
- Improve transparency and allow for scientific assessments by reporting emissions from the electricity sector in a transparent manner. This includes making data on emissions from large combustion plants, including coal power plants publicly available (and reporting data to E-PRTR), to allow independent research and assessment to be carried out.
- Make statistics on the health status of the population and cases of disease at local level publicly available.
- Make energy sector planning more streamlined by connecting strategies and legislation from economic, energy and environmental sectors and increase transparency by allowing experts and the general public to participate.
- Opt for sustainable forms of renewable energy and energy savings. Take advantage of the falling costs of solar and wind.
- Ratify the landmark Paris Climate Agreement, and set an ambitious Nationally Determined Contribution, as well as targets for increasing the share of renewables. A stronger commitment to climate change also includes the adoption of an ambitious 2030 GHG reduction target, and targets for renewable energy, energy efficiency. All these measures will lead to public health benefits as well as cost savings.

Recommendations for the health sector

- Increase health and medical organisational and individual capacity to engage in debates on the health impacts and costs of coal and energy production, through communication and by providing evidence, e.g. in public consultations.
- Highlight the evidence and materials produced by the World Health Organization (WHO), including the WHO manifesto for a healthy recovery from COVID-19[43], the WHO strategy[44] and roadmap on health, environment and climate change[45], the WHO resolution on addressing the health impact of air pollution[46], as well as the WHO Ostrava Ministerial Declaration on environment and health, to enable better air quality and climate action for greater public health gains and a quicker energy transition.
- Share the Lancet Countdown's publications[40], which highlights that every country, whether rich or poor, is already affected by climate change.
- Highlight the true costs of coal power generation in economic and public health deliberations and decisions, and work towards increasing public understanding of how public health will benefit from reducing coal's unpaid health bill.
- As health ministries, participate and provide input to the development and implementation of clean air activities and plans, as well as energy and climate policies, supporting measures to reduce coal pollution and ambitious phase out plans and mitigation measures.

8.

Annexes

Annex 1: Health impacts and associated health costs

Table 1 Estimated health impacts of air pollutant emissions from coal-fired power plants in Turkey and across the region in 2019

Effect	Pollutant	Unit	Impacts
Deaths	all	cases	4,818
- Adult deaths	$PM_{2.5}$	cases	4,270
- Deaths of children up to 1 year	$PM_{2.5}$	cases	27
- Adult deaths	NO_2	cases	173
- Adult deaths	mercury	cases	352
Preterm birth	$PM_{2.5}$	cases	3,070
Bronchitis in children	PM_{10}	number of children affected	26,500
Incidence of chronic bronchitis in adults	PM_{10}	new cases	3,230
Respiratory and cardiovascular hospital admissions	$PM_{2.5}$, NO_2 and ozone	cases	5,664
Asthmatic and bronchitis symptoms in asthmatic children	PM_{10} and NO_2	days	237,037
Work days lost (age 20-65 years)	$PM_{2.5}$	days	1,480,000
Sickness days (for the population up to 20 years, and over 65)	$PM_{2.5}$	days	11,300,000
Neurological damage (lost IQ points)	mercury	lost IQ points per year	8,850

Table 2 Estimated economic cost of health impacts associated with air pollutant emissions from coal-fired power plants in Turkey in 2019, million EUR

Effect	Pollutant	Unit	Low	High
Deaths	all	cases	4,730	10,003
- Adult deaths	$PM_{2.5}$	cases	4,400	8,950
- Deaths of children up to 1 year	$PM_{2.5}$	cases	36	122
- Adult deaths	NO_2	cases	215	542
- Adult deaths	mercury	cases	82	397
Preterm birth	$PM_{2.5}$	cases	65	142
Bronchitis in children	PM_{10}	number of children affected	-2*	14
Incidence of chronic bronchitis in adults	PM_{10}	new cases	45	201
Respiratory and cardiovascular hospital admissions (including stroke)	$PM_{2.5}$, NO_2 and ozone	cases	0	9
Asthmatic and bronchitis symptoms in asthmatic children	PM_{10} and NO_2	days	9	7
Work days lost (age 20-65 years)	$PM_{2.5}$	days	41	55
Sickness days (for the population up to 20 years, and over 65)	$PM_{2.5}$	days	308	387
Neurological damage (lost IQ points)	mercury	lost IQ points per year	8	40
TOTAL			**5,200**	**10,900**

Low and high values correspond to the 95% confidence intervals of the concentration-response functions, except for mercury damage costs which correspond to the low and high estimates in AMAP/UN Environment (2019) emission data.

*Ozone results and relative SOMO35 are negative because the net effect of the power plant emissions on total population ozone exposure is negative. Ozone chemistry is complex, and SO_2 emissions can reduce ozone formation, while NO_x emissions varyingly increase or decrease ozone formation depending on whether ozone formation is limited by NO_x or VOC availability.The sign of the impact can vary by area and by time of year even for the same power plant. These negative results are reflected on "Bronchitis in children".

Table 3 Estimated health impacts of air pollutant emissions from coal-fired power plants in Turkey only, in 2019

Effect	Pollutant	Unit	Impact
Deaths	all	cases	1,852
- Adult deaths	$PM_{2.5}$	cases	1,670
- Deaths of children up to 1 year	$PM_{2.5}$	cases	16
- Adult deaths	NO_2	cases	166
- Adult deaths*	mercury	cases	
Preterm birth	PM_{25}	cases	1,345
Bronchitis in children	PM_{10}	number of children affected	12,043
Incidence of chronic bronchitis in adults	PM_{10}	new cases	1,452
Asthmatic and bronchitis symptoms in asthmatic children	PM_{10} and NO_2	days	102,922
Respiratory hospital admissions	$PM_{2.5}$, NO_2 and ozone	cases	1,490
Cardiovascular hospital admissions (including stroke)	$PM_{2.5}$ and ozone	cases	1,209
Work days lost (age 20-65 years)	$PM_{2.5}$	days	282,193
Sickness days (for the population up to 20 years, and over 65)	$PM_{2.5}$	days	5,163,216
Neurological damage (lost IQ points)*	mercury	lost IQ points per year	

*Health effects and costs from mercury are not feasible to be calculated within any country boundary.

Table 4 Estimated economic cost of health impacts associated with air pollutant emissions from coal-fired power plants in Turkey alone in 2019

Effect	Pollutant	Unit	Cost, mln EUR low	Cost, mln EUR high
Deaths	all	cases	2,598	5,420
- Adult deaths	$PM_{2.5}$	cases	2,367	4,811
- Deaths of children up to 1 year	$PM_{2.5}$	cases	27	91
- Adult deaths	NO_2	cases	205	518
- Adult deaths	mercury	cases		
Preterm birth	$PM_{2.5}$	cases	34	74
Bronchitis in children**	PM_{10}	number of children affected	-1	6
Incidence of chronic bronchitis in adults	PM_{10}	new cases		2
Asthmatic and bronchitis symptoms in asthmatic children	PM_{10} and NO_2	days	0	3
Respiratory hospital admissions	$PM_{2.5}$, NO_2 and ozone	cases	0	3
Cardiovascular hospital admissions (including stroke)	$PM_{2.5}$ and ozone	cases	0	0
Work days lost (age 20-65 years)	$PM_{2.5}$	days	11	15
Sickness days (for the population up to 20 years, and over 65)	$PM_{2.5}$	days	192	241
Neurological damage (lost IQ points)*	mercury	lost IQ points per year		
TOTAL COST in Million EUR			**2,860**	**5,880**
TOTAL COST in Million TRY			**26,073**	**53,604**

Low and high values correspond to the 95% confidence intervals of the concentration-response functions, except for mercury damage costs which correspond to the low and high estimates in AMAP/UN Environment (2019) emission data.

*Health effects and costs from mercury are not feasible to be calculated within any country boundary.

**Ozone results and relative SOMO35 are negative because the net effect of the power plant emissions reduce ozone formation, while NO_x emissions varyingly increase or decrease ozone formation depending on whether ozone formation is limited by NO_x or VOC availability.The sign of the impact can vary by area and by time of year even for the same power plant. These negative results are reflected on "Bronchitis in children".

Annex 2: Overview on large coal plants included in this report

The table below lists the PM, SO_2 and NO_x emissions of the large coal power plants (in alphabetical order) on an annual basis.

Data on electricity generation has been retrieved from EPIAS Transparency Platform database, which is an official resource providing real time data. Boiler and filtration types as included in the table below have been retrieved from an article from the Chamber of Mechanical Engineers[47], the suspension status of the plants in 2020 was analysed from the official statement of the Minister of Environment and Urbanism[48].

Sources for further details at plant level can be found in "Annex 4".

Table 5 Details on Large Coal Power Plants, including Air Pollutant Emissions

Plant name	City	Capacity (MW)	Number of Units	Electricity Generation, 2019 (MWh)	Coal type (2019)	Boiler Type (2019)	Dust Suspension (2019)	$DeSO_x$ (2019)	$DeNO_x$ 2019)	First instalment	Age	PM emissions (tonnes/ year)	PM ranking (1-28)	SO_2 emissions (tonnes/ year)	SO_2 ranking (1-28)	NO_x emissions (tonnes/ year)	NO_x ranking (1-28)	Operator (2019)	Status in 2020
18 Mart Çan	Çanakkale	320	2	2,133,825	Lignite	Fluidized bed	Exist -EP	None	None	2005	15	70	27	5,918	13	1,268	26	Public	Inspected and was not suspended in 2020. Permanent environment permit was given in January 2020. $DeSO_x$ (wet limestone scrubbers) was installed in 2020.
Afsin Elbistan A	Kahramanmaraş	1,355	4	1,898,604	Lignite	Pulverized coal injection	Exist -EP	None	None	1984	36	3,666	3	70,232	4	4,316	16	Privatised in 2019	Inspected and all units were suspended for the first 6 months of 2020. Later 2 units had installed temporary $DeSO_x$ and gained temporary environment permits on 8th June 2020.
Afsin Elbistan B	Kahramanmaraş	1,440	4	2,772,803	Lignite	Pulverized coal injection	Exist -EP	Exist-Wet limestone scrubbers	None	2005	15	368	18	8,612	11	4,860	13	Public	Inspected and was not suspended in 2020. Temporary environment permit was given in January 2020.

Not suspended, received permanent environmental permits in January 2020

Not suspended, received temporary environmental permits in January 2020

Suspended for the first 6 months in 2020, received temporary environmental permits in June 2020

Inspected, partially suspended for the 12 months in 2020, partially received temporary environmental permits in January 2020

Plant name	City	Capacity (MW)	Number of Units	Electricity Generation, 2019 (MWh)	Coal type	Boiler Type	Dust Suspension	$DeSO_x$	$DeNO_x$	First instalment	Years after the first instalment	PM emissions	PM ranking	SO_2 emissions	SO_2 ranking	NO_x emissions	NO_x ranking	Operator	Status in 2020
Atlas	Hatay	1,200	2	8,501,980	Imported hard coal	Super critic-pulverized coal injection	Exist- Bag Filter	Exist-Wet limestone scrubbers	Exist-SCR	2014	6	256	22	5,102	17	5,102	11	Private	No inspectation. Continues to operate.
Bekirli	Çanakkale	1,200	2	8,658,498	Imported hard coal	Super critic-pulverized coal injection	Exist -EP	Exist-Sea water	Exist-SCR	2011, 2014	9	1,298	6	10,390	7	5,196	9	Private	No inspectation. Continues to operate.
Bolu Göynük	Bolu	270	2	1,963,560	Lignite	Fluidized bed	Exist -EP	Exist-Wet limestone scrubbers	None	2015, 2016	5	206	24	1,378	26	1,378	25	Private	No inspection. Continues to operate.
Cenal	Çanakkale	1,320	2	9,166,738	Imported hard coal	Ultra super critic-pulverized coal injection	Exist -EP	Exist-Sea water	Exist-SCR	2017	3	788	10	5,250	16	5,250	8	Private	No inspectation. Continues to operate.
Çan-2	Çanakkale	330	1	1,523,738	Lignite	Critical pulverize (pulverized coal injection)	Exist -EP	Exist-Wet limestone scrubbers	Exist	2018	2	157	25	1,045	28	1,045	27	Private	No inspection. Continues to operate.
Çatalağzı	Zonguldak	300	2	1,493,878	Local hard coal	"Pulverized coal injection "	Exist -EP	None	None	1989	31	338	19	2,268	21	4,140	17	Privatised in 2014	Inspected and all units were suspended for the first 6 months of 2020. Later 2 units had installed temporary $DeSO_x$ and gained temporary environment permits in June 2020.
Çayırhan	Ankara	620	4	4,311,860	Lignite	Pulverized coal injection	Exist -EP	Exist-Wet limestone scrubbers	None	1987, 1997, 1998	33	1,634	5	18,142	6	9,319	3	Privatised in 2000 &2001	Inspected and was not suspended in 2020. Temporary environment permit was given in January 2020. In 2020, operator change to EUAS (public).
Çolakoğlu 2	Kocaeli	190	2	1,191,008	Imported hard coal	Fluidized bed	Exist -EP	Exist-Wet limestone scrubbers	None	2015	5	30	28	1,264	27	858	28	Private	No inspectation. Continues to operate.
İÇDAŞ Biga	Çanakkale	405	3	3,163,873	Imported hard coal	Fluidized bed	Exist -EP	None	None	2005	15	510	13	4,089	18	5,112	10	Private	No inspectation. Continues to operate.

Plant name	City	Capacity (MW)	Number of Units	Electricity Generation, 2019 (MWh)	Coal type	Boiler Type	Dust Suspension	$DeSO_x$	$DeNO_x$	First instalment	Years after the first instalment	PM emissions	PM ranking	SO_2 emissions	SO_2 ranking	NO_x emissions	NO_x ranking	Operator	Status in 2020
İzdemir	İzmir	350	1	2,484,070	Imported hard coal	Super critic-pul-verized coal injection	Exist -EP	Exist-Wet limestone scrubbers	Exist-SCR	2015	5	80	26	1,605	23	1,605	22	Private	No inspectation. Con-tinues to operate.
Kangal	Sivas	457	3	2,587,547	Lignite	Pulverized coal injection	Exist -EP	Exist-only in 3rd unit (wet limestone scrub-bers).	None	1989, 1990, 2000	31	503	14	98,288	2	4,921	12	Privatised in 2013	Inspected and 2 units without DeSOx systems were sus-pended for the first 6 months of 2020, the 3rd unit continued to operate. Later, 2 units had installed tem-porary DeSOx and gained temporary environment permits in June 2020.
Kemerköy	Muğla	630	3	4,127,562	Lignite	Pulverized coal injection	Exist -EP	Exist-Wet limestone scrubbers	None	1993, 1994, 1995	27	336	20	10,020	9	7,896	4	Privatised in 2014	Inspected and was not suspended in 2020. Permanent environment permit was given in Janu-ary 2020.
Orhaneli	Bursa	210	1	1,570,302	Lignite	Pulverized coal injection	Exist -EP	Exist-Wet limestone scrubbers	None	1992	28	459	15	1,819	22	3,528	18	Privatised in 2015	Inspected and was not suspended in 2020. Temporary environment permit was given in Janu-ary 2020.
Seyitömer	Kütahya	600	4	3,967,990	Lignite	Pulverized coal injection	Exist -EP	None	None	1973, 1977, 1989	47	10,455	1	93,258	3	4,843	14	Privatised in 2013	Inspected and all units were sus-pended for the first 6 months of 2020. Later 2 units had installed temporary DeSOx and gained temporary envi-ronment permits in June 2020.
Silopi	Şırnak	405	3	2,323,761	Asphal-tite	Fluidized bed	Exist -EP	None	None	2009, 2015	11	762	11	3,429	19	1,524	24	Private	No inspection. Con-tinues to operate.

Plant name	City	Capacity (MW)	Number of Units	Electricity Generation, 2019 (MWh)	Coal type	Boiler Type	Dust Suspension	$DeSO_x$	$DeNO_x$	First instalment	Years after the first instalment	PM emissions	PM ranking	SO_2 emissions	SO_2 ranking	NO_x emissions	NO_x ranking	Operator	Status in 2020
Soma Kolin	Manisa	510	2	2,527,179	Lignite	Fluidized bed	Exist -EP	Exist-Limestone with Circulating fluidized beds (CFB)	Exist-SNCR	2018	2	234	23	1,564	24	1,564	23	Private	No inspection. Continues to operate.
Soma B	Manisa	990	6	5,059,070	Lignite	Pulverized coal injection	Exist -EP	None	None	1982, 1985, 1986, 1991, 1993	38	2,672	4	102,930	1	10,038	2	Privatised in 2015	Inspected and 2 units had been suspended for 2020 when 4 units were given temporary environment permits on 1st January 2020. Soma-B provides household heating.
Sugözü İsken	Adana	1,210	2	7,109,924	Imported hard coal	Pulverized coal injection	Exist -EP	Exist-Wet limestone scrubbers	Exist-SCR	2003	17	690	12	9,188	10	4,594	15	Private	No inspectation. Continues to operate.
Tufanbeyli	Adana	450	3	3,283,071	Lignite	Fluidized bed	Exist -EP	Exist-Wet limestone scrubbers	None	2016	4	393	16	2,613	20	2,613	19	Private	No inspection. Continues to operate.
Tunçbilek	Kütahya	365	3	1,051,462	Lignite	Pulverized coal injection	Exist -EP	None	None	1965, 1977, 1978	55	8,244	2	44,141	5	2,608	20	Privatised in 2013 & 2015	Inspected and all units were suspended for the first 6 months of 2020. Later 2 units had installed temporary DeSOx and gained temporary environment permits in June 2020.

Plant name	City	Capacity (MW)	Number of Units	Electricity Generation, 2019 (MWh)	Coal type	Boiler Type	Dust Suspension	$DeSO_x$	$DeNO_x$	First instalment	Years after the first instalment	PM emissions	PM ranking	SO_2 emissions	SO_2 ranking	NO_x emissions	NO_x ranking	Operator	Status in 2020
Yatağan	Muğla	630	3	3,764,110	Lignite	Pulverized coal injection	Exist -EP	Exist-Wet limestone scrubbers	None	1982, 1983, 1984	38	1,176	7	10,146	8	18,405	1	Privatised in 2014	Inspected and was not suspended in 2020. Temporary environment permit was given in January 2020.
Yeniköy	Muğla	420	2	2,997,155	Lignite	Pulverized coal injection	Exist -EP	Exist-Wet limestone scrubbers	None	1986, 1987	34	278	21	8,488	12	6,214	5	Privatised in 2014	Inspected and was not suspended in 2020. Permanent environment permit was given in January 2020.
Yunus Emre	Eskişehir	145	2	0	Lignite	Fluidized bed	Exist -EP	Exist	None	2016, 2018	4	-		-		-		Private	-
ZETES 1	Zonguldak	160	1	1,141,181	Imported hard coal	Fluidized bed	Exist -EP	None	None	2010	10	369	17	1,475	25	2,212	21	Private	No inspectation. Continues to operate.
ZETES 2	Zonguldak	1,230	2	8,931,440	Imported hard coal	Super critic-pulverized coal injection	Exist -EP	Exist-Wet limestone scrubbers	Exist-SCR	2010	10	804	9	5,358	15	5,358	7	Private	No inspectation. Continues to operate.
ZETES 3	Zonguldak	1,400	2	9,211,843	Imported hard coal	Super critic-pulverized coal injection	Exist -EP	Exist-Wet limestone scrubbers	Exist-SCR	2016	4	830	8	5,528	14	5,528	6	Private	No inspectation. Continues to operate.

Annex 3: Comparison of air pollution limits in industrial pollution regulations

Limit values for Turkey are retrieved from the "Regulation on the Control of Industrial Air Pollution" (regulation number 29211, updated on 20.21.2014)[49]. Turkish Ministry of Environment and Urbanism is responsible to monitor the stack emissions of large industrial sources, including the coal power plants and apply charges if the limits are exceeded.

Limits values for the EU are retrieved from Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control)[50].

Table 6 Stack emission limit values for existing plants in Turkey

Thermal Power	Dust (mg/Nm^3)		SO_2 (mg/Nm^3)		NO_2 (mg/Nm^3)	
	2004	2019	2004	2019	2004	2019
≥50-100 MW	100	100	2000	2000	800**	600
≥100-300 MW			1300	2000-400*		
≥300-500 MW			1000			
≥ 500 MW		50	1000	400		200

*Linear reduction

**1,800 mg/Nm^3 if pulverized hard coal is used and hard coal leaves fusion(melted) ash, 1,300mg/Nm^3 if pulverized hard coal is used and hard coal leaves dry ash.

Table 7 Stack emission limit values for existing plants in the EU

Thermal Power	Dust (mg/Nm^3)		SO_2 (mg/Nm^3)		NO_2 (mg/Nm^3)	
	2016	2021	2016	2021	2016	2021
≥50-100 MW	30	18	400	360	300, 450**	270
≥100-300 MW	25	14	250	200	200	180
≥300 MW	20	10, 8*	200	130, 180***		150, 175****

*10 mg/Nm^3 until 1,000 MW capacity, 8mg/Nm^3 limit for and above 1,000 MW capacity.

**450 mg/Nm^2 for pulverized lignite injection boilers.

***180 mg/Nm3 for fluidized bed boilers,130 mg/Nm^3 for pulverized boilers.

****175 mg/Nm^3 for pulverized lignite injection boilers and fluidized bed boilers if the plant started operation before 7th January 2014. 150 mg/Nm^3 if the plant started operation after 7th January 2014 and uses pulverized coal injection (except lignite).

Table 8 Stack emission limit values for new plants in Turkey

Thermal Power	Dust (mg/Nm³)		So_2 (mg/Nm³)		NO_2 (mg/Nm³)	
	2004	2019	2004	2019	2004	2019
≥50-100 MW	100	50	2000	850	800*	400
≥100-300 MW		30	1300	200		200
≥300 MW			1000			

*1,800 mg/Nm³ if pulverized hard coal is used and hard coal leaves fusion(melted) ash, 1,300 mg/Nm³ if pulverized hard coal is used and hard coal leaves dry ash.

Table 9 Stack emission limit values for new plants in the EU

Thermal Power	Dust (mg/Nm³)		So_2 (mg/Nm³)		NO_2 (mg/Nm³)	
	2016	2021	2016	2021	2016	2021
≥50-100 MW	20	5	400	200	300, 400**	150
≥100-300 MW			200	150	200	100
≥300 MW	10		200, 150*	75	150,200***	85

*200 mg/Nm³ for fluidized bed boilers.

**400 mg/Nm³ for pulverized lignite injection boilers.

***200 mg/Nm³ for pulverized lignite injection boilers.

Annex 4: Methodology and sources for health impact modelling

The methodology used in this report can be summarised in four steps:

1. Identify the emission from coal power plants operating in Turkey in 2019.
2. Model the pollutant exposure resulting from the stack emissions.
3. Calculate the health impacts associated with modelled pollutant exposure.
4. Calculate the cost of the modelled health impacts.

1 Emissions

The main approach adopted in this project is based on the following equation for calculating the emissions rate:

ER = CAP / EFF * SFGV * FGC

CAP is the electric output capacity of the power generating unit, EFF is thermal efficiency, SFGV is the specific flue gas volume of the fuel per energy unit (in Nm^3/GJ) and FGC is the pollutant concentration in flue gas.

When possible, the values of FGC were based on plant-specific measurements or emission limit values. For new plants commissioned since 2010, emission limit values are generally based on Turkish regulation, making the assumption that pollution controls at the plants are designed to satisfy the regulatory emissions limit. For older plants, stack measurements were available from the LCP Twinning Project data (BMU 2006), IAEA (2006), Güven et al (2007), Ministry of Environment and Urbanization (2017) and from a 1994 measurement campaign[47]. Generally, measurements carried out at different times were consistent, but when this was not the case, expert judgment had to be used to assess which measurement was most likely to be representative of the current situation. Measurement values were discarded at plants that had substantial emission control retrofits after the time of measurement.

For older plants equipped with SO_2 controls that are not sufficient to meet the emission standards, FGC was calculated as:

FGC = FGC0 * (1 - CE)

FGC_0 is the pollutant concentration in untreated flue gas and CE is the pollutant control efficiency, or the percentage of the pollutant captured by the plant's emission control techniques. In most cases, a design efficiency of 95% was used. At plants lacking emission controls, CE is zero.

1

Emissions

For most plants burning domestic lignite, fuel calorific value (NCV) as well as dust (A), moisture (M) and sulfur (S) content were available from various sources compiled by HEAL. This information was used to calculate SFGV using empirical formula ISO EN-12952-15:

SFGV = [-0.06018 * (1 - A - M) + 0.25437 * (NCV + 2.4425 M)] / NCV

In other cases, default values of 350mg/Nm3 and 380mg/Nm3 were used for hard coal and lignite, respectively.

FGC_0 for SO_2 was calculated based on reported fuel sulfur content assuming full conversion of S into SO_2:

FGC_0 = S * 2 * NCV / SFGV

2 is the ratio of the molar masses of SO_2 and S.

Plant thermal efficiency was taken from LCP Twinning project data (BMU 2006)[51]. Where plant-specific data was not available, default values of 39%, 42% and 44% were used for subcritical, supercritical and ultra supercritical plants, respectively.

The dust emissions estimates were converted to PM_{10} using a PM_{10}:TSP ratio of 54/80 and to $PM_{2.5}$ emissions using a $PM_{2.5}$:PM_{10} ratio of 24/54, based on the U.S. EPA AP-42 default emissions factors for electrostatic precipitators at coal-fired utility boilers.

Annual emissions are then calculated based on the emissions rate and annual electricity generation of the plant, based on electric output reported on the EPIAS Transparency Platform[52].

Mercury emissions estimates were taken from AMAP/UN Environment (2019) Global Mercury Assessment 2018[53].

There are significant uncertainties in the emissions estimates, particularly related to control efficiencies. For some older plants, there is at least anecdotal evidence that design control efficiencies are not being achieved due to poor maintenance.

Details of plant-by-plant data

HEAL gathered required information at the plant level such as dust, moisture, sulphur and calorie content of the national mined coal lignite, hard coal and asphaltite, boiler technology and efficiency, stack dimension, filtration types and electricity generation in 2019.

For all coal power plants, electricity generation is retrieved from EPIAS Transparency Platform database[52], which is an official source and provides real time data, data on boiler and filtration types are retrieved from an article from Chamber of Mechanical Engineers[54], suspension status of the plants in 2020 were analysed from the official statement of the Minister of Environment and Urbanism[55].

1

Emissions

Dust, humidity and sulfur content for Orhaneli, Seyitömer, Tunçbilek, Soma B, Çan 18 Mart, Yatağan, Yeniköy and Kemerköy are retrieved from TR-2008-IB-EN-03 Twinning project report in 2012[56].

Sulfur content (based on information from the mine supplying the power plants) for Orhaneli, Afşin Elbistan A & B plants, and dust, humidity and sulfur content as well as calorific values for Çayırhan , Tufanbeyli, Silopi, Aksa Göynük plants were retrieved from a report of Turkish National Committee at World Energy Council in 2017[57].

Stack design, coal calorific value, and SO_2 control efficiency for Çan-2 and Çan 18 Mart power plants, were gathered from their EIA reports. Design efficiencies and stack characteristics were obtained from the Ministry of Environment at local levels via written official requests with Turkish Chamber of Environmental Engineers. For all coal power plants in Çanakkale, stack measurements were retrieved from an article on Çanakkale coal power plants[58].

Coal details for Atlas CPP were retrieved from the operator's website[59].

For Silopi, coal properties were obtained from the EIA report, stack details retrieved from an official answer to Turkish Chamber of Environmental Engineers request.

Coal use and properties as well as stack properties for Tufanbeyli were taken from EnerjiSA Presentation[60] on Turkish Coal Enterprise website.

2

Atmospheric modelling

The air quality and health impacts of the different scenarios (baseline and zero-out) were projected using the atmospheric chemical-transport model for the European region developed under the European Monitoring Programme Meteorological Synthesizing Centre - West (EMEP MSC-W) of the Convention on Long-Range Transboundary Air Pollution (CLRTAP). Model code (version rv4.36, based on the version used on the EMEP status reporting of the year 2020) and the required input datasets were provided by EMEP MSC-W and the Norwegian Meteorological Institute. These inputs include the baseline emissions inventory for 2015, containing the emissions from all source sectors and locations. This inventory was modified first by eliminating power sector emissions in the grid cells containing coal power plants in Turkey, and the model was run with this "zero-out" inventory to obtain a baseline without emissions from coal power. Simulations were then performed by adding the projected emissions from the power plants to the zero-out inventory and comparing the projected air pollutant concentrations to the zero-out results to project the air quality impact of the studied power plants.

3

Health impacts

The health impacts of the changes in pollutant concentrations in the different scenarios were assessed following WHO (2013) recommendations for health impact assessment of air pollution in Europe, as implemented in the report Europe's Dark Cloud (Huscher et al 2017).

The health impacts resulting from the increase in $PM_{2.5}$ concentrations, compared with the baseline simulation with no coal power emissions, were evaluated by assessing the resulting population exposure, based on high-resolution gridded population data for 2015 from CIESIN (2017)[61], scaled to national population totals in 2019, and then applying the health impact assessment recommendations of WHO HRAPIE (2013) as implemented in Huescher et al (2017), and with preterm births quantified using the concentration-response relationship established by Trasande et al (2016). Baseline mortality for different causes and age groups, and total population by age group for Turkey and neighboring countries were obtained from Global Burden of Disease results (GBD 2019), and baseline rates of preterm births were taken from Chawanpaiboon et al (2019)[62].

The health impacts of mercury emissions were calculated following the health impacts per kilogram of emissions for European coal-fired power plants derived by Nedellec&Rabl (2016)[63].

It is important to note that while the health impacts evaluated here do not include impacts from direct exposure to SO_2, SO_2 emissions are a major contributor to the $PM_{2.5}$ health impacts through formation of sulfate particles.

Table 10 Risk ratios (RRs) used for the health impact assessment, for a 10µg/m³ change in annual average pollutant concentration (95% confidence interval)

Effect	Pollutant	RR: central	RR: low	RR: high
Bronchitis in children, PM_{10}*	PM_{10}	1.08	0.98	1.19
Asthma symptoms in asthmatic children, PM_{10}*	PM_{10}	1.028	1.006	1.051
Incidence of chronic bronchitis in adults, PM_{10}*	PM_{10}	1.117	1.04	1.189
Long-term mortality, all causes	$PM_{2.5}$	1.062	1.04	1.083
Cardiovascular hospital admissions	$PM_{2.5}$	1.0090	1.0017	1.0166
Respiratory hospital admissions*	$PM_{2.5}$	1.019	0.9982	1.0402
Restricted activity days (applied to non-working age population)*	$PM_{2.5}$	1.047	1.042	1.053
Work days lost (age 20-65)	$PM_{2.5}$	1.046	1.039	1.053
Bronchitic symptoms in asthmatic children* (for 1µg/m³ change)	NO_2	1.021	0.99	1.06
Respiratory hospital admissions[64]	NO_2	1.018	1.0115	1.0245
Long term mortality, all causes*	NO_2	1.055	1.031	1.08
Preterm birth	$PM_{2.5}$	1.15	1.07	1.16

* Refers to Group-B which is identified as "pollutant–outcome pairs for which there is more uncertainty about the precision of the data used for quantification of effects" by the WHO HRAPIE project. However Group-B RRs were taken into account to prevent underestimates of the health risk.

Table 11 Factors used in assessing health impacts and economic costs of mercury emissions into the air (Nedellec & Rabl 2016)

Outcome	Cases/kg	Valuation, EUR, 2010 prices per kg	Valuation, EUR, 2019 prices per kg
Years of life lost	0.56	126,000	141,749
Deaths	0.054	NA	NA
Neurological damage (lost IQ points)	1.36	16,272	18,306

Mercury from coal power plants in Turkey disperse to the continent. Thus a limited and defined mercury emission at country scale was not possible. Considering these limitations, valuation in 2019 solely considers the inflation in the EU countries.

4

Economic costs

Air pollution causes a range of negative health impacts: chronic respiratory diseases, hospitalizations, preterm births and other health effects. These lead to increased health care costs; economic productivity loss due to sickness and inability to work, or due to an employee having to call in sick to care for an unwell child or other dependant; and shortened life expectancy welfare loss for affected people.

The original valuations were taken from EEA (2014)[65], given for the European Union in 2010 at 2005 prices, except for preterm births which was taken from Trasande et al (2016)[66]. The values were first converted to 2019 prices using European Union inflation rates, and then the valuations were adjusted for different levels of GDP per capita and costs.

Adjustment by GDP PPP refers to value transfer on the basis of GDP per capita at purchasing power parity, assuming an elasticity of 0.8. This is based on OECD recommendations for valuing mortality[67]. This adjustment is also applied to other health effects that are valued on a willingness-to-pay basis.

Adjustment by PPP means that the costs are scaled by the general cost levels of different countries, as measured by the price level ratio of PPP conversion used for calculating GDP PPP.

Adjustment by GDP means value transfer on the basis of GDP at market prices, with unit elasticity.

Price level ratio of PPP conversion for the European Union was calculated as a GDP-weighted average of the ratios for EU member states. All required economic data was obtained from the World Bank DataBank[68].

The valuation of different health impacts of major air pollutants is given in Table 9, and health impacts of mercury in Table 10.

Table 12 Valuation of health impacts (based on EEA 2014, except preterm births from Trasande et al 2016)

Effect Name	Valuation, EU, 2010	Valuation, Turkey, 2019	Adjustment
Long-term mortality, all causes	2,810,000	2,170,000	GDP PPP
Cardiovascular hospital admissions	2,810	875	PPP
Respiratory hospital admissions	2,810	875	PPP
Restricted activity days	54	42	GDP PPP
Work days lost	166	46	GDP
Postneonatal mortality	4,210,000	3,260,000	GDP PPP
Bronchitis in children	750	234	PPP
Asthma symptoms in asthmatic children	54	17	PPP
Incidence of chronic bronchitis in adults	68,400	53,000	GDP PPP
Bronchitic symptoms in asthmatic children	750	234	PPP
Short-term mortality, all causes*	2,810,000	2,170,000	GDP PPP
Preterm birth	275,000	51,800	GDP

* Short term mortality from all causes due to exposure to ozon are calculated in the model. However due to uncertainities over the chemisty of ozon in the atmosphere (see Annex 1- Table 2), the health burden is considered in the results (health effects and costs) but not listed in the report.

NOTES

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3. Large means an installed capacity over 100 MW.
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18. According to the national dataset "public electricity and heat production" alone is the leading factor behind Turkey's SO_x emissions. Energy has accounted for more than half of the SO_x emissions since the first inventory in 1990 and since 2013 it has gone up from 60% to 70% in 2018. Over the last 20 years, the power plants that have been privatised and do not use $DeSO_x$ infrastructure, are definitely a big contributor to Turkey's increasing SO_x pollution.
19. This includes the 1985 Helsinki Protocol on the Reduction of Sulphur Emissions, the 1994 Oslo Protocol on Further Reduction of Sulphur Emissions, the 1988 Sofia Protocol concerning the Control of Emissions of

Nitrogen Oxides or their Transboundary Fluxes, the 1991 Geneva Protocol concerning the Control of Emissions of Volatile Organic Compounds or their Transboundary Fluxes, the 1998 Aarhus Protocol on Persistent Organic Pollutants (POPs), the 1998 Aarhus Protocol on Heavy Metals, and the 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone.

20. Premature deaths are the combined number of premature deaths due to $PM_{2.5}$, NO_2 and mercury combined. To avoid the possible overlap identified with $PM_{2.5}$ mortality impacts identified by WHO (2013), 2/3 of the NO_2 mortality is included in the central estimates of total premature deaths, as well as in the low end of the confidence intervals, while the full mortality is included in the high end of the confidence interval.
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