Health Impacts of Germany's Proposed Coal Power Plant Emissions Limits

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CREA
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CREA is an independent research organisation focused on revealing the trends, causes, and health impacts, as well as the solutions to air pollution.

Key findings

- Based on the plant air pollution limits and coal phase-out schedule currently backed by the German government, emissions from German coal-fired power plants are set to be responsible for a projected 26,000 attributable deaths between 2022 and 2038.
- The social costs related to the associated healthcare, reduced economic productivity and welfare losses amount to an estimated present value of €73 billion.
- Requiring power plants that are allowed to operate beyond 2030 to apply best available air pollutant emissions control technology would reduce the number of air pollution-related attributable deaths by 65%, to 9,200 and costs to €21 billion.
- Bringing forward the coal phase-out to 2030, in line with the necessary carbon cuts for developed countries to uphold the Paris Agreement, would further halve the health impacts.

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Introduction

German hard coal and lignite-fired power plants are among the worst industrial polluters in Europe, responsible for an estimated 4,400 deaths in 2013, second only to Poland (Jones et al 2016).

The European Environment Agency's (2014) ranking of the industrial plants similarly found that out of the 20 European thermal power plants causing the most economic damage through their air pollutant emissions, five were in Germany.

Under the European industrial emissions regulation (Best Available Technology Reference documents for Large Combustion Plants, LCP BREF), each member state can set emissions limits for industrial plants within the range specified in the Union-wide reference documents. While the German government is still delaying the final transposition of these limits into national law, there are indications that policymakers are considering opting for the most lenient emissions limits that are allowed under EU law, with few exceptions. These limits are far from representing best available technology for public health protection, and also much weaker than those followed in e.g. China, Japan and South Korea.

We assessed the health impacts of air pollutant emissions from German power plants under the emission limits currently being proposed by the government, and under two alternative scenarios applying more stringent limits.

We projected air pollutant emissions by year from the entire fleet of German coal and lignite-fired power plants under the latest proposed emission limits in the General Binding Rules for large combustion plants (**GBR scenario**), assuming that power generation follows the phase-out timetable. This means lignite-fired power plants are closed in line with the phase-out law and tender procedure for hard coal plants follow a steady and linear phase-out path.

For each power plant, current average air pollutant concentrations in flue gas were estimated based on air pollutant and CO2 emissions reported for 2017, the latest year for which data is available. The emissions reductions resulting from applying new emissions norms were estimated on this basis.

In addition to the GBR emissions limits, we constructed two alternative scenarios. The **"BAT on all plants" scenario** assumes that all power plants, regardless of retirement year, are required to meet emissions limits corresponding to the use of best available pollution control techniques, resulting in meeting the lower (stricter) end of the emission ranges given in the LCP BREF. A more practical **"strong limits" scenario** assumes that large plants (>300MW_{th}) operating beyond 2030 are required to install best available technology, and the operating hours of other plants are limited to 17,500 hours over a period of 10 years. As a result, the same amount of power is generated from coal and the same amount of capacity is available at peak times, but air pollutant and mercury emissions over the 2020s are substantially lower. This approach more than halves total required investment in emission controls, compared with the option of requiring all plants to comply with the strictest limits, while achieving nearly all of the air pollutant emissions reductions.

Importantly, the amount of coal-fired power generation and amount of coal-fired capacity to meet peak demand is equal in all scenarios, so differences between the scenarios are solely due to different emissions control requirements and performance.

The air quality and health impacts of the different scenarios were projected using the atmospheric chemical-transport model for the European region developed under the European Monitoring Programme (EMEP) of the Convention on Long-Range Transboundary Air Pollution (CLRTAP) and WHO recommendations for health impact assessment of air pollution in Europe, as implemented in the report Europe's Dark Cloud.

What are attributable deaths and other attributable health impacts?
A strong body of scientific studies shows that long-term, chronic exposure to air pollution increases the risk of death from different diseases and the risk of different health conditions, such as asthma attacks. Based on such studies, the World Health Organization has recommended concentration-response relationships that link air pollution exposure to an increase in risk. Using these relationships, we can assess how much of the current health burden from different causes is attributable to air pollution - in other words, how many deaths or asthma attacks would be avoided annually if everyone was breathing clean air. Furthermore, by combining these concentration-response relationships with atmospheric models that track the dispersion, removal and chemical transformation of pollutants in the atmosphere, we can assess avoided deaths in alternative scenarios, such as reducing or eliminating the air pollutant emissions from German coal-fired power plants.

This approach enables us to say that a certain number of deaths or other health impacts would be avoided if air pollution exposure was reduced, even if we cannot pinpoint the specific people whose deaths were attributed to air pollution - just as we cannot tell if a specific person who died from lung cancer would have avoided this fate by not smoking.

A commonly used term for deaths linked to air pollution is “premature deaths”. This term dates back to a time when we only understood the short-term, acute impacts of air pollution which mainly affect people who are already ill. In the case of these acute impacts, the life of the affected person might be shortened by some months or days because of a spike in air pollutant levels. However, the current scientific understanding of the health impacts of air pollution is that most of these impacts relate to chronic, long-term exposure, rather than short-term spikes in pollution. The average loss of life from a death attributed to air pollution in Europe is approximately 10 years. Therefore, the term “premature” deaths could give the wrong impression.

Results

Under the government-proposed emissions limits ('GBR scenario'), German coal plants would cause a projected **26,000 attributable deaths** between 2022 and 2038. The 'strong limits' scenario would reduce this to **9,200 deaths** and require all plants to apply best available technology further to **5,800 deaths**.

The plants would emit an estimated cumulative total of **28,000 kilograms of mercury** over this period under the GBR scenario. This could be reduced by two thirds to **8,200 kilograms** in the strong limits scenario, and to **3,800 kilograms** if all plants had to install best available emissions controls. The mercury emissions permitted under the GBR scenario would lead to an estimated 1,100 deaths and harm to children's neurological development amounting to the loss of 400,000 IQ-points.

Health impacts and mercury emissions remain significant even in the stricter scenarios, as they assume Germany's coal power plants will continue to run until 2038. The cumulative CO2 emissions under this assumption also exceed the emissions budgets allowable under the goals of the Paris agreement. Health impacts and cumulative air pollutant and heavy metals emissions could be approximately halved by speeding up the phase-out timetable to 2030.

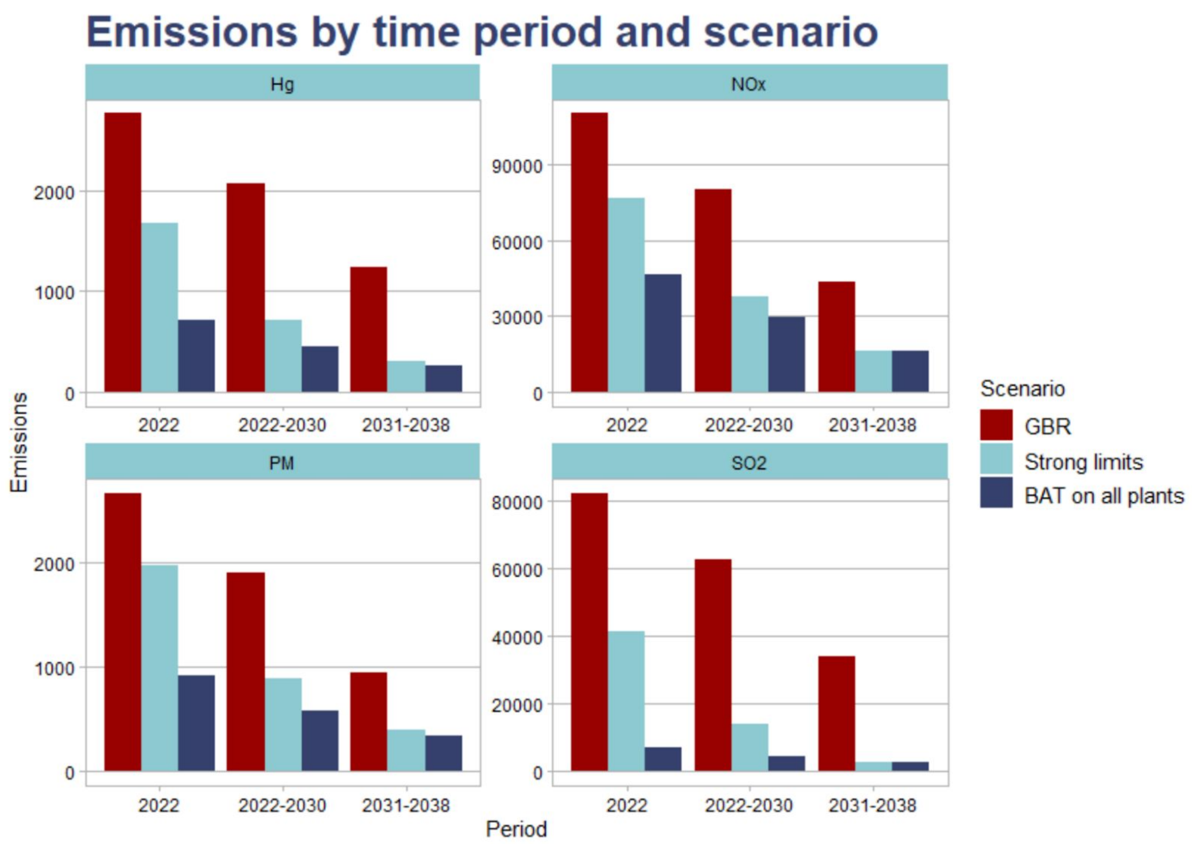


Figure 1. Average emissions of different pollutants by time period and scenario (tonnes per year for other pollutants; kilograms per year for mercury). PM refers to particulate matter (dust) emissions of all sizes.

Cumulative health impacts attributed to German coal power plants by scenario 2022-2038

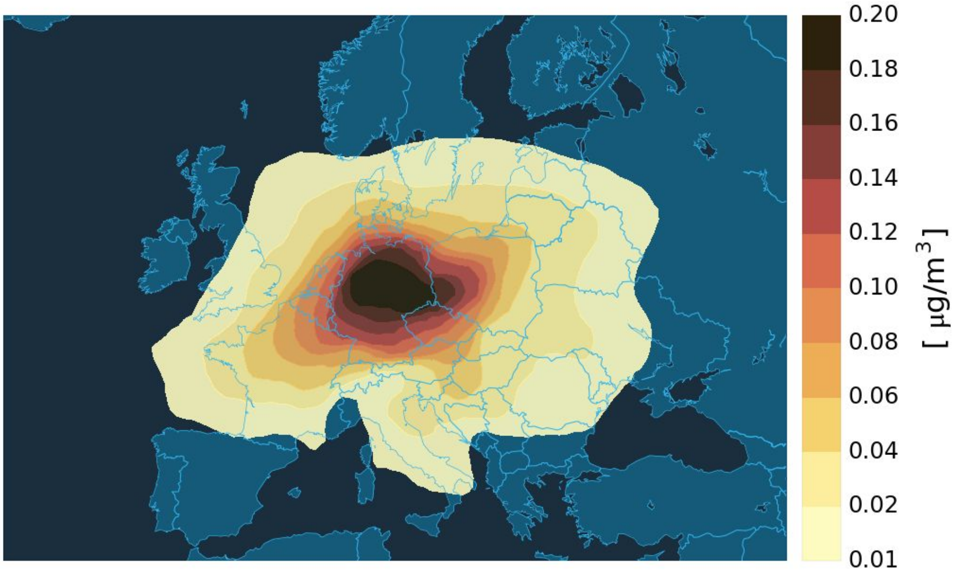
Effect	Pollutant	Unit	GBR	Strong limits	BAT on all plants
deaths	PM2.5	cases	18200	5850	4330
deaths	NO2	cases	7000	3100	2400
deaths	mercury	cases	1010	350	220
premature deaths	Total	cases	26200	9210	5820
asthmatic symptoms in children	PM10	days of symptoms	429000	142000	107000
bronchitic symptoms in asthmatic children	NO2	years of symptoms	1810	805	631
bronchitis in children	PM10	cases	36000	11800	8900
chronic bronchitis in adults	PM10	new cases	10400	3400	2560
hospital admissions	NO2	cases	4280	1880	1440
hospital admissions	PM2.5	cases	14400	4600	3390
lost working days	PM2.5	million days	7940000	2580000	1900000
preterm births	PM2.5	births	2700	860	460

Cumulative health costs attributed to German coal power plants by scenario 2022-2038 (EUR mln)

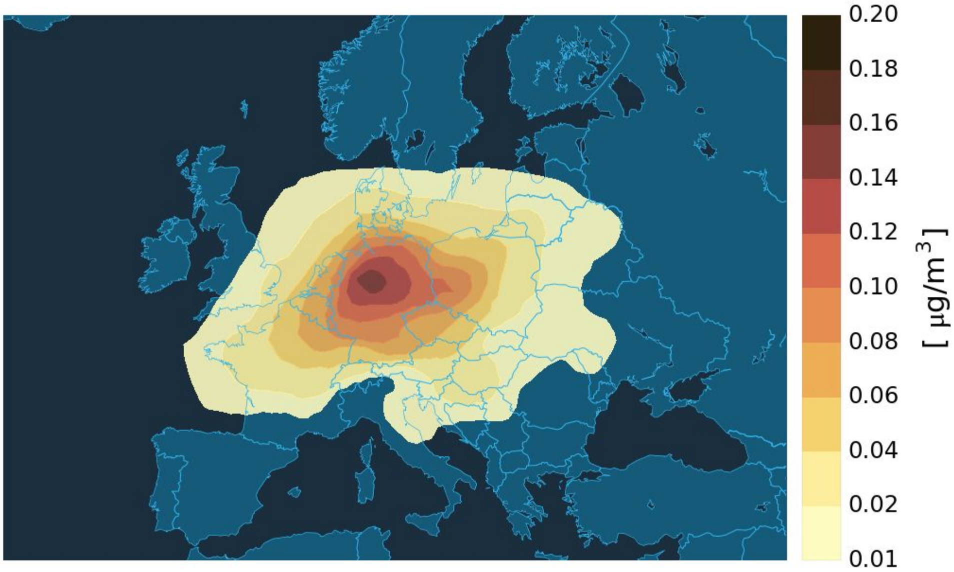
Effect	Pollutant	GBR	Strong limits	BAT on all plants
deaths	PM2.5	48067	11436	8343
deaths	NO2	18487	8187	6455
deaths	mercury	407	140	89
lost working days per year	PM2.5	1238	296	217
preterm births	PM2.5	728	172	125
chronic bronchitis in adults	PM10	668	165	118
asthmatic symptoms in children	NO2	1	1	0
bronchitic symptoms in asthmatic children	PM10	22	5	4
bronchitis in children	PM10	25	6	4
hospital admissions	NO2	3	1	1
hospital admissions	PM2.5	10	2	2
sickness days per year, non-working age population	PM2.5	3046	727	393
neurological damage (lost IQ points)	mercury	41	14	9
Total		72745	21153	15761

Annual average PM2.5 concentrations attributed to emissions from German coal-fired power plants in 2022

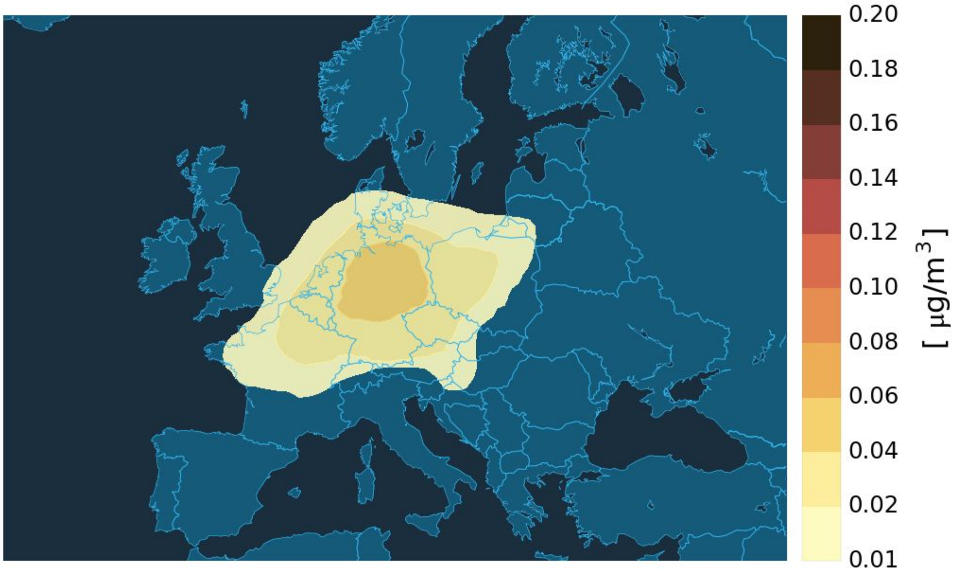
Proposed emissions limits



Best available technology for plants operating beyond 2030



Best available technology for all plants



Methodology

Emissions projections

The basis for the emissions calculations was the latest emissions data reported by Germany to the European Pollutant Release and Transfer Register (E-PRTR), for the year 2017. Basic data on power plant unit age, fuel type, status, announced retirement date and electric capacity was taken from the European Coal Database maintained by Europe Beyond Coal (EBC 2020).

We identified all power generating units from the database that are expected to be in operation and using coal or lignite as their main fuel in 2022 as the starting point of the analysis.

The E-PRTR contains annual total emissions of CO_2, SO_2, NO_x, PM_{10} and mercury, among other pollutants. To project the effect of imposing different annual emissions limit values, we needed to estimate the average concentrations of different pollutants in the flue gas. Emissions of pollutant p in year i were then calculated as:

$E_{i,p} = E_{2017,p} * FGC_{i,p} / FGC_{2017,p} * E_{i,CO2} / E_{2017,CO2}$

where FGC denotes annual average flue gas concentration. We estimated the FGC in 2017 by calculating the total normalized flue gas volume based on a ratio of 3563 normalized cubic metres (Nm^3) of flue gas per tonne of CO_2 emissions, calculated from EEA (2008). Since dry flue gas with normalized oxygen content is a uniform mixture of CO_2 and ambient air, this ratio is near-constant. As E-PRTR reports emissions on the plant level, we divided the emissions volumes to different units in proportion to their electric capacity.

FGC in future years corresponded to the annual emission limits imposed in different scenarios. The GBR scenario reflects the limits as contained in a draft regulation from the Environmental Ministry as of August 2019 (13. BimschV, the federal-level maximum emission limits for combustion plants with a thermal capacity above 50MW). The SO_2 emissions limits for plants with capacity of 300MW_{th} or more in the 2003-Altanlage category firing lignite are based on the minimum desulfurization rate provision. Plants that have already made investments in SO_2 controls were assumed to not employ this provision and therefore the Altanlage category SO_2 emissions limits were applied. (See tables 1 and 2.)

CO_2 emissions in future years were projected on the unit level taking into account announced retirements, including the agreed lignite phase-out timetable. Utilization for the remaining units was scaled to match the projected power generation under the coal phase-out plan (r2b 2018), assuming that oldest units reduce output the most.

Due to a high reporting threshold, mercury emissions were not reported for almost 30% of the capacity. For these plants, we calculated the average FGC from plants in the same category, differentiated into hard coal and lignite plants and by age group, that did report emissions and estimated mercury emissions in 2017 on this basis.

The reported PM10 emissions were used to estimate total dust emissions (TSP) using a PM10:TSP ratio of 54/80 and PM2.5 emissions using a PM2.5:PM10 ratio of 24/54, based on the U.S. EPA AP-42 default emissions factors for electrostatic precipitators at coal-fired utility boilers.

Table 1: Emissions limits in the proposed GBR

Capacity, MWth	Age	Combustion type	Coal Type	Annual average emission limit value SO2 (mg/Nm3)	NOx (mg/Nm3)	PM (mg/Nm3)	Hg (µg/Nm3)
0-100	Altanlage	FBC	hard coal	350	250	18	5
100-300	Altanlage	FBC	hard coal	200	180	14	5
300-1000	Altanlage	FBC	hard coal	180	175	10	2
1000-	Altanlage	FBC	hard coal	180	175	8	2
0-100	Altanlage	PC	hard coal	360	250	18	5
100-300	Altanlage	PC	hard coal	200	180	14	5
300-1000	Altanlage	PC	hard coal	130	150	10	2
1000-	Altanlage	PC	hard coal	130	150	8	2
0-100	Altanlage	FBC	lignite	350	250	18	10
100-300	Altanlage	FBC	lignite	200	180	14	10
300-1000	Altanlage	FBC	lignite	180	175	10	5
1000-	Altanlage	FBC	lignite	180	175	8	5
0-100	Altanlage	PC	lignite	360	250	18	10
100-300	Altanlage	PC	lignite	200	180	14	10
300-1000	Altanlage	PC	lignite	130	175	10	5
1000-	Altanlage	PC	lignite	130	175	8	5
0-100	New	FBC	hard coal	200	150	5	2
100-300	New	FBC	hard coal	150	100	5	2
1000-	New	FBC	hard coal	75	85	5	1
0-100	New	PC	hard coal	200	150	5	2
100-300	New	PC	hard coal	150	100	5	2

1000-	New	PC	hard coal	75	85	5	1
0-100	New	FBC	lignite	200	150	5	2
100-300	New	FBC	lignite	150	100	5	2
1000-	New	FBC	lignite	75	85	5	1
0-100	New	PC	lignite	200	150	5	2
100-300	New	PC	lignite	150	100	5	2
1000-	New	PC	lignite	75	85	5	1
0-100	2003-Altanlage	FBC	lignite	350	250	18	10
100-300	2003-Altanlage	FBC	lignite	200	180	14	10
300-1000	2003-Altanlage	FBC	lignite	320	175	10	5
1000-	2003-Altanlage	FBC	lignite	320	175	8	5
0-100	2003-Altanlage	PC	lignite	360	250	18	10
100-300	2003-Altanlage	PC	lignite	200	180	14	10
300-1000	2003-Altanlage	PC	lignite	320	175	10	5
1000-	2003-Altanlage	PC	lignite	320	175	8	5
1000-	Bestehende	PC	hard coal	130	100	8	2

Table 2. Amended emissions limits for large plants in the “Strong limits” and Full BAT scenarios.

Capacity, MWth	Combustion type	Coal Type	Annual average emission limit value SO2 (mg/Nm3)	NOx (mg/Nm3)	PM (mg/Nm3)	Hg (µg/Nm3)
300-	FBC	hard coal	20	50	2	1
300-	PC	hard coal	10	65	2	1
300-	FBC	lignite	20	50	2	1
300-	PC	lignite	10	50	2	1

Atmospheric modelling

The air quality and health impacts of the different scenarios 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 (Open Source version rv4.33) 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 subtracting the 2015 emissions from German coal power plants reported to the E-PRTR 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 for different scenarios and different points in time 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.

Simulations were run using projected emissions for the year 2022, average of the projected emissions for the years 2022-2030, and for 2031-2038 to estimate the cumulative health impacts under different scenarios.

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 PM2.5 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), 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 for Germany and neighboring countries were obtained from Global Burden of Disease results (GBD 2017), and baseline rates of preterm births were taken from Chawanpaiboon et al (2019).

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).

It is important to note that while the health impacts evaluated here don't include impacts from direct exposure to SO2, SO2 emissions are a major contributor to the PM2.5 health impacts through formation of sulfate particles.

Table 7 Risk ratios (RRs) used for the health impact assessment, for a 10µg/m3 change in annual average pollutant concentration.

Effect	Pollutant	RR: central	RR: low	RR: high
bronchitis in children, PM10	PM10	1.08	0.98	1.19
asthma symptoms in asthmatic children, PM10	PM10	1.028	1.006	1.051
incidence of chronic bronchitis in adults, PM10	PM10	1.117	1.04	1.189
long-term mortality, all causes	PM2.5	1.062	1.04	1.083
cardiovascular hospital admissions	PM2.5	1.0091	1.0017	1.0166
respiratory hospital admissions	PM2.5	1.019	0.9982	1.0402
restricted activity days (applied to non-working age population)	PM2.5	1.047	1.042	1.053
work days lost	PM2.5	1.046	1.039	1.053
bronchitic symptoms in asthmatic children	NO2	1.021	0.99	1.06
respiratory hospital admissions	NO2	1.018	1.0115	1.0245
long term mortality, all causes[1]	NO2	1.055	1.031	1.08
respiratory hospital admissions	NO2	1.0015	0.9992	1.0038
preterm birth	PM2.5	1.15	1.07	1.16

[1] To avoid the possible overlap identified with PM2.5 mortality impacts identified by WHO (2013), 2/3 of the NO2 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.

Table 8 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	valuation, EUR, 2018 prices
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

Economic costs

Air pollution causes a range of negative health impacts: chronic respiratory diseases, hospitalizations, preterm births and other health effects lead to increased health care costs; economic productivity is lowered either 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 and increased risk of death caused by air pollution means a welfare loss to affected people.

The assessment of economic costs of the health impacts projected in this report follows the methodology and valuation used in the EEA (2014) report "Costs of air pollution from European industrial facilities 2008–2012", with the addition of preterm births based on costs estimated by Trasande et al (2016). The costs have been converted to 2018 prices using inflation (GDP deflator) in Germany. For cumulative health impacts taking place over the period 2022 to 2038, we have discounted the costs at 3%/year, assuming a 2% increase in GDP/capita and therefore in the valuations of the different health impacts, resulting in the present value of health impacts falling by 1%/year.

The valuation of different health impacts of major air pollutants is given in Table 9, and health impacts of mercury in Table 8.

Table 9 Valuation of health impacts (based on EEA 2014, except preterm births from Trasande et al 2016).

Effect	Pollutant	Unit	valuation, EUR, 2005 prices	valuation, EUR, 2018 prices
asthmatic and bronchitic symptoms in children	NO2	years of symptoms	588	758
asthmatic and bronchitic symptoms in children	PM10	days of symptoms	42	54
bronchitis in children	PM10	cases	588	758
chronic bronchitis in adults	PM10	new cases	53600	69100
hospital admissions	NO2	cases	588	758
hospital admissions	PM2.5	cases	588	758
lost working days	PM2.5	cases	130	168
preterm births	PM2.5	births	NA	290000
deaths	NO2	cases	2200000	2840000
deaths	PM2.5	cases	2200000	2840000
sickness days, non working-age population	PM2.5	cases	92	119

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