Health Impacts of Coal Power Plant Emissions in Ukraine

Lauri Myllyvirta, lead analyst
Rosa Gierens, researcher
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Centre for Research on Energy and Clean Air

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

- Ukraine is home to some of the most highly emitting coal power plants in Europe and in the world.
- Emissions from Ukrainian coal power plants were associated with an estimated 5,000 (95% confidence interval: 3,200–6,700) deaths in 2019, increasing from 3,300 (2,200–4,500) in 2018. In 2019, 2,700 (1,700–3,600) of the associated deaths occurred in Ukraine, 1,300 (850–1,700) in the EU and 1,000 (660-1,400) in other countries. The most affected regions in Ukraine were Donetsk, Kyiv, Dnipropetrovsk and Lviv with estimated 430, 410, 280 and 230 annual deaths, respectively.
- 8 of the 20 power plants exceeded their emissions ceilings in 2019. If the ceilings had been respected, an estimated 2,300 deaths would have been avoided.
- The social costs related to the associated healthcare, reduced economic productivity and welfare losses amounted to an estimated present value of €8.4 billion (95% confidence interval: €5.5 to 11.2 billion) in 2019, of which €3.2 billion (€2.1 to 4.3 billion) in Ukraine and €5.1 billion (€3.4 to 6.9 billion) in other countries.
- The plants expose an estimated 8.7 million people to exceedances of World Health Organization air quality guidelines, even without considering the compounded impact together with other sources of emissions.

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Introduction

Ukraine is home to one of the most polluting coal power plant fleets in the world, with a recent report (Alparslan 2021) ranking the country's coal-burning plants the largest emitters of SO2 and fly ash in the European region.

According to the World Health Organisation's information on mortality and the burden of diseases from ambient air pollution, Ukraine has 2,538 disability-adjusted life years lost annually per 100,000 people (WHO 2016) - the highest number in Europe.

Ukraine is now in the process of implementing the Industrial Emissions Directive into national legislation and adopting Best Available Techniques (BAT). The government is currently working to establish efficient and transparent environmental regulation in line with the country's obligations under Association Agreement and Energy Community Treaty, but progress is lacking. In July 2021 parliament issued Resolution on the implementation of the National Emission Reduction Plan for large combustion plants, which was approved by the Order of the Cabinet of Ministers of Ukraine in November 2017, urging the government and national energy regulatory authority to take necessary steps for fulfillment of the plan.

Meanwhile, coal-fired power plants in Ukraine are responsible for 80% of the total emissions of sulfur dioxide in Ukraine and 25% of nitrogen oxides, while there are essentially no emissions controls for sulfur and nitrogen oxides at Ukrainian coal plants. Levels of fly ash emissions are particularly high and exceed the Large Combustion Plants Directive emission limit values by up to 40 times. According to analysis of reported emissions data (Alparslan 2021), 72% of the total volume of fly ash emitted by coal plants in the EU, Energy Community member states and Turkey combined comes from Ukrainian thermal power plants. Among the top 30 ranking of large combustion plants with highest fly ash emissions, there are 18 Ukrainian TPPs.

In this report, we assess the air quality and health impacts of Ukraine's coal-fired power generation 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 Ukrainian 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

Emissions from Ukrainian coal power plants increase the concentrations of $PM_{2.5}$, SO_2, NO_2 and ozone in ambient air across the country and beyond, exposing tens of millions of people to increased concentrations of these pollutants (Figures 1 and 2). This increases the risk of a range of acute and chronic diseases and the risk of death from these diseases.

The emissions were associated with an estimated 5,000 (95% confidence interval: 3,200–6,700) deaths in 2019, increasing from 3,300 (2,200–4,500) in 2018. In 2019, 2,700 (1,700–3,600) of the associated deaths occurred in Ukraine, 1,300 (850–1,700) in the EU and 1,000 (660-1,400) in other countries (see Table 3). The most affected regions in Ukraine were Donetsk, Kyiv, Dnipropetrovsk and Lviv with estimated 430, 410, 280 and 230 annual deaths, respectively (Figure 3).

Other health impacts of the coal power emissions in 2019 include 6,800 children suffering from bronchitis, 68,000 days of asthmatic and bronchitis symptoms in children, 3,000 hospital admissions, 800,000 lost working days, and 5,300,000 sickness days, 400 low birth weight births and 2,100 new cases of chronic bronchitis in adults.

8 of the 20 power plants exceeded their emissions ceilings in 2019 (Table 1 & 2). If the ceilings had been respected at all plants, an estimated 2,300 deaths would have been avoided (Table 4).

The social costs related to the associated healthcare, reduced economic productivity and welfare losses amounted to an estimated present value of €8.4 billion (95% confidence interval: €5.5 to 11.2 billion) in 2019, of which €3.2 billion (€2.1 to 4.3 billion) in Ukraine and €5.1 billion (€3.4 to 6.9 billion) in other countries (Table 5). Emissions in excess of emission ceilings were responsible for estimated economic losses of €3.7 billion, or almost 50% of the total.

The plants expose an estimated 8.7 million people to exceedances of World Health Organization air quality guidelines, even without considering the compounded impact caused together with other sources of emissions.

Table 1. *Coal power plants in Ukraine with highest emissions in 2019, tonnes* [1]

Plant Name	SO_x	NO_x	PM
Burshtynska TPP	190,371	16,757	47,495
Kurakhivska TPP	96,160	12,449	39,113
Zaporizka TPP	68,825	21,830	4,193
Vuhlehirska TPP	62,229	7,768	6,961
Slovyanska TPP	44.805	7,611	6,741
Ladyzhynska TPP	39,905	5,409	4.903
Zmiivska TPP	37,659	3.575	15,389
Prydniprovska TPP	32,617	6,481	3,696
Trypilska TPP	32,483	5,422	17,758
Dobrotvirska TPP	23,701	3,665	3,742
Luhanska TPP	21,702	5,985	16,764
Kryvorizka TPP	20,840	5,572	4,342
Kaluska CHP	10,599	612	2,354
Chernihivska CHP	5,782	1,305	1,869
Darnytska CHP	4,572	2,131	2,665
Cherkaska CHP	4,488	7,804	3,626
Kharkivska CHP-2	3,241	1,258	2,817
Myronivska CHP	2,753	454	219
Kramatorska CHP	1,966	685	1,891
Sumska CHP	598	345	829

[1] Officially reported under Art. 72 of the IED (2010/75/EU)

Table 2. *Coal power plants in Ukraine with exceedances of emissions ceilings in 2019 (exceedance of ceiling in tonnes)*

Plant Name	SO_x	NO_x	PM
Burshtynska TPP	131,564	10,804	41,452
Vuhlehirska TPP	62,099	0	562
Kurakhivska TPP	47,992	8,028	20,244
Slovyanska TPP	12,967	2,792	6,471
Kaluska CHP	9,337	344	2,101
Prydniprovska TPP	8,022	0	0
Dobrotvirska TPP	4,264	1,110	552
Kharkivska CHP-2	3,241	1,258	2,817

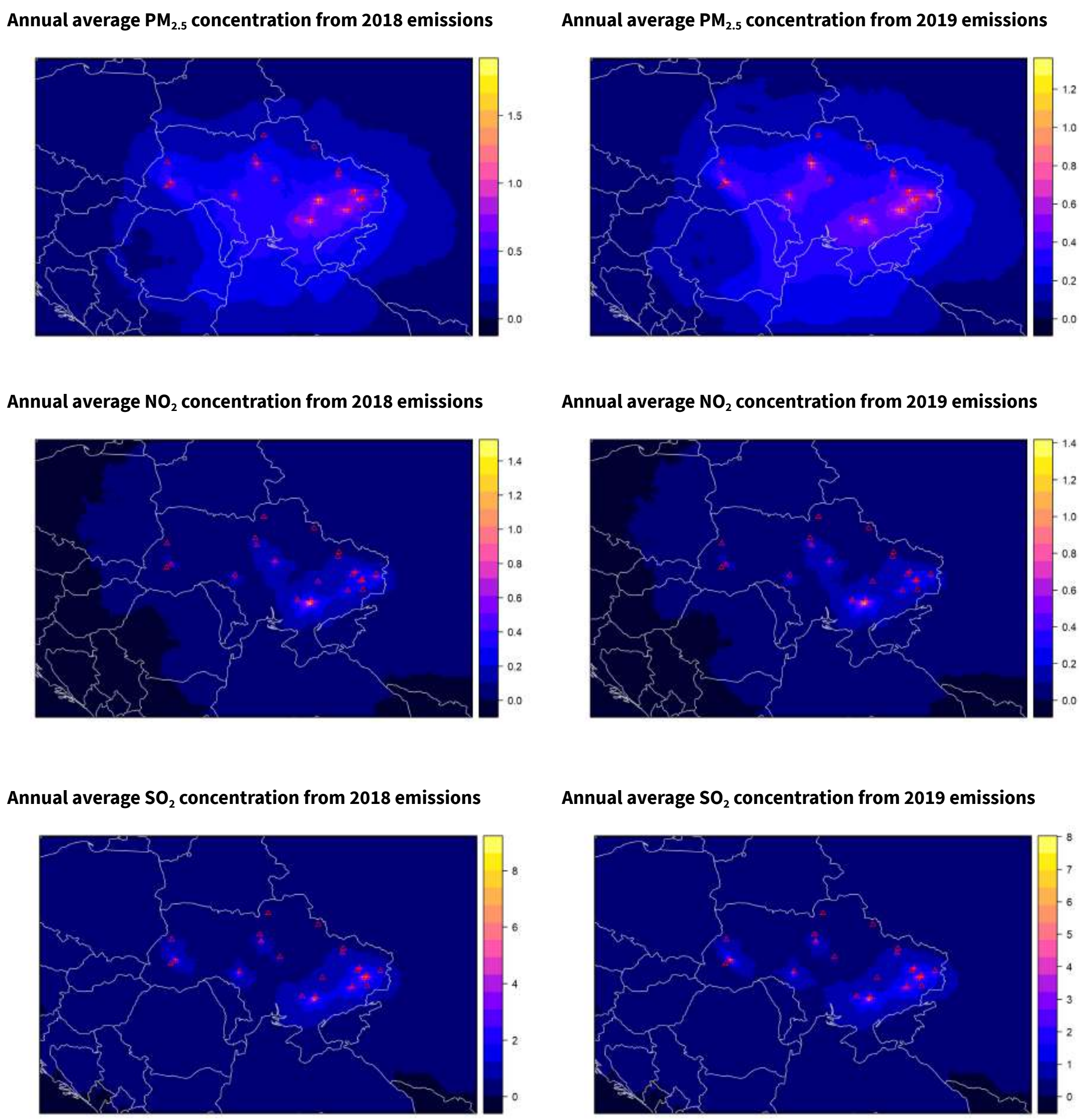


Figure 1. *Annual average concentrations of PM2.5, NO2 and SO2 from the modelled plants in 2018 and in 2019.*

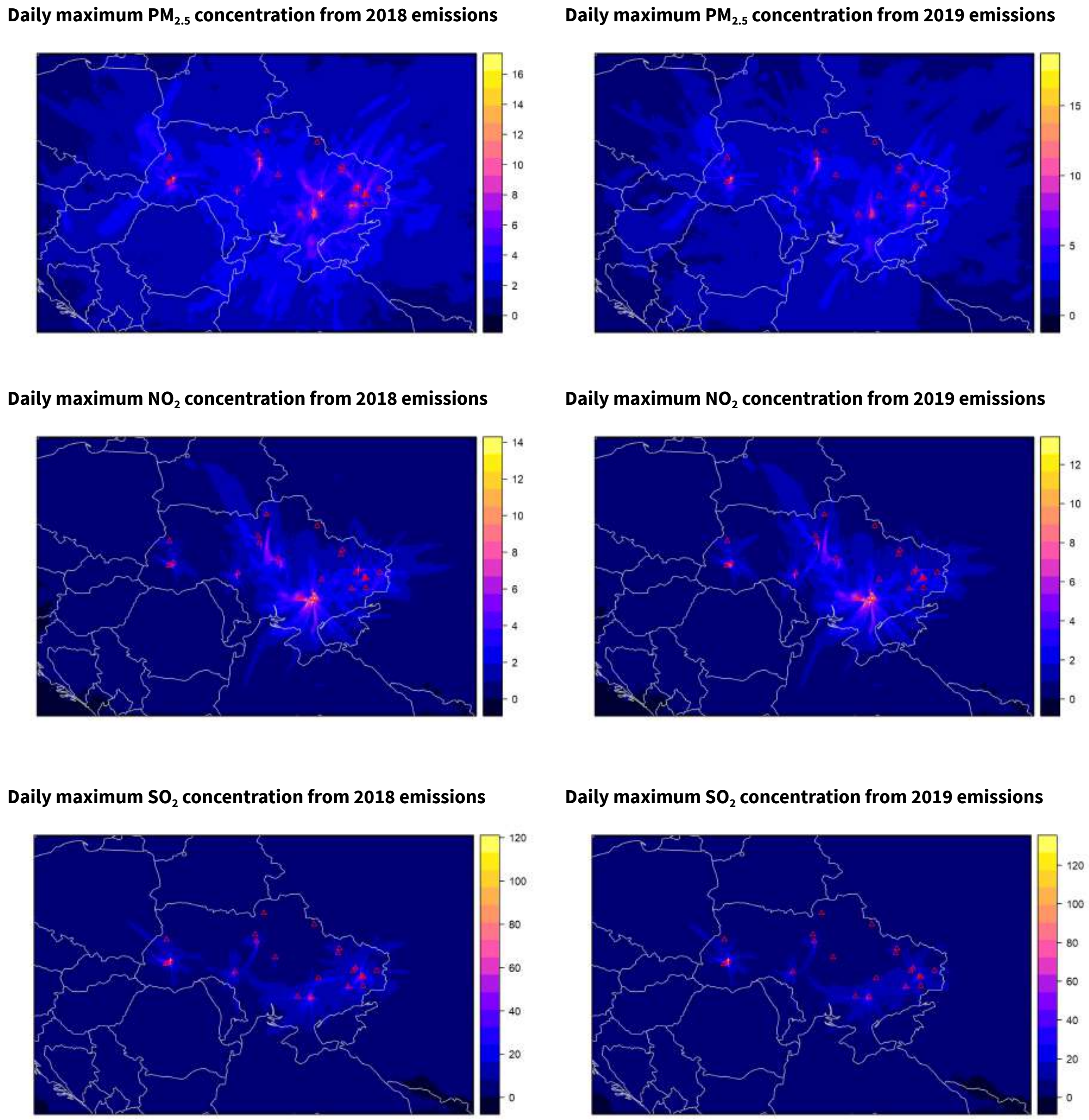


Figure 2. *Daily maximum concentrations of PM2.5, NO2 and SO2 from the modelled plants in 2018 and in 2019.*

Table 3. *Health impacts from Ukrainian power plants' emissions in 2019*

Cause	Pollutant	Ukraine	EU	Other regions	Total
Asthma symptom days in asthmatic children	PM_{10}	30,364 (6,578–54,694)	23,378 (5,064–42,110)	14,649 (3,173–26,386)	68,391 (14,815–123,190)
Bronchitis in children	PM_{10}	3,046 (0–6,886)	2,297 (0–5,191)	1,498 (0–3,386)	6,841 (0–15,463)
Cardiovascular hospital admissions	$PM_{2.5}$	574 (108–1,043)	488 (92–887)	261 (49–474)	1,323 (249–2,404)
Low birth weight births	$PM_{2.5}$	153 (48–266)	137 (42–237)	108 (34–188)	398 (124–691)
Mortality, all causes	all	2,690 (1,730–3,598)	1,315 (855–1,746)	1,023 (662–1,363)	5,028 (2,347–6,707)
Respiratory hospital admissions	all	755 (0–1,487)	516 (0–1,070)	303 (0–619)	1,574 (0–3,176)
Restricted activity days	$PM_{2.5}$	2,450,792 (2,195,356–2,755,710)	1,761,030 (1,577,485–1,980,131)	1,113,939 (997,837–1,252,530	5,325,761 (4,770,678–5,988,372)
Work days lost	$PM_{2.5}$	197,681 (168,166–226,998)	389,458 (331,311–447,217)	210724 (179262–241976)	797,862 (678,739–916,191)

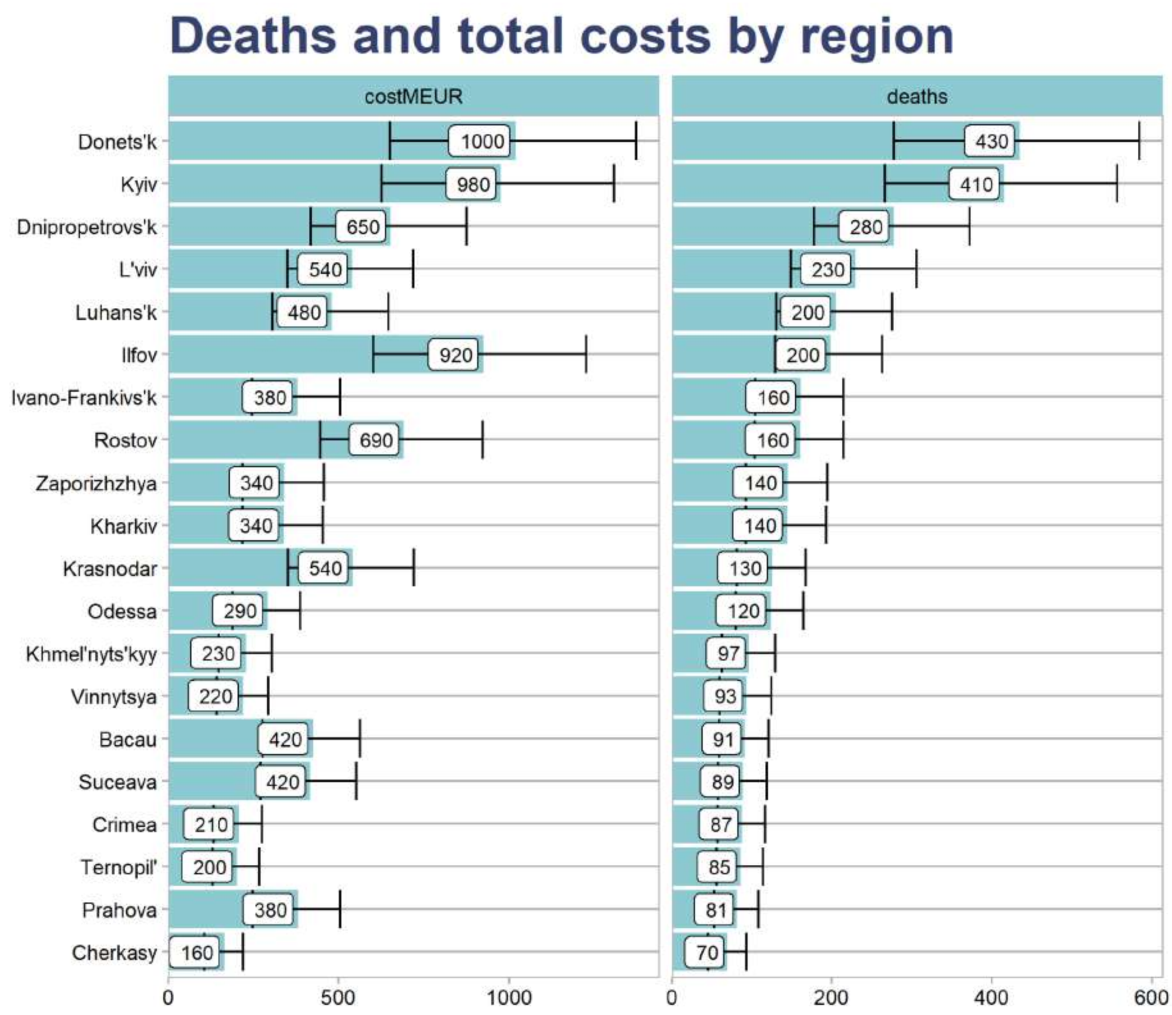
Table 4. *Avoided health impacts and costs in 2019 if ceilings had been respected, total in all regions*

Cause	Pollutant	Number of cases avoided, in 2019	95% Confidence interval	Cost, EUR mln	95% Confidence interval
Asthma symptom days in asthmatic children	PM_{10}	32,196	6,974–57,993	0.6	0.13–1.09
Bronchitis in children	PM_{10}	3,207	0–7,248	0.84	0–1.90
Cardiovascular hospital admissions	$PM_{2.5}$	623	117–1,132	0.63	0.12–1.14
Low birth weight births	$PM_{2.5}$	184	57–319	-	-
Mortality, all causes	all	2,252	1,459–2,999	3,699	2,398–4,923
Respiratory hospital admissions	all	710	0–1,449	0.70	0–1.43
Restricted activity days	$PM_{2.5}$	2,475,801	2,217,758–2,783,831	82	73.4–92.1
Work days lost	$PM_{2.5}$	383,239	326,020–440,076	23	19.6–26.5

Table 5. *Total deaths and economic costs attributed to Ukrainian coal-fired power plants, by region and country, in 2019*

Country/Region	Deaths (central value)	Deaths (95% confidence interval)	Total cost, EUR million (central value)	Total cost, EUR million (95% confidence interval)
Ukraine	2,690	1,730–3,598	3,211	2,068–4,291
EU27, of which	1,315	855–1,746	3,294	2,152–4,359
Romania	*534*	*347–710*	*1,277*	*832–1,692*
Poland	*325*	*211–431*	*857*	*560–1,133*
Hungary	*153*	*100–204*	*393*	*257–520*
Bulgaria	*124*	*81–165*	*240*	*157–318*
Slovakia	*55*	*36–73*	*142*	*93–188*
Czech Republic	*38*	*25–50*	*119*	*78–156*
Austria	*29*	*19–39*	*120*	*79–157*
Croatia	*28*	*18–37*	*65*	*43–86*
Lithuania	*20*	*13–26*	*56*	*37–74*
Other regions, of which	1,023	662–1,363	1,943	1,260–2,584
Russia	*615*	*397–820*	*1,352*	*875–1,799*
Moldova	*170*	*110–226*	*208*	*135–276*
Belarus	*132*	*86–176*	*221*	*144–294*
Serbia	*68*	*44–90*	*111*	*73–147*
Bosnia and Herzegovina	*17*	*11–22*	*23*	*15–31*
Kosovo	*11*	*7–15*	*12*	*8–16*
Total	5,028	3,247–6,707	8,449	5,480–11,234

Figure 3. Breakdown of deaths and costs by region.



Policy recommendations

Bringing Ukraine's thermal power plant fleet into compliance with emissions norms represents a major opportunity for public health and economic improvements.

Plant operators should be obliged to comply with the permit conditions for air emissions and to minimize the harmful impact of their activities on public health and the environment.

This should apply to all power units that will continue to operate after 2023, when synchronization of Ukraine's power system with the European continental grid ENTSO-e is scheduled. Adherence to this necessary condition should be a pre-requisite for continuation of operating permits.

Another requirement to the LCP operators from permitting authority should be to install continuous emission monitoring systems (CEMS) and automatically submit CEMS data to the central repository for all units that apply for continuation of permits after 2023.

Emission reductions for all major pollutants (PM10, SO2, NOx) can be achieved most cost-effectively through an integrated approach that involves changing the structure of power generation, optimizing dispatch, as well as refurbishing and gradually decommissioning coal-fired capacities.

National energy regulatory authority, transmission system operator and ministry of energy of Ukraine should create the conditions for the development of clean energy sources, including wind and solar, ensuring grid access and an enabling framework for development of flexibility options for balancing intermittent renewables.

The European Commission and Energy Community Secretariat need to prioritize talks with the Ukrainian government on implementation of the Industrial Emissions Directive and enforcement of the National Emissions Reduction Plan. These issues should be points of major concern, as the integration of the Ukrainian power sector into the EU's energy market will be significantly complicated if it means importing extremely highly polluting electricity into the EU.

Methodology

Emissions

The air quality simulations use officially reported plant-by-plant emissions data from the Ministry of energy and coal production of Ukraine for 2018 and 2019 (Ministry of Energy 2019, 2021). The emissions reporting also includes precise locations of the emitters.

We also derived a scenario where all plants respect their plant-specific emissions ceilings for 2019. In this scenario, the emissions of each plant and each pollutant were taken as the minimum of 2019 reported emissions and 2019 ceiling.

The reported total particle emissions (TSP) were used to estimate PM10 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.

Atmospheric modelling

The air quality and health impacts of 2018 and 2019 emissions 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 ensuring that power sector emissions in the inventory are at least as large as the reported emissions from Ukrainian coal power plants in each grid cell, and the model was run with this modified baseline inventory to obtain baseline air quality results. Simulations were then performed by subtracting the emissions from the power plants for different scenarios from the baseline inventory and comparing the projected air pollutant concentrations to the baseline results to project the air quality impact of the studied power plants.

Simulations were run using reported emissions for the years 2018 and 2019, as well as modified emissions for 2019 assuming that no plants exceed their emissions ceilings for that year.

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), 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 Ukraine 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) (Table 6).

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

Table 6. *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	1.08	0.98	1.19
asthma symptoms in asthmatic children	PM10	1.028	1.006	1.051
incidence of chronic bronchitis in adults	PM10	1.117	1.04	1.189
long-term mortality, all causes	$PM_{2.5}$	1.062	1.04	1.083
cardiovascular hospital admissions	$PM_{2.5}$	1.0091	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	$PM_{2.5}$	1.046	1.039	1.053
bronchitic symptoms in asthmatic children	NO_2	1.021	0.99	1.06
respiratory hospital admissions	NO_2	1.018	1.0115	1.0245
long term mortality, all causes[2]	NO_2	1.055	1.031	1.08
respiratory hospital admissions	NO_2	1.0015	0.9992	1.0038
preterm birth	$PM_{2.5}$	1.15	1.07	1.16

[2] 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.

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 the EU and then adjusting to the economic conditions of different countries. We base the adjustment on GDP PPP for impacts that are valued on willingness to pay-basis (e.g. mortality), on GDP at market prices for productivity impacts (e.g. lost work days), and price levels (GDP deflator) for healthcare costs (e.g. hospitalizations. Mortality impacts are adjusted with an income elasticity of 0.8 as recommended by the OECD (2012) and other impacts with unit elasticity.

The valuation of different health impacts of major air pollutants is given in Table 7.

Table 7. *Valuation of health impacts (based on EEA 2014).*

Effect and pollutant	Valuation in the EU, EUR, 2005 prices	Valuation in Ukraine, EUR, 2019 prices
long-term mortality, all causes, $PM_{2.5}$	2,200,000	1,160,000
cardiovascular hospital admissions, $PM_{2.5}$	2,200	740
respiratory hospital admissions, $PM_{2.5}$	2,200	740
sickness days, non working-age population, $PM_{2.5}$	42	22.1
work days lost, $PM_{2.5}$	130	18.5
postneonatal mortality, PM10	3,300,000	1,740,000
bronchitis in children, PM10	588	198
asthma symptoms in asthmatic children, PM10	42	14.1
incidence of chronic bronchitis in adults, PM10	53,600	28,200
bronchitic symptoms in asthmatic children, NO_2	588	198
respiratory hospital admissions, NO_2	2,200	740
short-term mortality, all causes, ozone	2,200,000	1,160,000
cardiovascular hospital admissions, ozone	2,200	740
respiratory hospital admissions, ozone	2,200	740
long term mortality, all causes, NO_2	2,200,000	1,160,000

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