Methodology

Air Quality and Health Impacts of Gas-Fired Power Generation in the EU and the UK

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Summary

We assessed the health impacts of gas-fired power generation in the EU and the UK, using latest officially reported emissions data, for 2017 to 2020 depending on country and facility. We used default emissions factors for pollutants for which there are major gaps in reporting (ammonia and volatile organic compounds). We then modeled the impacts of these emissions on air quality across Europe, using the high-resolution version of the chemical-transport model developed under the European Monitoring Programme of the Convention on Long-Range and Transboundary Air Pollution. To estimate health impacts, we applied the WHO recommendations for health impact assessment of air pollution, updated for newer concentration-response relationships for adult deaths associated with nitrogen dioxide exposure, and for pre-term births linked to $PM_{2.5}$ exposure. We relied on an approach to economic valuation of health impacts used by the European Environment Agency to project the associated economic losses.

Emissions

The gas-fired power plant emission data for the report is based on the EEA's Industrial Reporting Database (IRD).

We compiled the air pollutant emissions for all power plant units (boilers or turbines, referred to as "installation part" in the database) that fired at least 90% fossil gas as their energy input. We first calculated the energy input by unit from the Large Combustion Plant (referred to as "installation") data in the IRD. SO_2, NO_x and dust emissions are reported for all LCPs. Emissions of other species are reported through the E-PRTR system, by "facility". Area of economic activity, which we relied on to identify power plants, is reported for "facilities" but not for "installations". There is no one-to-one correspondence between "installations" and "facilities"; we cross-referenced the two datasets to identify exact matches. For the rest of the installations, we designated ones with a term referring to power generation in the name as power plants - e.g. "kraftwerk", "elektrownia", "CTCC" (combustion turbine/combined cycle), "cogeneration", "IKW" (industriekraftwerk), TEC (termoelektrocentrale), or "GT" (gas turbine).

For every unit, we used the latest year of data available, in the interval 2017 to 2020. Including data over such a long period was necessary because some countries, most importantly Germany, have not reported data since 2017. This means that some of the individual modeled units are likely to have been retired after the data was reported, and others that only started operating after the latest reported year of data are missing from the results. However, on the aggregate level there was no clear downward trend in emissions from 2017 to 2020 in those countries that did report data, and gas-fired power generation did not fall in the EU and the UK as a whole over this period, so the emission input data is representative of the situation before the gas price shock and Russia's invasion of Ukraine.

Most plants do not report their ammonia (NH3) and volatile organic compounds (VOC) emissions because of E-PRTR reporting limits set at excessively high levels for these pollutants. Generalizing emission factors (specific emissions per unit of energy input) from the plants that did report emissions could introduce bias, as plants with higher emission factors are more likely to exceed the reporting limit. We therefore estimated the missing emissions using the energy input reported in the IRD, EMEP default emission factor for gas-fired power plants for VOCs, and the US EPA AP-42 emission factor for NH3. Since we didn't have data on which plants are equipped with selective catalytic reduction (SCR) equipment for NO_x control, we conservatively used the emission factor for plants with non-catalytic NO_x control (SNCR) for all plants.

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 (version rv4.36, based on the version used in EMEP status reporting for 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. We used the "high-resolution" version of the model, with a horizontal resolution of 0.1x0.1 degrees (approximately 10 km).

We first ran the model using the default emissions inventory, to obtain baseline results for air pollutant concentrations. We then modified the emissions inventory by subtracting the gas plant emissions from the default power sector emissions and ran the model again with this "zero-out" inventory to produce predicted concentration results without the gas plant emissions. The difference in concentrations between the baseline and zero-out simulations is the estimated impact of gas power plants to air pollutant concentrations.

Before the simulations, the default emissions inventory was "padded" to ensure that the power sector emissions in each grid cell and for each species were at least as large as the reported gas plant emissions, to ensure that there were enough emissions to perform the subtraction.

Health impacts

The health impacts of the changes in pollutant concentrations were evaluated by assessing the resulting population exposure, based on the gridded population data for 2020 from CIESIN (2017), and then applying the health impact assessment recommendations of WHO HRAPIE (2013) as implemented in Huescher et al (2017). We updated the concentration-response function for mortality related to long-term exposure to NO_2 based on the recent meta-analyses of available epidemiological studies carried out to inform the update of the World Health Organization air quality guidelines by Huangfu & Atkinson (2020). We also added the concentration-response function for preterm births from Sapkota et al (2012).

Baseline mortality for different causes and age groups and different countries were obtained from Global Burden of Disease results (IHME 2020), the incidence of preterm births from Chawanpaiboon et al (2019) and the baseline incidence of other health outcomes from the same sources as in Huescher et al (2017).

It is important to note that while most of the health impacts attributed to gas power plant emissions in our results are related to $PM_{2.5,}$ the main contributor to these emissions are the emissions of NO_x, NH_3 and VOCs through their effects on the formation of particulate pollution in the atmosphere.

Table 1.	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	Reference
Bronchitis in children, PM_{10}	PM_{10}	1.08	0.98	1.19	WHO 2013
Asthma symptoms in asthmatic children, PM_{10}	PM_{10}	1.028	1.006	1.051	WHO 2013
Incidence of chronic bronchitis in adults, PM_{10}	PM_{10}	1.117	1.04	1.189	WHO 2013
Long-term mortality, all causes	$PM_{2.5}$	1.062	1.04	1.083	WHO 2013
Cardiovascular hospital admissions	$PM_{2.5}$	1.0090	1.0017	1.0166	WHO 2013
Respiratory hospital admissions	$PM_{2.5}$	1.019	0.9982	1.0402	WHO 2013
Restricted activity days (applied to non-working age population)	$PM_{2.5}$	1.047	1.042	1.053	WHO 2013
Work days lost	$PM_{2.5}$	1.046	1.039	1.053	WHO 2013
Bronchitis symptoms in asthmatic children	NO_2	1.021	0.99	1.06	WHO 2013
Respiratory hospital admissions	NO_2	1.018	1.0115	1.0245	WHO 2013
Long term mortality, all causes	NO_2	1.055	1.031	1.08	Huangfu & Atkinson 2020
Preterm births, $PM_{2.5}$	$PM_{2.5}$	1.15	1.07	1.16	Sapkota et al 2012

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 basis for valuing the economic costs of the health impacts projected in this report is the valuations used in the EEA (2014) report "Costs of air pollution from European industrial facilities 2008–2012".

The values in EEA (2014) are given for the European Union in 2010 at 2005 prices. 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. The basis for adjusting each cost is given in Table 2. We follow EEA (2014) in applying the same valuations in all EU countries, rather than valuing the mortality risk in higher-income member states at a higher value.

Adjustment by GDP refers to value transfer on the basis of GDP per capita at market prices, assuming unit elasticity. This is based on Viscusi&Masterman (2017) approach for valuing mortality. This adjustment is also applied to other health effects that are valued on 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. This is applied to costs that reflect healthcare costs, such as hospital admissions.

Adjustment by GDP means value transfer on the basis of GDP at market prices, with unit elasticity. This is applied to costs that reflect economic productivity losses, such as lost working days.

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 (https://databank.worldbank.org/).

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

Table 2. Valuation of health impacts for EU countries (based on EEA 2014, except preterm births on Trasande et al 2016)

Effect	Unit	valuation, EUR, 2005 prices	valuation, EUR, 2019 prices	Adjustment basis
Postneonatal mortality	Cases	3,300,000	4,434,658	GDP
Bronchitis in children	Number of children affected	588	855	PPP
Asthma symptoms in asthmatic children	Days	42	61	PPP
Incidence of chronic bronchitis in adults	New cases	53,600	72,030	GDP
Adult mortality	Cases	2,200,000	2,956,439	GDP
Hospital admissions	Cases	2,200	3,201	PPP
Restricted activity days	Days	42	56	GDP
Work days lost	Days	130	177	GDP
Minor RADs	Days	42	56	GDP
Bronchitis symptoms in asthmatic children	Number of children affected	588	855	Inflation
Preterm births	Cases	242,097	199,633	GDP growth

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