CLIMATE ANALYTICS

ASSESSING THE HEALTH BENEFITS OF A PARIS-ALIGNED COAL PHASE OUT FOR SOUTH KOREA

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AUTHORS

Gaurav Ganti
Andreas Anhäuser*
Lauri Myllyvirta**
Deborah Ramalope
Bill Hare
Anne Zimmer
Charlotte Plinke
Carley Reynolds
Matthew Gidden

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* Affiliation: Greenpeace
** Affiliation: Centre for Research on Energy and Clean Air

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Key findings

- To contribute to the achievement of the Paris Agreement, South Korea needs to phase out coal from its electricity sector before 2030. The country's 9th Basic Plan for Electricity Power Supply and Demand (9th BPESD) presents a unit-level operation schedule for coal power plants that would see nearly 29 GW of coal-fired power capacity still online in 2034, with coal eventually being phased out in 2054, almost 25 years later than is required to be Paris Agreement compatible.

- In this work we present two unit-level decommissioning schedules that are aligned with a Paris Agreement compatible CO_2 emission reduction pathway. Both of these schedules require 4.2 GW of coal capacity to be retired each year, and units currently under construction would only be able to operate for four years at the most.

- Coal-fired power plants are a significant source of air pollution in South Korea, which has been linked to premature deaths due to increased risk for cardiovascular diseases, chronic and acute respiratory diseases, and other health impacts such as pre-term births and depression.

- Following the two Paris-compatible decommissioning schedules presented in this study could halve the number of premature deaths linked to air pollution from South Korean coal plants within the next 5 years and save over 18,000 lives (over 12,000 lives within South Korea) until the end of their operation, when compared to the current policy plan of phasing out coal in 2054.

Avoided health impacts under accelerated coal phase out (Market Scenario)									
Outcome	Total			Domestic			Abroad		
	95%-confidence interval			95%-confidence interval			95%-confidence interval		
	best estimate	low estimate	high estimate	best estimate	low estimate	high estimate	best estimate	low estimate	high estimate
Premature deaths	18,482	12,034	25,589	12,619	8,168	17,363	5,863	3,866	8,226
Years of potential life lost	339,294	219,361	474,593	228,161	147,813	314,663	111,133	71,548	159,930
Preterm births	1,734	839	1,842	830	402	882	904	437	960
Asthma: New cases	3,261	706	7,373	2,552	552	5,787	709	154	1,586

Table: *Avoided impacts (selected) in a Paris Agreement consistent coal phase out scenario compared to current policies.*

- A corresponding reduction of over 1,700 preterm births (800 within South Korean boundaries), 3,000 new asthma cases (2,500 within South Korean boundaries) and more than 4.6 million work absence days (2.8 million within South Korean boundaries) is estimated to result from the accelerated decommissioning schedule as compared to current policy plans (see Table above).

Introduction

South Korea relies heavily on coal for electricity generation (coal accounted for 29% of installed capacity in 2020)—a significant contributor to air pollution and its associated health impacts. South Korea consistently ranks high among the countries where air pollution levels recommended by the World Health Organisation are exceeded by a wide margin [1].

This has led the South Korean government to declare air pollution a 'social disaster' that necessitates emergency mitigation measures [2]. Despite this, the government plans to continue to build coal-fired power plants with nearly 7.3 GW of coal capacity still at various stages of construction and planning [3].

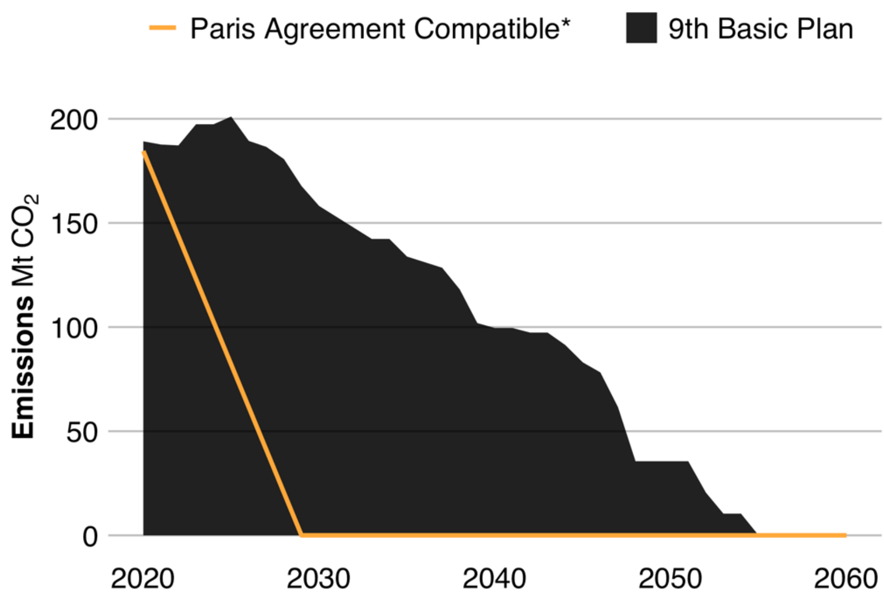


***Figure 1** Comparison between potential CO_2 emissions from coal generation under the 9th BPESD and a Paris Agreement consistent emission reduction pathway. *see explanation in footnote 1*

The continued expansion of coal capacity stands in stark contrast to the benchmark coal phase out date of 2029 (**Figure 1**) that is consistent with the achievement of the Paris Agreement temperature limit[1] [4]. The 9th BPESD (**Box 1**) released in December 2020 lays out a decommissioning trajectory that would see over 30 GW of coal capacity still online in 2030.

Such a trajectory would lock South Korea into a future that is not only inconsistent with greenhouse gas emission reduction targets (with emissions from coal-fired generation peaking only around 2025), but also exposes its population to elevated immediate health risks due to air pollution.

In this brief, we present two alternate decommissioning schedules that are consistent with meeting the 2029 benchmark for a complete coal phase out and highlight the health impacts avoided due to accelerated decommissioning of coal-fired power units in South Korea.

[1] Climate Analytics modelled a Paris Agreement consistent emission reduction pathway for coal generation in South Korea based on a downscaling model applied to the IEA's Energy Technology Perspectives "Beyond 2°C Scenario", taking into account historical emissions until 2019. This pathway has been assessed by Climate Analytics to have characteristics that are consistent with the Long-Term Temperature Goal of the Paris Agreement. The Paris Agreement establishes a global commitment to limit warming "well below 2°C" and to pursue efforts to limit warming to 1.5°C.

Box 1 The 9th Basic Plan for Electricity Supply and Demand

The 9th Basic Plan for Electricity Supply and Demand

The Basic Plan for Electricity Supply and Demand is a biennial report that is prepared by the Ministry of Trade, Industry and Energy in accordance with Article 25 of the Electricity Business Act and Article 15 of the Enforcement Decree. The document presents the long-term supply and demand plan (for a period of 15 years) for electricity in South Korea.

The 9th plan (December 2020) aims to decrease coal and nuclear capacity while increasing natural gas and renewable energy capacities to meet growing demand. The following are some of the key characteristics of the 9th plan:

- 7.2 GW of coal capacity is set to come online in the next five years;
- Installed coal capacity is set to peak at 40.6 GW in 2024 and then decline to 29 GW by 2034;
- 24 units (12.7 GW) of coal-fired power plants to be converted to run on natural gas by 2034;
- Increase natural gas capacity to 58 GW and renewable energy capacity to 78 GW (59% solar and 32% wind) in 2034.

Unit-level decommissioning schedules

Based on the emission reduction pathway presented in **Figure 1**, we propose two different decommissioning schedules for South Korea's coal generation units based on a method we have developed to construct a "priority order" for unit-level retirements [5]. The "priority order" is based on two different perspectives:

- **Regulator perspective:** In this perspective, the most carbon emission-intensive coal power units are prioritised for decommissioning. Put differently, the decommissioning date for each unit is determined primarily by the amount of CO_2 emitted per unit of electricity generated and secondarily (to break ties between units that have the same emission intensity) by the highest Long Run Marginal Cost (LRMC).

- **Market perspective:** The primary objective of this approach is to reduce the overall national cost of the shutdown by prioritising the decommissioning of units with the highest generation costs[2] per unit of electricity generated. We use estimates for the generation costs from the Carbon Tracker Initiative [6].

The decommissioning calculations are then performed step by step. For each year in which the sum of emissions from coal plants is above levels consistent with the long-term goal of the Paris Agreement, plants are decommissioned until the emissions are at or below this level.[3] Further details about the calculation methods for the two perspectives are presented in **Annex I**.

[2] We select the Long Run Marginal Cost (LRMC) in line with the recommendation from Carbon Tracker Initiative reports given that the South Korean electricity market is heavily regulated by the government.

[3] These scenarios do not account for significant factors including the importance of each unit to grid stability and expected return on investment. They are, by design, stylised scenarios that are meant to provide an insight into how different strategies could differ (or lead to similar conclusions, as we highlight in this brief).

The average annual capacity reduction of coal-fired power is 4.2 GW in both perspectives, with the last units shutting down in 2029. The phase out date differs by less than 2 years between the two perspectives for 50 out of 67 units (i.e., 75% of all units). This indicates that, while the perspective matters to some extent in the precise retirement year of the units, the narrow window for the retirement of all units is the most important aspect to keep in mind. We provide information per unit and a description of some insights at the unit-level in **Annex II**.

Air pollution and health impacts of continued reliance on coal

Coal combustion is not only an issue because of CO_2 emissions, but also because it generates large amounts of air pollutants which are linked to a number of damaging environmental and public health impacts. Since both stem from the same process – fossil fuel combustion – air pollution can be avoided by policy measures primarily aimed at reducing carbon emissions [7]-[11].

Fine particulate matter ($PM_{2.5}$) is known to increase the risk of severe health conditions, such as cardiovascular disease, chronic and acute respiratory disease, lung cancer and premature births [12]-[15], among others. Sulphur dioxide (SO_2) causes acid rain [16], toxic heavy metals such as mercury can damage the nervous system, including the brain [17] and nitrogen oxides (NO_x) affect the respiratory system, while also contributing to the formation of additional particulate matter and harmful ozone (O_3) [18].

While air pollution has been labelled a 'social disaster' by the South Korean government, the rhetoric has not been accompanied by sufficient policy measures [2]. In the recent past, the concentration levels of $PM_{2.5}$ in Seoul has been around two times higher than the recommended limits in the guidelines of the World Health Organisation [19].

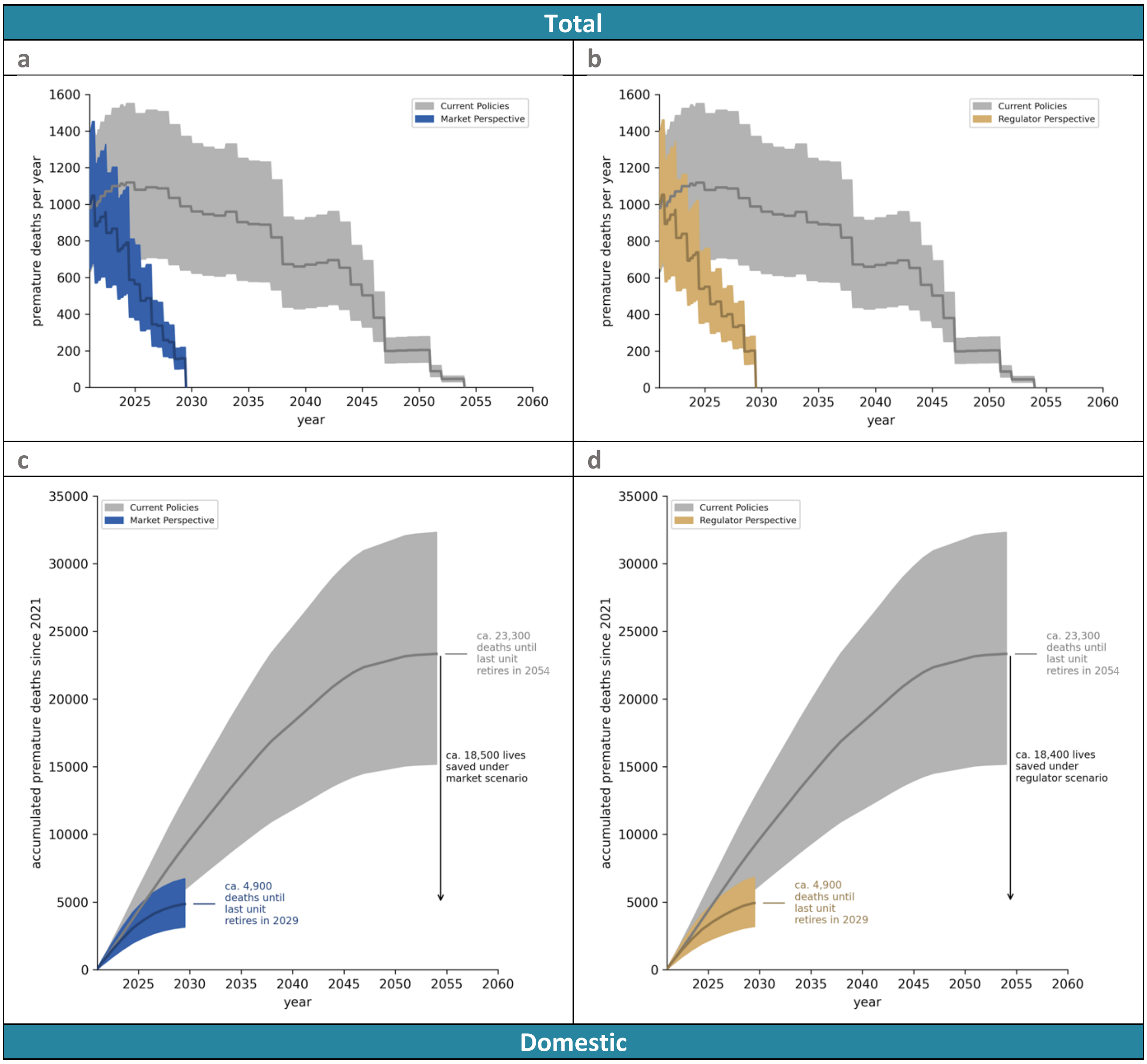
While there has been a substantial decrease in coal-related fine particulate matter emissions compared to 2018,[4] the country's 60 coal-fired power plants still emitted 3,527 tonnes of PM2.5-related air pollutants in December 2020 [20]. According to the Ministry of Environment, the progress in reducing air pollution emissions was achieved by shutting down old coal-fired power plants early, halting operation during seasons with high air pollution levels and enforcing emission standards for coal power plants [20], demonstrating that an accelerated coal phase out can be an effective approach to cutting air pollutants.

Air quality and health benefits of accelerated coal decommissioning schedules

The population exposed to air pollution from coal-fired power plants would benefit substantially from an accelerated, Paris Agreement compatible decommissioning schedule. In order to assess this quantitatively, we conducted a modelling study using a numerical weather model with a chemistry module to study the dispersion of pollutants emitted by the power plants. We present a brief overview of the method in **Box 2** and a detailed overview in **Annex III**.

[4] The Ministry of Environment reports a 60% decrease from the 8,781 tons emitted in December 2018 compared to December 2020 [20]. The actual effectiveness of the more recently adopted measures to manage air pollution from coal power plants, such as the most recent Comprehensive Plan on Fine Dust Management (CPFDM) implemented in November 2019 [25], remains to be seen when the economy recovers from COVID-19.

Both schedules consistent with the Paris Agreement would result in a steep reduction of close to 79% in the estimated number of premature deaths resulting from air pollution from South Korean coal power plants when compared to the projection under the 9th BPESD (**Figure 2a and b** for total effect **and 2e and f** for domestic effect). While there is little difference between the two phase out scenarios, the potential reduction in accumulated effects between the current policy scenario and the accelerated decommissioning schedules is substantial. The number of premature deaths per year is almost halved in the next five years under these schedules, as opposed to an increase under the 9th BPESD. Cumulatively, around 18,000 premature deaths[5] - more than 12,500 of these within South Korea - can be avoided in the Paris Agreement schedules as compared to the 9th BPESD (which sees more than 23,000 premature deaths until 2054, almost 15,900 of these within South Korea – see **Figure 2c and d and Table 1-3**).



[5] Best estimate. 95%-confidence ranges are shown in Tables 1-3.

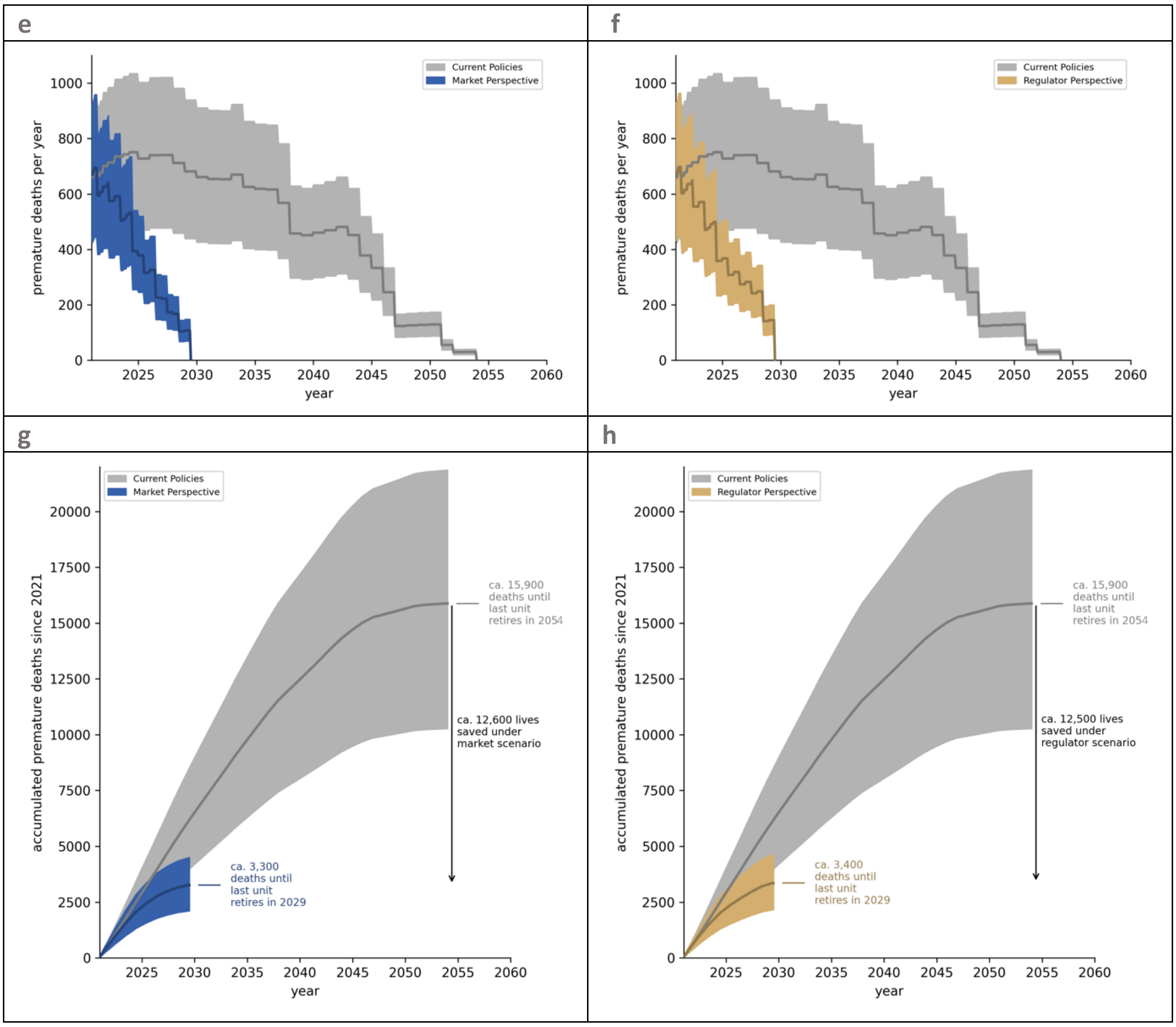


Figure 2: *Estimated total premature deaths per year (figures a and b for total and e and f for domestic) and cumulative premature deaths accumulated over the time of the phase out (figures c and d for total and g and h for domestic) related to air pollution from South Korean coal power plants comparing the current policy trajectory of the 9th BPESD with the accelerated coal phase out scenarios in line with the Paris Agreement (Left – Market Perspective, Right – Regulator perspective). Shaded areas show 95%-confidence intervals.*[6]

There is significant variation in the regional impacts of air pollution. We construct a hypothetical case overlaying the emissions of all operating and planned coal power plants to illustrate the regional per capita impacts[7] (shown in **Figure 3** as air pollution deaths per million inhabitants). Coal power related air pollution deaths are especially high in the vicinity of the power plants, which are grouped in three clusters: one in the South, one in the North-East and one in the West. The 10 most affected municipalities (in terms of deaths per population if all units were online at the same time) are:

[6] The rate of premature deaths from coal-fired power plants (panel a, b, e and f) is changing over time due to two opposing effects competing against each other. 1) Sharp downward cuts appear when a power plant unit goes offline (often multiple units at a time). In the early years, some new units go online, which leads to a sharp increase. 2) These sharp sudden drops are superposed to an underlying constant increase in the death rate which is due to the changing demography: The population is projected to age, which makes people more vulnerable to air pollution-related deaths (see Annex II A2). The numbers in this figure are rounded – for underlying numbers please see tables I-III in Annex IV.

[7] In reality, some power plant units are planned to already be taken offline before new ones currently in the pipeline go online. Thus, there is no time when all units are online concurrently. Yet, the map shows very clearly that there are regions that suffer the highest health impacts from coal power generation in relative terms (i.e. accounting for differences in population density).

Gwangyang, Boryeong, Suncheon, Donghae, Hongseong, Hadong, Gurye, Gokseong, Sacheon and Samcheok. In terms of absolute numbers, the most populous areas suffer the most premature deaths, as a higher population density also increases the number of people exposed to the air pollution from a particular coal power plant (not shown).

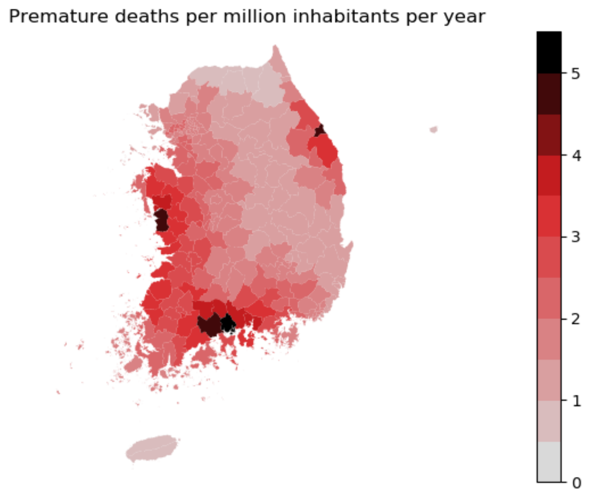


***Figure 3**: Regional distribution of coal power related air pollution deaths per capita when modelling air pollutant emission of all current and future coal power plants in South Korea combined (best estimate). Note that this shows a hypothetical case with all power plant units emitting at the same time to illustrate which regions are affected the most. In reality, some units would already be phased out when newly constructed power plants would come online.*

On average, each of these premature deaths cut short a person's life, leading close to 430,000 years of potential life lost due to air pollution from South Korea's coal power fleet until their end of operation under current policies (**Annex IV Table I**). Over 280,000 of these potential life years are lost to residents of South Korea, the remaining more than 140,000 to people abroad. Under either of the Paris compatible phase out scenarios, these numbers are drastically decreased to around 90,000 years of potential life lost, saving more than 330,000 life years in total (**Tables 1 and 2** as well as **Tables I, II and III in Annex IV**).

***Table 1:** Accumulated avoided health impacts of South Korean coal-fired power plants from 2021-2054, total, domestic and abroad, under the Regulator Perspective Scenario compared to the Current Policies Scenario.*

Avoided health impacts under Regulator Scenario

Outcome	Total			Domestic			Abroad		
	95%-confidence interval			95%-confidence interval			95%-confidence interval		
	best estimate	low estimate	high estimate	best estimate	low estimate	high estimate	best estimate	low estimate	high estimate
Premature deaths	18,410	11,993	25,480	12,527	8,113	17,232	5,883	3,880	8,248
Years of potential life lost	337,632	218,417	472,071	226,502	146,807	312,305	111,130	71,610	159,766
Preterm births	1,728	836	1,835	827	400	879	901	436	956
Asthma: New cases	3,239	701	7,323	2,528	547	5,732	711	154	1,591
Asthma: Emergency room visits	7,307	4,544	10,047	4,122	2,581	5,650	3,185	1,963	4,397
Work absences (person days)	4,647,484	3,953,635	5,336,693	2,809,835	2,390,349	3,226,511	1,837,649	1,563,286	2,110,182

Table 2: *Accumulated avoided health impacts of South Korean coal-fired power plants from 2021-2054, total, domestic and abroad, under the Market Perspective Scenario compared to the Current Policies Scenario.*

Avoided health impacts under Market Scenario									
Outcome	Total			Domestic			Abroad		
	95%-confidence interval			95%-confidence interval			95%-confidence interval		
	best estimate	low estimate	high estimate	best estimate	low estimate	high estimate	best estimate	low estimate	high estimate
Premature deaths	18,482	12,034	25,589	12,619	8,168	17,363	5,863	3,866	8,226
Years of potential life lost	339,294	219,361	474,593	228,161	147,813	314,663	111,133	71,548	159,930
Preterm births	1,734	839	1,842	830	402	882	904	437	960
Asthma: New cases	3,261	706	7,373	2,552	552	5,787	709	154	1,586
Asthma: Emergency room visits	7,326	4,555	10,072	4,136	2,589	5,669	3,190	1,966	4,403
Work absences (person days)	4,652,626	3,958,009	5,342,597	2,819,235	2,398,346	3,237,305	1,833,391	1,559,663	2,105,292

Air pollution also causes a variety of non-lethal negative health impacts. Under current policies, more than 2,300 preterm births (of these 1,100 in South Korea) between 2021-2054 are estimated to be attributed to air pollution from South Korean coal power, around three quarters of which would be avoided by either of the two phaseout scenarios (**Annex IV Table 1**). Under both phaseout scenarios, the number of future new asthma cases can be reduced by over 3,000 and the number of emergency room visits due to an exacerbated pre-existing asthma condition can be reduced by well over 7000 cases (**Table 1** and **Table 2**).

All of these health impacts not only cause personal harm to the affected individual, but also entail economic losses to the society due to the need to use health care services, but also through loss of productivity, manifesting in more than 6.3 million work absences (person days) under current policies (see **Table I in Annex IV**). This number would be reduced by 73% to around 1.7 million under either of the phase out scenarios.

***Box 2:** Air pollution impact calculation methodology*

Methodology

The unit-level decommissioning schedules serve as an input to estimate the respective air quality benefits of an accelerated South Korean coal phase out. Using the concentration-response functions for various health outcomes, we computed the health impacts of the continued operation of the power plants in the future. This captures the contribution of each coal unit to air pollutant concentration, which is then used to calculate impacts on human health for the exposed population within South Korea as well as neighbouring countries,[8] taking projected population developments and changes in age structures into account. We assess these impacts in comparison to the expected health impacts under the 9th BPESD. Further details on the methodology are presented in **Annex III**.

Conclusion

Our results show that an accelerated phase out of coal power generation in South Korea is not only needed to comply with the internationally agreed goals of the Paris Agreement, which South Korea has ratified, it would also save about 18,000 lives (over 12,000 domestically) compared to the current policy plan of phasing out coal in 2054.

In just five years' time, implementing an accelerated coal phase out could halve the number of premature deaths per year stemming from air pollution from South Korean coal plants. The choice of the criteria for ranking which coal power plant units should be phased out in which order matters only slightly, with phasing out more carbon-intensive coal power plants first resulting in a slightly higher number of lives that could be saved compared to taking the marginal cost perspective for ranking coal units for phase out.

Our findings are corroborated by findings from recent scientific literature. Maamoun et al (2020) rank over 2,000 operating coal-fired power plants in the world based on their age, carbon intensity and air pollution potential, and identify the top plants to be retired early according to these criteria to be located in China, India and South Korea [22], supporting our findings for a need for an accelerated coal phase out in South Korea.

Quantifying the health benefits from reduced air pollution for South Korea achieving ambitious climate mitigation targets, Kim et al (2020) estimate that the economic health benefits could considerably

[8] China, Japan and North Korea.

outweigh the total costs of climate change mitigation in South Korea [23]. They estimate savings from reduced health expenditures to be about 0.14 billion USD and those from reducing the number of work hours lost to 0.38 billion USD, while the valuation of avoiding premature deaths alone could reduce economic health costs by about 23 billion USD applying a value of statistical life approach. A recent study focussed on coal in the power sector found that the cumulative cost of health impacts under the 9th BPESD could be as high as 21 billion USD [26].

It is important to note that the results presented in this brief only consider the air pollution and health impacts from the coal-fired power plants themselves. In this regard, the presented health benefits of an accelerated coal phase out can be considered conservative for two reasons:

- First, the processes along the supply chain for coal, including mining, hauling, storage and coal ash disposal also cause considerable air pollution and health impacts that are not included in our estimates.
- Moreover, the 9th BPESD foresees that 24 coal power plants are transformed into natural gas power plants. Recent research has demonstrated that a coal-to-gas transition in the electricity system is unlikely to be consistent with achieving the warming limit of the Paris Agreement [27], and instead direct transition to renewables may be a better pathway. Natural gas also contributes to air pollution impacts, which are not considered here.

- As a consequence, the total air pollution as well as CO_2 emissions stemming from power generation under the business-as-usual scenario can be expected to be even higher, and thus the health and climate benefits of an accelerated coal phase out (without transforming coal power into natural gas power plants) would be even higher.

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Annex I – Methodology for unit-level phase out schedules and emission calculations

In this study we consider two approaches to determine the phase out schedule at the unit level:

- "Regulator" perspective: it adopts an environmental integrity approach and prioritises the shutdown of the least efficient units, while also taking into account the maximisation of the revenue they can generate. For this perspective, we assume generation units are sorted primarily according to their carbon intensity (amount of CO_2 emitted per unit of electricity generated). To reduce the overall economic loss of the phase out and given that many generation units have similar carbon intensity characteristics, a second sorting is applied where priority for phase out is given to the units with lower LRMC in each of the carbon intensity ranges. We assume a constant capacity factor of 70% over time for our scenarios (further details on the emission calculation below).
- "Market" perspective: it aims to reduce the overall national cost (regardless of region) of the shut down for investors and owners by keeping units with higher economic value online as long as possible. Similar to the Regulator perspective, the sorting of the units is done using a two-step approach. Units are sorted according to the LRMC and then ties are broken using the emission intensity of electricity generation.

The shutdown is performed in a step-by-step manner. For each year in which the sum of emissions from the coal plants are above target emissions pathway, plants need to be shut down until the emissions are below this level. Coal power units are sorted as explained above and those units with highest priority will be shut down in a certain year, as depicted in Figure 13.

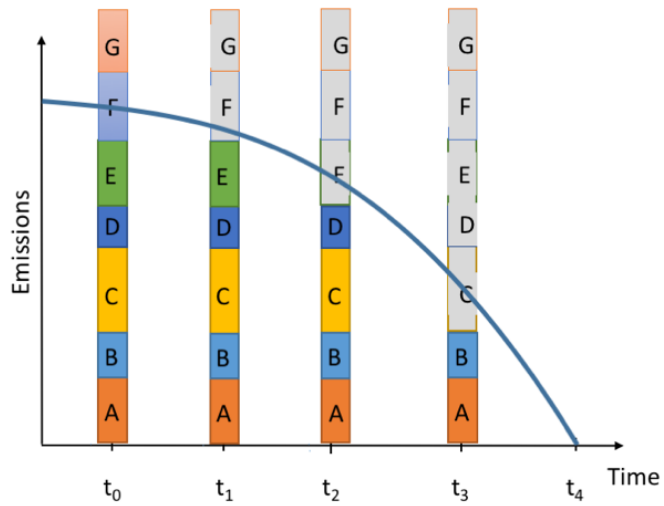

Figure 13 – Schematic overview of methodology. Each of the boxes labelled A to G shows emissions from a power unit. The blue line indicates cost optimal coal emissions pathways in line with the Paris Agreement Long-Term Temperature Goal, and t0 through t4 depict the time steps (years). If we assume that our shutdown regime starts in t1, this means that plants G and F need to shut down – as indicated by the grey colour. In t2 plant E needs to be shut down under a least cost strategy and in t3 only plants A and B may remain in operation. In t4 all remaining plants need to be shut down, as emissions need to reach zero.

To estimate emissions resulting from currently operating and planned coal power plants in South Korea we used the Global Coal Plant Tracker (GCPT) database, which provides information on every known coal-fired power generation unit, including its location, status, investor, capacity, combustion technology[9] and fuel, year of opening and planned retirement. We merge the data with data from KEPCO and assign a capacity factor of 70% to all units. The data used in this report comprise of detailed information per plant concerning the country, its capacity, status and combustion technology, which allows to estimate CO2 from these plants, using the following formula:

Yearly emissions:

$$Emi_{it} = Cap_i * \frac{1}{eff_i} * lf_{it} * ef_i * \boldsymbol{\phi}$$

with:

$\boldsymbol{Emi_i t}$ are the yearly emissions of plant unit i in Mt CO2 in a particular year.

$\boldsymbol{Cap_i}$ is the Capacity of plant unit i in MWel. MWel describes the electrical output of a power plant (unit). About two-thirds (actual value depending on the combustion technology) of the energy contained in a coal power plant's fuel is lost while converting it into electricity. The thermal energy released during the conversion is usually not used anymore but gotten rid of via cooling towers or rivers.

$\boldsymbol{eff_i}$ is the conversion efficiency of a power plant unit: How much of the energy contained in the fuel (coal) is converted to electricity. In general, this is higher for modern plants, which dominate South Korea's coal power generation.

$\boldsymbol{lf_{it}}$ is the load factor of the power plant in a particular year. The load factor is the ratio of the actual power plant output over its theoretical maximum output and is usually calculated over the course of a year. The theoretical maximum output can be calculated by assuming that a power plant runs at its nameplate capacity 24 hours a day, 365 days a year i.e. a power plant unit with a capacity of 100 MW has a theoretical maximum output of:

$$100\ \mathrm{MW_{el}} * 10\,\frac{\mathrm{hours}}{\mathrm{day}} * \mathrm{ayr}\,\frac{\mathrm{days}}{\mathrm{year}} = 876.000\ \mathrm{MWh}.$$

Actual output over a given year is lower since the plant will always operate at full output – e.g. due to demand fluctuations – and has to be taken offline completely for maintenance. There is uncertainty around future utilisation rates of coal power plants in South Korea, and hence we select a default value of 70% for our calculations. It is important to note that this would not impact the emission intensity of electricity generation that are used in the regulator scenario.

$\boldsymbol{ef_i}$ is the emissions factor, which contains information on how much CO_2 is released for a given amount of coal burned. Unit is kg CO_2/TJ. Higher-grade coal contains a higher share of carbon, which is converted to CO_2 during combustion. We use emission factors from (IPCC, 2006). Since this source contains only emission factors for pure types of coal, we assumed a 50/50 share for plants that use two different coal grades, e.g., bituminous and sub-bituminous coal.

ϕ is a conversion factor to end up with the correct units (Mt CO_2/yr).

[9] The database distinguishes between different combustion technologies in the following categories: subcritical, supercritical and ultra-supercritical without or with CCS, ranking from least to most efficient respectively. We do not consider coal-fired power plants retrofitted with CCS technology further in our analysis.

Annex II – Unit-level phase out schedules

Unit Name	Policy Retirement	Regulator Retirement	Market Retirement	Emission Intensity (g CO2 / kWh)	LRMC (Unit)
Boryeong #1	2020	2020	2020	1045.552	50.66
Boryeong #2	2020	2020	2020	1045.552	50.54
Donghae #1	2028	2020	2020	1256.639	55.36
Donghae #2	2029	2021	2020	1166.901	54.32
Honam #1	2021	2021	2021	1175.02	49.16
Honam #2	2021	2021	2021	1175.02	49.16
Samchonpo #1	2021	2021	2021	1012.987	54.15
Samchonpo #2	2021	2021	2021	1012.987	53.9
Taean #2	2025	2022	2021	939.6995	52.92
Samchonpo #4	2024	2021	2021	972.3855	52.3
Samchonpo #3	2024	2021	2021	972.3855	51.4
Dangjin #3	2030	2023	2021	861.3834	51.1
Yeosu #1	2046	2022	2021	881.4979	50.76
Taean #4	2029	2022	2021	939.6995	50.45
Dangjin #4	2030	2023	2021	861.3834	49.97
Gangreung Anin #1	2052	2026	2022	795.0736	51.63
Gangreung Anin #2	2052	2026	2022	795.0736	51.63
Taean #3	2028	2022	2022	939.6995	49.6
Dangjin #1	2029	2024	2022	861.3834	49.53
Gosung Hai #1	2051	2026	2022	795.0736	49.43
Gosung Hai #2	2051	2026	2022	795.0736	49.43
Samcheok Greenpower #2	2047	2027	2022	795.0736	49.35
Yeosu #2	2041	2021	2023	1094.004	49.27
Taean #1	2025	2022	2023	939.6995	49.15
Boryeong #3	2043	2021	2023	969.909	49.01
Dangjin #9	2045	2028	2023	770.3096	48.92

Yeongheung #1	2034	2024	2023	861.3834	48.65
Dangjin #2	2029	2024	2023	861.3834	48.59
Dangjin #8	2037	2024	2024	847.3219	48.51
Dangjin #7	2037	2025	2024	847.3219	48.48
Yeongheung #2	2034	2024	2024	861.3834	48.25
Dangjin #10	2046	2029	2024	770.3096	48.19
Taean #10	2047	2029	2024	770.3096	48.14
Bukpyeong #2	2047	2023	2024	867.3625	48.1
Bukpyeong #1	2047	2023	2024	867.3625	48.06
Boryeong #4	2043	2021	2024	969.909	47.93
Taean #7	2037	2025	2024	847.3219	47.82
Boryeong #5	2025	2021	2025	969.909	47.53
Boryeong #6	2025	2022	2025	969.909	46.82
Dangjin #6	2036	2023	2025	874.5617	47.73
Taean #5	2032	2024	2025	861.3834	47.73
Hadong #1	2026	2022	2025	939.6995	47.72
Hadong #2	2027	2022	2025	939.6995	47.72
Dangjin #5	2035	2023	2025	874.5617	47.72
Hadong #3	2028	2022	2026	939.6995	47.66
Yeongheung #5	2044	2028	2026	783.0674	47.64
Yeongheung #6	2044	2028	2026	783.0674	47.62
Hadong #4	2028	2024	2026	861.3834	47.6
Hadong #5	2031	2024	2026	861.3834	47.53
Hadong #6	2031	2024	2026	861.3834	47.47
Samchonpo #5	2027	2022	2027	969.909	44.34
Shin-Seocheon	2051	2027	2027	795.0736	47.51
Boryeong #8	2038	2023	2027	874.5617	47.49
Samcheok Greenpower #1	2046	2027	2027	795.0736	47.41
Sinboryeong #2	2047	2027	2027	795.0736	47.25
Samchonpo #6	2028	2022	2028	969.909	43.62

Samcheok Blue Power #1	2054	2025	2028	808.2415	47.18
Samcheok Blue Power #2	2054	2025	2028	808.2415	47.18
Yeongheung #4	2038	2029	2028	770.3096	47.15
Sinboryeong #1	2047	2028	2028	795.0736	47.08
Taean #8	2037	2025	2029	847.3219	46.97
Taean #9	2046	2029	2029	770.3096	46.85
Taean #6	2032	2024	2029	861.3834	46.79
Boryeong #7	2038	2023	2029	874.5617	46.55
Yeongheung #3	2038	2029	2029	770.3096	46.54
Hadong #7	2038	2025	2029	847.3219	45.88
Hadong #8	2039	2029	2029	770.3096	45.83

On average, the Market scenario presents a phase out schedule that takes place 11.5 years sooner than that of current policy, whereas the Regulator scenario sees it come forward by 11.9 years. There is not a significant difference between the two. Here, we present some key insights:

a. We first explore the units that retire earlier in the Regulator scenario as compared to the Market scenario:

   i. Samcheonpo 6 and Boryeong 7 retire 6 years earlier.

   ii. Samcheonpo 5 and Taeahn 6 retire 5 years earlier.

   iii. Hadong 3 and 7, Boryeong 5 and 8 and Taeahn 8 retire 4 years earlier.

   iv. Hadong 1 and 2, Samcheok Blue Power 1 and 2, Boryeong 4 and 6 retire 3 years earlier.

   v. Apart from Samcheok Blue Power 1 and 2 (that are equipped with ultrasupercritical boilers), all units are equipped with supercritical boilders.

b. We now explore the units that retire earlier in the Market scenario as compared to the Regulator scenario:

   i. Taeahn 10, Samcheok Green 2, Dangjin 9 and 10 retire 5 years earlier.

   ii. Gosung Hi 1 and 2, Gangreung Anin 1 and 2 retire 4 years earlier.

   iii. These units are equipped with ultrasupercritical boilers. Gangreun Anin 1 and 2 are under construction, while all other units are either operating or near completion.

c. In the market scenario, the units under construction (including Gosung Hi 1 and 2, Gangreung Anin 1 and 2, Samcheok Blue Power 1 and 2, and Shinseocheon) would retire almost immediately after their completion – in the regulator scenario they would operate for at most four years. This demonstrates the high risk that these units face of becoming stranded assets, even if completed.

i. Among the ultrasupercritical units completed around 2016-2017, such as Bukpyeong 1 and 2, Dangjin 9 and 10, Taeahn 10, Shinboryeong 1 and 2, Samcheok Green 1 and 2, those located along the East coast (Samcheok Green 2, Bukpyeong 1 and 2, etc.) would need to retire relatively sooner.

ii. Among the existing supercritical /subcritical units, Yeosu 1 and 2, Boryeong 3 and 4, Yeonheung 5 and 6, Taeahn 7, Dangjin 7 and 8 were identified as the ones that would need to be retired sooner than the current policy schedule. Several factors could be considered in the prioritisation of these, such as recent equipment investment made in those units, etc.

d. In the Regulator scenario, the retirement sequence is almost identical to the order of construction years. This sheds light on a potential path to an accelerated coal phase out process. Aging units that are still kept due to various policy concerns, for example Donghae 1 and 2, could be pushed forward. Then, units located in the vicinity of others with an expedited retirement schedule, such as Samcheonpo 3 and 4, Boreyong 3,4,5, and6, Taeahn 1,2,3 and 4, and Hadong 1,2 and 3, could also be retired earlier.

i. Among the new units, Bukpyeong 1 and 2 have considerably higher pollutant emissions in our calculations, and this can be validated and confirmed by an investigation of the causes.

Annex III – Methodology air pollution and health impacts

A.1 Atmospheric dispersion modelling system

The atmospheric dispersion model consists of two major components. A meteorology module is used to simulate the regional meteorological conditions around the power plants (A.1.1). This is combined with a chemistry-transport model to study the propagation of the power plant emissions to the environment (A.1.2).

A.1.1 Meteorology module

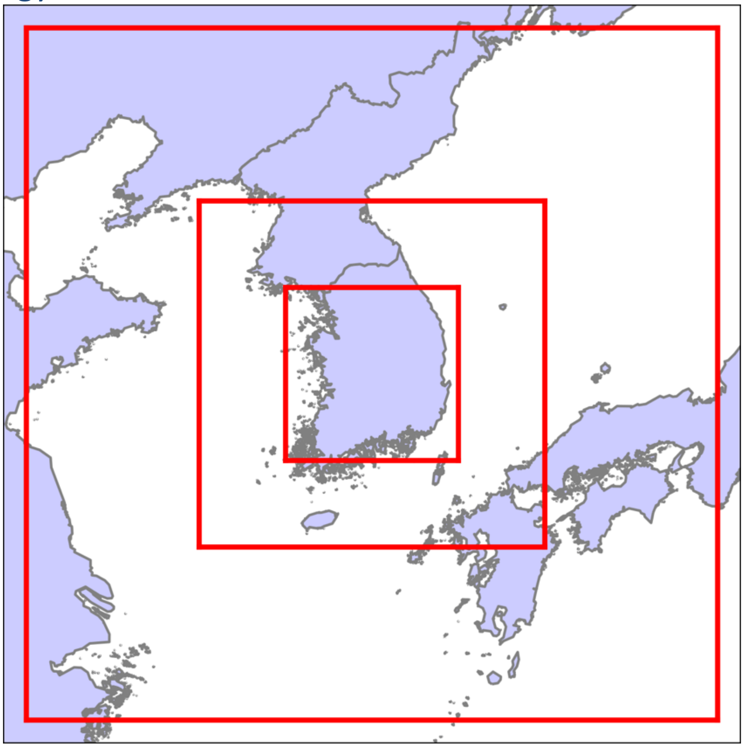

Figure A.1: A numerical weather model is run on three nested domains (red boxes) centred around South Korea.

- **Model.** The meteorology around the power plants is modelled using version 3 of the *The Air Pollution Model* (TAPM). Although TAPM includes the ability to model pollutant dispersion, only the meteorology component of TAPM is used.
- **Domains.** The meteorology module is run on three nested 75x75 grids centred in South Korea with spatial resolutions of 20 km, 10 km and 5 km, respectively, getting finer towards the centre (Figure A.1).
- **Boundary conditions** are derived from the GASP model data of the Australian Bureau of Meteorology.
- **Spin up and analysis period.** We ran the meteorology module for one year (model time). Since we analysed the multi-year health impact, a recent yet representative year was selected. In each simulation, the model is run for the last seven days of 2015 and the whole year of 2016. The first seven days are used to let the model spin up, and only the 2016 data are used for the analysis.
- **Selection of the model year.** In order to choose a year which is as representative for the long run as possible, we performed a rough statistical analysis of meteorological surface observations between 2005-2018. We analysed wind speed, wind direction, temperature, humidity, rainfall, cloud base height and sky cover from standard airport weather observations

through NOAA's ISD data and screened for a year in which the values are close to average and none are the extreme values for the past 10 years. Based on this criterion, we selected 2016 as representative model year.

A.1.2 Chemistry-transport module

- **Model.** The atmospheric dispersion, chemical transformation and deposition of the power plant emissions is modelled by version 7 of the *CALPUFF* model.
- **Receptor array.** The chemistry-transport module is run on an irregular array of 11,224 receptors centred around each of the power plants. The spatial resolution of the receptors ranges from 700m in the immediate surrounding of the power plant and 20km at the edge of the outermost domain of the meteorology module.
- **Other pollution sources.** As we are solely focusing on the impacts from the power plants, no emission sources other than the studied power plants are included in the model. The influence of other sources of emissions on the chemical transformation of power plant emissions is taken into account indirectly by inputting the monthly concentrations of background chemical species (NH_3, O_3, H_2O_2) from Koplitz et al (2017) into CALPUFF.
- **Pollutant species.** Modelled are the power plants emissions of mercury (elemental, divalent and particle-bound), NO, NO_2, SO_2 and primary $PM_{2.5}$.
- **Background concentrations** of O_3, NH_3 and H_2O_2 are included for use by the chemistry module.
- **Output.** The model outputs a time series of near-surface concentrations of the pollutants for analysis to gridded receptor locations across the model domains.
- **Accounting for operation time.** The model is run for the whole year at the full-operation emissions rates. The resulting ground-level pollutant concentration fields are used as such for assessing maximum short-term air quality impact. For the purposes of health impact assessment (Section A.2), the average concentrations are scaled down by the plant's projected load factor, effectively spreading the plant's annual emissions volume evenly through the year.

Power plant geometry and emission data sources

The pollutant emission rates and flue gas release characteristics used for the modelling are based, as far as possible, on self-reported data by power plant owners and government sources. Other publicly available information was used in the analysis. Over 90% of data was collected from the Korean government's information disclosure system and data reported by the power plant owners to the parliament member's office of the National Assembly. The following parameters have been used to determine power plant emission characteristics;

- Reported annual emissions from the power plant owners and government statistics
- Emission limit values or average stack emission concentrations
- Amount of actual or expected air pollutant ($PM_{2.5}$, NO_2, SO_2) emissions
- Unit age, capacity and thermal efficiency
- Annual operating hours
- Calorific value of coal
- Flue gas volume flow (FGV)
- Flue gas exit speed and temperature
- Stack height
- Stack inner diameter

The location of the power plants was sourced from visual inspection of satellite imagery provided by the Google map platform by and from environmental impact assessment documents published by the power plant owners. The stack inner diameter was measured from high-resolution satellite imagery, when actual information was not available from regulatory sources or literature. When information on stack height and flue gas temperature was not available, median values in the South Korean dataset for units with the same size were used. Flue gas release velocity was calculated from stack diameter and flue gas flow, when not available. When annual emissions volumes were not reported, they were calculated as:

$$SFGV * CAP / EFF * CF * FGC,$$

where SFGV is specific flue gas volume (Nm^3/GJ thermal input), estimated as the median for plants for which flue gas flow rate, capacity and thermal efficiency were known; CAP is electric capacity, EFF is thermal efficiency, CF is the annual average capacity factor and FGC is pollutant concentration in flue gas, given in ppm for SO_2 and NO_x and mg/Nm^3 for dust.

As mercury emissions are not reported by plant operators, they were calculated using average mercury emission rate per tonne of coal burned in South Korea calculated from AMAP/UNEP Global Mercury Assessment.

The power plant and emission data shown in Table A1 is used as the basis of modelling the plants' air quality impacts using the CALMET-CALPUFF modelling system.

Table A1. *Stack and flue gas characteristics and baseline emission rates of the modelled power plants (metric units). Stack and flue gas parameters are reported by the operator. Emission data is (a) reported by the operator or (b) computed from expected capacity and assumptions on thermal efficiency and capacity factor, as explained above.*

Plant	Unit	Stack				Flue gas		Emissions			
		lat	lon	height	diameter	temperature	exit speed	SO_2	NO_x	PM	data source
		(deg)	(deg)	(m)	(m)	(°C)	(m/s)	(t/a)	(t/a)	(t/a)	
Yeosu	1	34.8404	127.6917	150	4.8	91	27.2	128	392	14	a
Yeosu	2	34.8404	127.6917	150	4.8	91	21.6	76	427	11	a
Yeongheung	1	37.2429	126.4463	200	6.6	90	18.1	1239	937	60	a
Yeongheung	2	37.2429	126.4463	200	6.6	90	18.1	1363	975	52	a
Yeongheung	3	37.2429	126.4463	198	6.3	90	20.4	888	536	16	a
Yeongheung	4	37.2429	126.4463	198	6.3	90	20.4	819	513	25	a
Yeongheung	5	37.2429	126.4463	200	6.9	95.3	17.4	497	450	22	a
Yeongheung	6	37.2429	126.4463	200	6.9	95.3	17.4	507	463	20	a
Taean	1	36.0004	126.2451	150	8.83	79.83	8.9	320	560	53	a
Taean	2	36.0002	126.2443	150	8.83	77.87	8.9	272	341	31	a
Taean	3	35.9999	126.2435	150	8.83	78.41	8.9	322	835	94	a
Taean	4	35.9997	126.2427	150	8.83	77.69	8.9	691	710	99	a
Taean	5	35.9991	126.2413	150	5.4	78.49	23.4	993	886	78	a
Taean	6	35.9991	126.2411	150	5.4	82.22	23.4	1353	1037	93	a
Taean	7	35.9986	126.2396	150	5.4	95.87	27.7	451	567	20	a
Taean	8	35.9986	126.2395	150	5.4	96.41	27.7	598	700	24	a
Taean	9	35.9972	126.2373	150	7.3	91	32.9	706	795	77	a
Taean	10	35.9973	126.2375	150	7.3	91	32.9	1011	816	53	a
Shin Boryeong	1	36.3840	126.4850	150	7.5	90	16.8	1150	507	29	a

Shin Boryeong	2	36.3840	126.4850	150	7.5	90	16.8	1005	763	45	a
Samcheonpo	1	34.9117	128.1092	200	5.3	119	37.5	687	1122	39	a
Samcheonpo	2	34.9117	128.1092	200	5.3	109	37.5	557	1178	57	a
Samcheonpo	3	34.9117	128.1092	200	5.3	95	37.5	1230	2035	75	a
Samcheonpo	4	34.9117	128.1092	200	5.3	100	37.5	1044	1302	71	a
Samcheonpo	5	34.9117	128.1092	200	5.3	139	24.2	645	521	118	b
Samcheonpo	6	34.9117	128.1092	200	5.3	148	23.8	726	586	133	b
Samcheok Green Power	1	37.1860	129.3400	90	8.8	90	15.1	595	1445	105	a
Samcheok Green Power	2	37.1840	129.3400	90	8.8	90	15.1	330	1008	60	a
Honam	1	34.5114	127.4404	150	7	90	6.6	681	862	17	a
Honam	2	34.5114	127.4406	150	7	90	6.6	1379	1558	32	a
Hadong	1	34.9500	127.8200	150	9.3	83	7.4	1113	1094	50	a
Hadong	2	34.9500	127.8200	150	9.3	83	6.6	1174	706	47	a
Hadong	3	34.9510	127.8200	150	9.3	83	6.6	1128	707	49	a
Hadong	4	34.9520	127.8190	150	9.3	83	6.5	970	855	30	a
Hadong	5	34.9520	127.8190	150	9.3	83	6.7	898	721	40	a
Hadong	6	34.9530	127.8190	150	9.3	83	6.8	819	1129	40	a
Hadong	7	34.9540	127.8180	150	5.4	82	18.6	720	808	37	a
Hadong	8	34.9540	127.8180	150	5.4	82	19.1	886	855	49	a
Donghae	1	37.2907	129.0847	150	4	154	16.2	770	262	7	a
Donghae	2	37.2909	129.0845	150	4	154	16.2	857	341	10	a
Dangjin	1	37.0315	126.3051	151	6.5	85	15.4	691	602	52	a
Dangjin	2	37.0315	126.3048	151	6.5	85	15.4	662	706	53	a
Dangjin	3	37.0316	126.3045	151	6.5	85	15.4	562	592	44	a
Dangjin	4	37.0317	126.3042	151	6.5	85	15.4	664	544	42	a
Dangjin	5	37.0318	126.3037	150	5.4	90	22.2	540	687	53	a
Dangjin	6	37.0319	126.3034	150	5.4	90	22.2	627	667	54	a
Dangjin	7	37.0320	126.3031	150	5.4	90	22.2	393	464	42	a
Dangjin	8	37.0320	126.3028	150	5.4	90	22.2	397	431	47	a
Dangjin	9	37.0323	126.3023	200	7.4	91	25.7	796	829	22	a
Dangjin	10	37.0324	126.3018	200	7.4	91	25.7	1079	1058	27	a
Bukpyeong	1	37.4770	129.1459	150	5.3	90	24.5	1212	1910	84	a
Bukpyeong	2	37.4770	129.1459	150	5.3	90	24.5	1212	1910	84	a
Boryeong	1	36.4020	126.4880	150	8.864	85	7.2	570	959	53	a

Boryeong	2	36.4020	126.4890	150	8.864	85	7.2	470	1320	40	a
Boryeong	3	36.4020	126.4900	150	8.788	90	8.8	516	416	94	b
Boryeong	4	36.4020	126.4910	150	8.762	90	7.3	804	464	26	a
Boryeong	5	36.4020	126.4920	150	8.788	90	7.3	1013	667	49	a
Boryeong	6	36.4020	126.4930	150	8.788	90	7.3	1146	689	34	a
Boryeong	7	36.4020	126.4940	150	5.4	90	17.2	235	312	43	a
Boryeong	8	36.4020	126.4940	150	5.4	90	17.2	229	604	32	a
Shin Seocheon	1	35.2394	126.5016	150	7.4	90	21.0	1364	1159	238	b
Goseong Hi	1	34.9020	128.1230	190	7.5	90	22.5	1500	1275	261	b
Goseong Hi	2	34.9020	128.1230	190	7.5	90	22.5	1500	1275	261	b
Gangneung Anin	1	37.7340	128.9780	102	7.6	101	21.9	1389	1121	254	b
Gangneung Anin	2	37.7340	128.9780	102	7.6	101	21.9	1389	1121	254	b
Samcheok Blue power	1	37.4070	129.1770	250	7.4	90	22.3	1415	1203	247	b
Samcheok Blue power	2	37.4070	129.1770	250	7.4	90	22.3	1415	1203	247	b

A.2 Health impact assessment

The results of the near-surface concentration of air pollutants emitted by the power plants as modelled by the atmospheric dispersion modelling system are used to assess the exposure of the human population to air pollution and its impact on public health.

A.2.1 Health outcomes

The number of people affected by negative health outcomes caused by the excess pollution have been assessed using empirical values of *relative risks* relating negative health outcomes (asthma symptoms, low birth weight, death) to increases in pollutant concentrations. The relative risk *r* expresses how much more likely an individual is to experience that health outcome if they (or their mother) are exposed to a certain excess pollution compared to if they were not exposed:

$$m_x / m_0 = r, \quad (1)$$

where m_x is the *incidence rate* under the increased pollution Δx, and m_0 is the incidence rate in absence of the excess pollution. The *incidence rate* is the number of cases where an individual experiences this health outcome per number of the relevant population group (asthmatic children, newborns, total population). In some epidemiological models, *r(x)* is given as an empirical function. In others, *r(x)* is an exponential function for $m_x << 1$:

$$r = \exp(c\,\Delta x), \quad (2)$$

with *c* being a constant called *concentration response factor.* Combining Eqs. (1) and (2) gives

$$m_x = m_0 \exp(c\,\Delta x).$$

Since the number of cases is the number of the relevant population group *P* times the incidence rate, the number of cases under the higher pollutant concentration is

$$d_x = P\, m_0 \exp(c\,\Delta x).$$

The number of cases attributable to the excess pollution is

$$\Delta d = d_x - d_0 = P\, m_0\, [\exp(c\, \Delta x) - 1].$$

Integrating Δ*d* spatially over the model domain gives the total number of cases attributable to the excess pollution within the model domain.

Data sources for the health impact assessment

- **Population (present and future).** Data on total **population** and population **age structure** were taken from the GBD project 2019 (IHME 2020).
- **Background incidence rates (present and future).**
  - Baseline **death rates** and **years of life lost** for South Korea were taken from the GBD project 2019 (IHME 2020).
  - Background incidence rates for other health impacts were taken from the same sources as in Myllyvirta (2020).
  - The health impacts are adjusted by age group-specific changes in population and all-cause mortality, based on historical data and projections in UNPD World Population Prospects 2019 (medium variant).
- **Background pollution.** The baseline concentrations of $PM_{2.5}$ and NO_2 were taken from van Donkelaar et al. (2016) and Larkin et al. (2017), respectively.
- **Administrative domain borders** are taken as defined in version 3.6 (May 2018) of the GADM project. These boundaries and those shown on any maps solely reflect the data source used and do not imply recognition or support to any party where there may be territorial disputes.
- **Concentration response functions (CRFs).** CRFs have been used from the same sources as in Myllyvirta (2020), except that NO_2-related mortality is taken from Faustini et al (2014) and SO_2-related mortality from Krewski et al (2009) (see Table A2).

Table A2. Concentration response functions.

Age group	Effect	Pollutant	Concentration-response function	Concentration change	No-risk threshold	Reference	Incidence data
1-18	New asthma cases	NO_2	1.26 (1.10 - 1.37)	10 ppb	2 ppb	Achakulwisut et al. 2019	Achakulwisut et al. 2019
0-17	Asthma emergency room visits	$PM_{2.5}$	1.025 (1.013–1.037)	10 µg/m^3	6 µg/m^3	Zheng et al. 2015	Anenberg et al. 2018
18-99	Asthma emergency room visits	$PM_{2.5}$	1.023 (1.015–1.031)	10 µg/m^3	6 µg/m^3	Zheng et al. 2015	Anenberg et al. 2018
Newborn	Preterm birth	$PM_{2.5}$	1.15 (1.07, 1.16)	10 µg/m^3	8.8 µg/m^3	Trasande et al. 2016	Chawanpaiboon et al. 2019
25-99	Deaths from non-communicable diseases and lower respiratory infections	$PM_{2.5}$	non-linear		2.4 µg/m^3	Burnett et al. 2018	IHME 2020

0-4	Deaths from lower respiratory infections	$PM_{2.5}$	non-linear		5.8 μg/m³	IHME 2020	IHME 2020
25-99	Deaths from lower respiratory infections	$PM_{2.5}$	non-linear		5.8 μg/m³	IHME 2020	IHME 2020
25-99	Premature deaths	NO_2	1.04 (1.02–1.06)	10 μg/m³	4.5 μg/m³	Faustini et al. 2014	IHME 2020
25-99	Premature deaths	SO_2	1.02 (1.014–1.026)	5 ppb	0.02 ppb	Krewski et al. 2009	IHME 2020

Annex IV – Health impacts across the three scenarios

Here, we present the results on the estimated health impacts in more detail, showing the estimates for the different scenarios.

Table I: *Accumulated health impacts of South Korean coal-fired power plants from 2021-2054, total, domestic and abroad, under current policies (9th Basic Plan for Electricity Power Supply and Demand).*

Current policies									
Outcome	Total			Domestic			Abroad		
	95%-confidence interval			95%-confidence interval			95%-confidence interval		
	best estimate	low estimate	high estimate	best estimate	low estimate	high estimate	best estimate	low estimate	high estimate
Premature deaths	23,332	15,188	32,309	15,880	10,273	21,857	7,452	4,915	10,452
Years of potential life lost	428,223	276,760	599,087	287,127	185,890	396,110	141,096	90,870	202,977
Preterm births	2,348	1,136	2,493	1,128	546	1,198	1,220	590	1,295
Asthma: New cases	4,382	948	9,909	3,451	746	7,825	931	202	2,084
Asthma: Emergency room visits	9,793	6,083	13,471	5,572	3,484	7,642	4,221	2,599	5,829
Work absences (person days)	6,376,941	5,424,894	7,322,620	3,905,690	3,322,604	4,484,870	2,471,251	2,102,290	2,837,750

Table II: *Accumulated health impacts of South Korean coal-fired power plants from 2021-2054, total, domestic and abroad, under the Regulator Perspective Scenario.*

Regulator Scenario									
Outcome	Total			Domestic			Abroad		
	95%-confidence interval			95%-confidence interval			95%-confidence interval		
	best estimate	low estimate	high estimate	best estimate	low estimate	high estimate	best estimate	low estimate	high estimate
Premature deaths	4,922	3,195	6,829	3,353	2,160	4,625	1,569	1,035	2,204
Years of potential life lost	90,591	58,343	127,016	60,625	39,083	83,805	29,966	19,260	43,211
Preterm births	620	300	658	301	146	319	319	154	339
Asthma: New cases	1,143	247	2,586	923	199	2,093	220	48	493

Asthma: Emergency room visits	2,486	1,539	3,424	1,450	903	1,992	1,036	636	1,432
Work absences (person days)	1,729,457	1,471,259	1,985,927	1,095,855	932,255	1,258,359	633,602	539,004	727,568

Table III: *Accumulated health impacts of South Korean coal-fired power plants from 2021-2054, total, domestic and abroad, under the Market Perspective Scenario.*

Market Scenario									
Outcome	**Total**			**Domestic**			**Abroad**		
	95%-confidence interval			95%-confidence interval			95%-confidence interval		
	best estimate	low estimate	high estimate	best estimate	low estimate	high estimate	best estimate	low estimate	high estimate
Premature deaths	4,850	3,154	6,720	3,261	2,105	4,494	1,589	1,049	2,226
Years of potential life lost	88,929	57,399	124,494	58,966	38,077	81,447	29,963	19,322	43,047
Preterm births	614	297	651	298	144	316	316	153	335
Asthma: New cases	1,121	242	2,536	899	194	2,038	222	48	498
Asthma: Emergency room visits	2,467	1,528	3,399	1,436	895	1,973	1,031	633	1,426
Work absences (person days)	1,724,315	1,466,885	1,980,023	1,086,455	924,258	1,247,565	637,860	542,627	732,458