Health Impact Assessment

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Health impacts of delaying coal power plant decommissioning in South Africa

Lauri Myllyvirta
Jamie Kelly
October 2023

CREA

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.

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Authors
Lauri Myllyvirta
Jamie Kelly

Editor(s)
Vera Tattari

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Health impacts of delaying coal power plant decommissioning in South Africa

Key findings

- Under South Africa’s current Integrated Resource Plan, issued in 2019, 11.3 GW of coal power at seven plants is scheduled to retire by 2030. However, there are proposals to delay all decommissioning until after 2030.
- To date only one power plant, Komati, has been retired although not yet decommissioned. We estimate that from 2020, when most units at the plant were placed in reserve, to 2023, the closure of the plant has already avoided negative health impacts including 220 deaths (95% confidence interval: 130 – 350) and R4.9 bln in health costs.
- The decommissioning delays already introduced in Eskom’s “Emissions Reduction Plan” published in 2022, compared with the 2019 Integrated Resource Plan, will lead to a projected 2,800 excess deaths (95% confidence interval: 1,700 – 4,300) and total economic costs of R61 bln.
- Delaying the decommissioning of all plants currently scheduled to begin decommissioning by 2030, so that decommissioning only begins in 2030 and beyond would cause a projected 15,300 excess air pollution-related deaths (95% confidence interval: 9,210 – 23,900) and total economic costs of R345 billion (95% confidence interval: 206 – 526).
- The delayed decommissioning of plants scheduled to close in the 2020s would be likely to have a further knock-on effect on the decommissioning of other units later, as they would overlap with the scheduled decommissioning of other power plants, leading to an implausibly high rate of removals of coal power capacity from the system.
- If the rate of decommissioning in the 2030s and 2040s is not accelerated from current plans (the current IRP and ERP), the further delays to the decommissioning of other units would multiply the health impacts of the delay to 32,300 deaths from air pollution (95% confidence interval: 19,700 – 49,500) and economic costs of R721.00 billion (95% confidence interval: 438.00 – 1,080.00).

Contents

Introduction

South Africa is the 7th largest coal producer in the world (Prater, 2018). The burning of this fuel in coal-fired power stations leads to the release of greenhouse gases, which are contributing to climate change, and to the formation of air pollutants which are dangerous for public health.

The health impacts of air pollution have been established through decades of research. Exposure to air pollution can lead to deaths among children and adults, through diseases including ischaemic heart disease, chronic obstructive pulmonary disease, lung cancer, stroke, and diabetes (Lelieveld et al., 2019, Burnet et al., 2018). In addition to death, exposure to air pollution is also associated with a range of other health outcomes, including asthma emergency room visits (Anenberg et al., 2018), premature and underweight babies (Chawanpaiboon et al., 2018), work absences (EEA, 2014), dementia and Alzheimer's disease (Shi et al., 2020; Shi et al., 2023), depression (Xue et al., 2021), bronchitis (Kelly, 2021), and pneumonia (Zhang et al., 2021).

In Africa, air pollution is the second leading cause of premature mortality, exceeded only by AIDS (Fischer et al., 2021; Murray et al., 2020). South Africa has a number of air pollution hotspots where air quality does not meet national air quality standards, let alone the WHO's health-based guidelines. These areas (the Mpumalanga Highveld, the Vaal Triangle and the Limpopo Waterberg and Bojanala) were declared air pollution priority areas under air quality legislation many years ago. Eskom's fleet of coal power stations, of which 12 are located in the Mpumalanga Highveld, and two are located in the Limpopo Waterberg, is responsible for most of the air pollution. Across these hotspots, as well as throughout the rest of South Africa, a major source of the pollution is coal combustion (Health Effects Institute, 2022; Marais et al., 2019; McDuffie et al., 2021).

In March 2022 South Africa's North Gauteng High Court ruled that the poor air quality in the Highveld Priority Area is in breach of residents' section 24(a) Constitutional right to an environment that is not harmful to their health and well-being.

The poor air quality in these areas causes significant health impacts. In 2017, it was estimated in an independent expert study that air pollution from Eskom's coal power stations alone is responsible for approximately 2,200 deaths annually, as well as more than 94,000 cases of asthma symptom days in children; more than 9,500 cases of bronchitis in children and almost 2,800 cases of chronic bronchitis in adults, 2,400 hospital admissions and 1 million lost working days a year (Holland, 2017).

While Eskom plans to decommission coal-fired power plants, the exact pathways that will be followed are unclear. In 2019, Eskom issued the Integrated Resource Plan (IRP), which set a timeline for decommissioning several plants well before 2030. They planned to start with the decommissioning of Grootvlei Power Station from 2018 to 2020 followed by Komati Power Station from 2019 to 2020; thereafter Hendrina and Camden Power Stations were scheduled to be decommissioned between 2020-2026 (Hendrina) and 2020-2023 (Camden). Arnot was scheduled for decommissioning from 2021 to 2029, and Kriel was scheduled for decommissioning from 2026 to 2029.

Later, in 2022, Eskom issued an "Emissions Reduction Plan"[1] which altered some of the previously established decommissioning timelines including an earlier retirement for Tutuka but delayed the retirement of many other plants, including: Komati Power Station (which closed in 2022); Grootvlei (decommissioning delayed to 2026–2028); Hendrina (delayed to 2023–2026); Camden (delayed to 2023–2026); Arnot (delayed to 2026–2029) and Kriel (delayed to 2026–2029).

Currently, the South African government plans to delay decommissioning even further. The current IRP 2019 is currently under review, and a new draft IRP is expected to be published for comment before the end of 2023. During the review process, it has been proposed that the decommissioning of all coal power plants currently scheduled for decommissioning before 2030 be delayed until 2030 and beyond.

It is important to recognize that the persistent load shedding in South Africa is not due to insufficient power capacity, but due to Eskom's failure to operate and maintain its power plant fleet in a way that ensures plant availability and reliable operation. The country has a total of 52 GW of dispatchable power capacity compared to the highest peak load of 33 GW in 2023, meaning that around 38 GW of reliably operating capacity would be sufficient to supply all demand and avoid loadshedding in all circumstances[2]. Timely decommissioning of the ageing coal power plants would reduce total operating and maintenance costs,

[1] "Eskom MES applications: Input to the Consultative Environmental Panel Hearings – Medupi and Matimba" Powerpoint presentation by Eskom, 24 November 2022 (ver 2)

[2] 43.5 GW coal-fired capacity based on the Global Coal Plant Tracker, not taking into account unplanned outages and downrates; other capacity includes 1.9 GW nuclear, 3.4 GW gas- and oil-fired capacity, 3.3 GW hydropower and pumped storage. Peak demand from Eskom. Amount of needed capacity based on 15% planning margin as recommended by the North American Electric Reliability Corporation for predominately thermal systems.

potentially freeing up resources to maintain and refit the rest of the fleet. Delaying decommissioning would saddle Eskom with an oversized fleet, making it harder and more expensive to achieve reliable operation or install efficient emission control systems.

Methodology

Emissions projections

Power generation and emissions for all plants are assumed to continue at the FY2021–22 level, for which data was compiled from Eskom's monthly emissions reports for an earlier CREA study. The exception is that where the Eskom Emission Reduction Plan includes retrofits or other improvements in plant emissions, we assume that these measures are completed fully and in time, with the projected emissions after improvements based on the same CREA study.

We projected emissions over time for four different scenarios:

- IRP 2019, based on the Integrated Resource Plan
- ERP 2022, based on Eskom's Emission Reduction Plan
- "Delay all to 2030s": introduce an 8-year delay to the decommissioning of all plants for which decommissioning is scheduled to start by 2030 in the ERP. This means that Hendrina's decommissioning starts in 2031, Camden's in 2032 and so on. We make this assumption because it does not seem plausible that after an 8-year delay, all six affected plants would start decommissioning at the same time in 2031.
- "Delay all to 2030s, with knock-on effects": Recognizing that the "Delay all to 2030s" scenario leads to much faster rates of decommissioning in 2030s than foreseen in the IRP or EPR, we model a scenario in which annual rates of capacity closure are kept similar to those scenarios. We accomplish this by introducing a delay that falls linearly from 8 years for plants scheduled to begin decommissioning in 2030 or earlier to zero by 2050. The duration of the decommissioning of each plant and the order in which the different plants are decommissioned is kept unchanged.

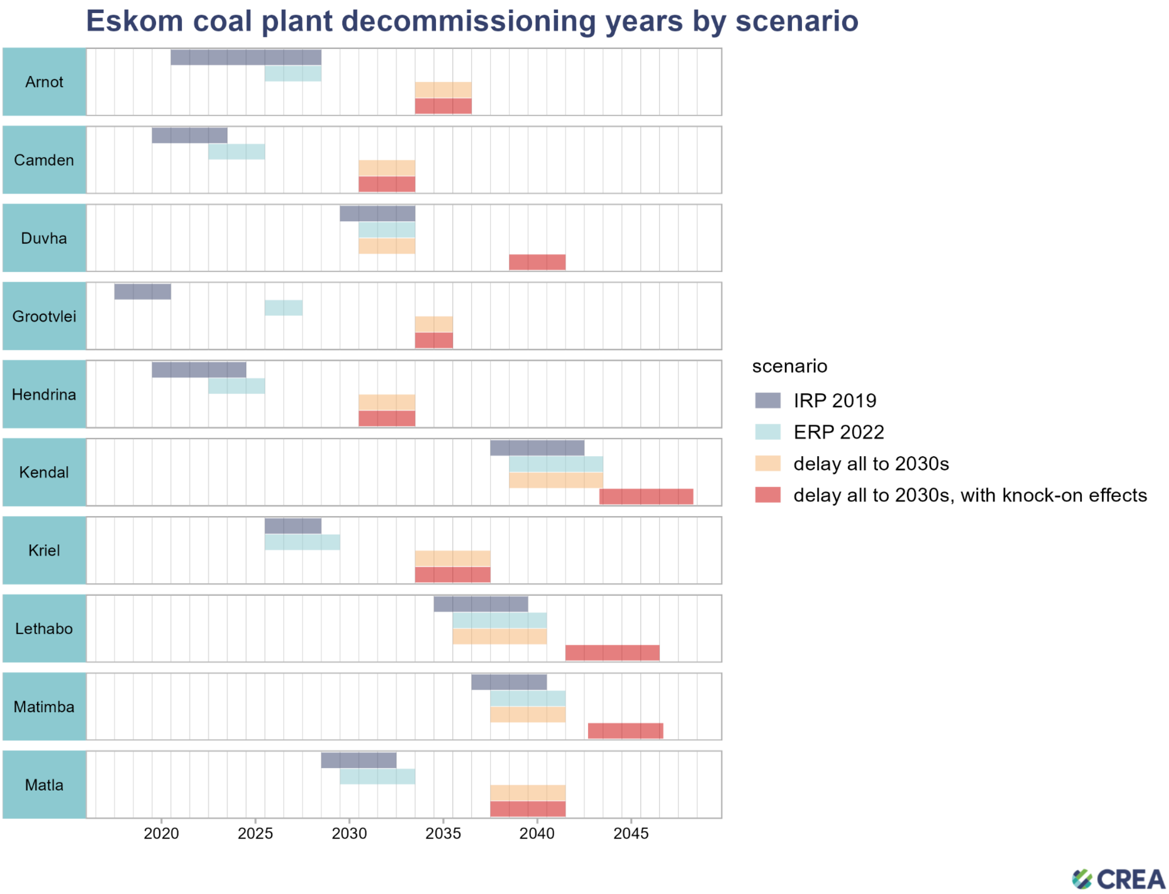

Figure 1. *Eskom coal plant decommissioning years by scenario. (CREA, 2023).*

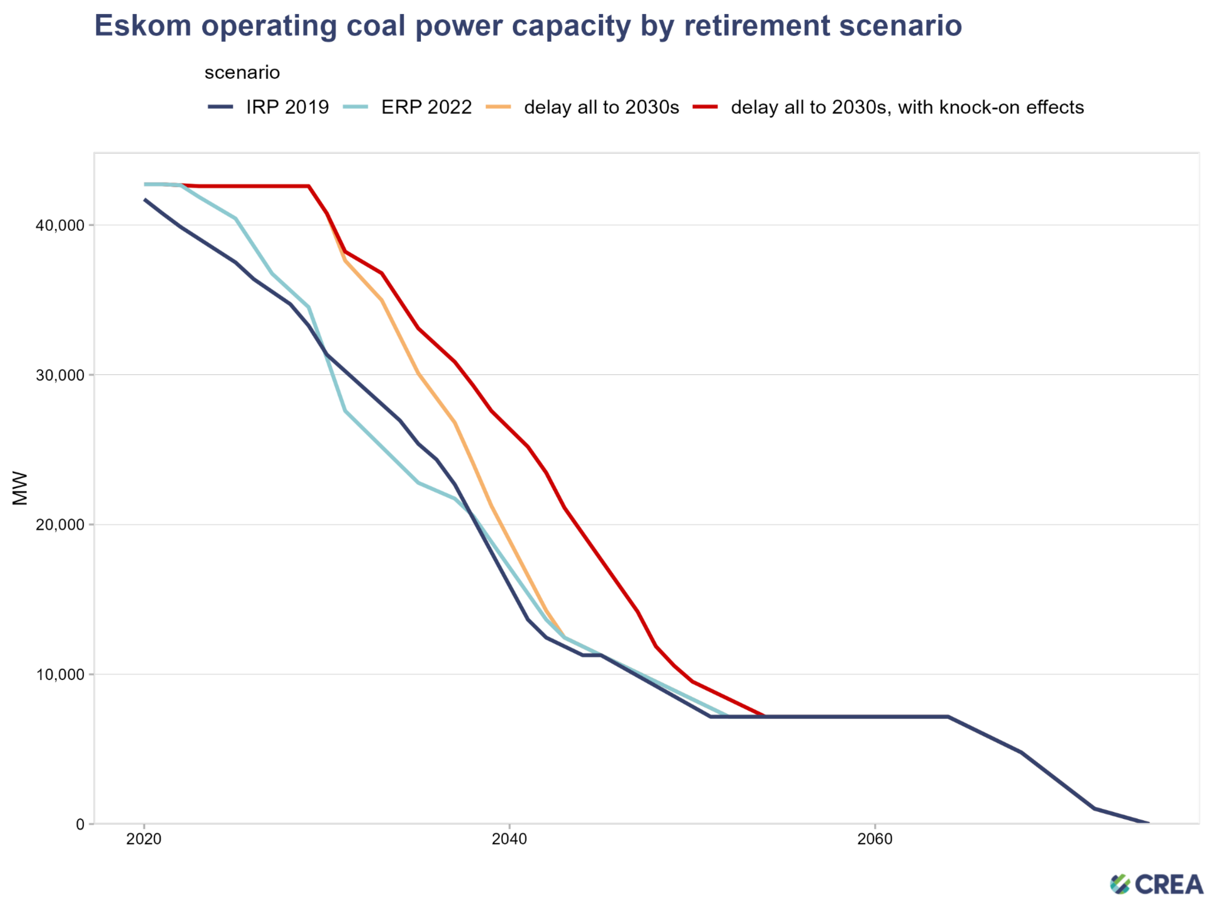

Figure 2. *Eskom operating coal power capacity by retirement scenario. (CREA, 2023).*

To assess the benefits of the closure of Komati, we average emissions from fiscal years 2015–16 and 2016–17 as the basis for a “continued full operation” scenario. The plant’s power generation fell steeply already in the following years but the first units were officially placed in reserve only in 2020. Therefore, we compared the projected health impacts for a “continued full operation” scenario to the actual plant emissions for the calendar years 2020–2023. Komati emissions were compiled from the power station’s annual and monthly emissions reports.

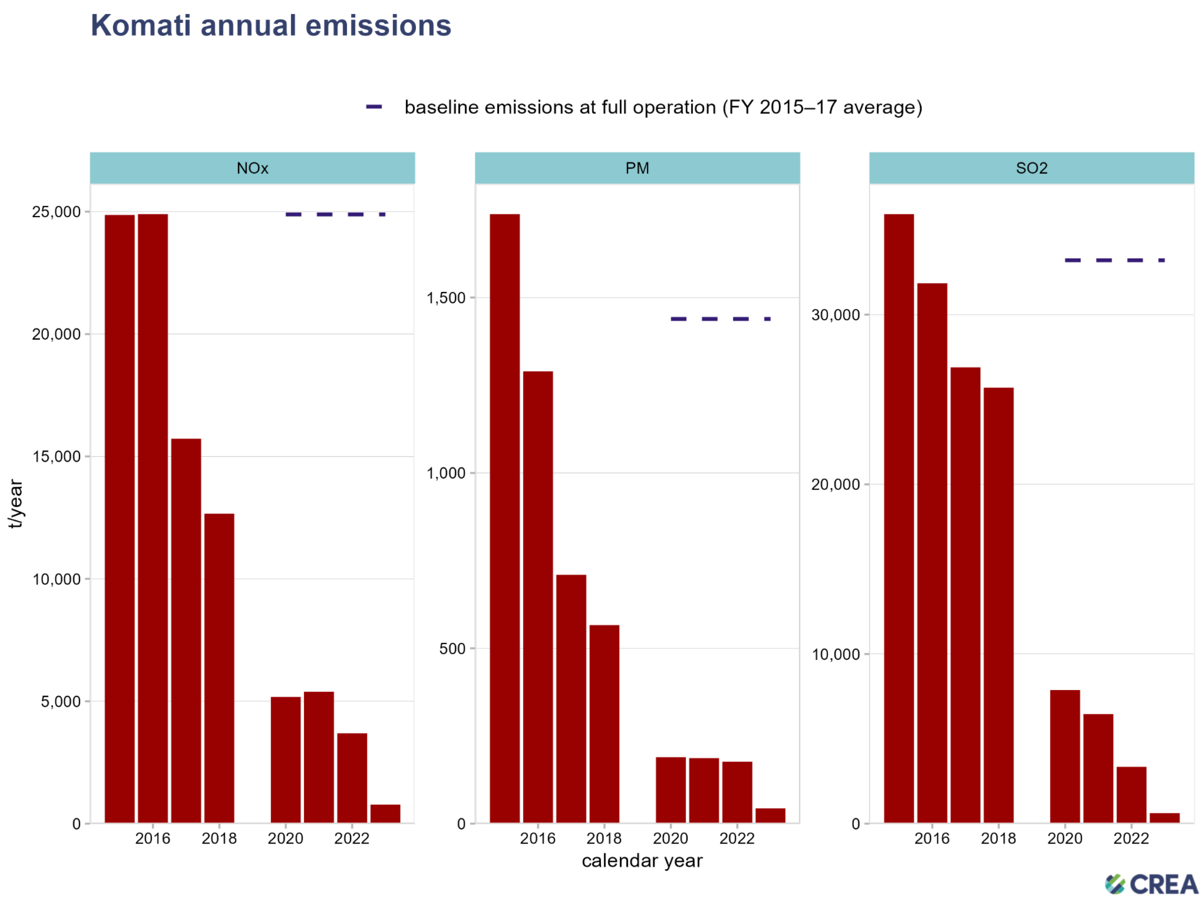

Figure 3. *Komati annual emissions by pollutant and calendar year. (CREA, 2023). 2019 data could not be obtained.*

Atmospheric modelling

We simulate air pollutant concentrations using the CALPUFF air dispersion model, version 7 (Exponent, 2015). CALPUFF is a widely-used industry standard model for long-range air quality impacts of point sources. The model has been evaluated extensively by the US Environmental Protection Agency, is open-source, and fully documented. CALPUFF calculates the atmospheric transport, dispersion, chemical transformation and deposition of the pollutants, and the resulting incremental ground-level concentrations attributed to the studied emissions sources. Chemical transformations of SO_2 and NO_2 to $PM_{2.5}$ are calculated using the ISORROPIA chemistry module in CALPUFF.

Background concentrations of oxidants (ozone, ammonia, hydrogen peroxide) are taken from a global atmospheric chemistry model. Meteorological input data are generated from the Weather Research Forecasting (WRF) model (Skamarock et al., 2008), version 4.2.2. WRF was set up with 33 vertical levels and 3 nested grids. The mother nest has a grid resolution of 15 km, and spans approximately 1,600 km in both the north-south and east-west directions. The inner nests both have a grid resolution of 5 km, spanning around 300 km in both the north-south and east-west directions. One is centred over the Lephalale (Limpopo) town and the other is centred over the town of Leandra (Mpumalanga), which is nearly 100 km east of Johannesburg. Mother and inner domains use a two-way nesting technique which ensures dynamic interaction between them. WRF simulations use initial and lateral boundary conditions from NCEP (National Centers for Environmental Prediction) CFRS (Climate Forecast System Reanalysis) dataset of NOAA (National Oceanic and Atmospheric Administration) producing three-dimensional, hourly meteorological data covering the full calendar year 2021.

The power plants were modelled as buoyant point sources, taking into account the stack height and thermal plume rise from the stacks. The stack characteristics were obtained from Eskom Atmospheric Impact Reports for the suspension of minimum emission standards at the power plants (DFFE, 2019).

CALPUFF simulations were run separately for each of the 15 power stations. Annual pollutant concentrations were then projected using the POSTUTIL facility in CALPUFF, which allows emissions inputs to be scaled, results from different simulations to be summed up and the nitrogen chemistry to be re-run to account for the interaction between the different plumes. This approach allowed the air pollutant concentrations to be projected for different scenarios and calculation years at a manageable computational cost.

Health and Economic Impact Assessment

CREA has developed a detailed globally implementable health impact assessment framework based on the latest science. This framework includes as complete a set of health outcomes as possible without obvious overlaps.

The emphasis is on outcomes for which incidence data are available at the national level from global datasets and outcomes that have high relevance for healthcare costs and labour productivity. These health endpoints were selected and quantified in a way that enables economic valuation, adjusted by levels of economic output and income in different jurisdictions.

For each evaluated health outcome, we have selected a concentration-response relationship that has already been used to quantify the health burden of air pollution at the global level in peer-reviewed literature. This indicates the evidence is mature enough to be applied across geographies and exposure levels. The calculation of health impacts follows a standard epidemiological calculation:

$$\Delta cases = Pop \times \sum_{age} \left[Frac_{age} \times Incidence_{age} \times \frac{RR_{conc,age} - 1}{RR_{conc,age}} \right],$$

where *Pop* is the total population in the grid location, *age* is the analysed age group (in the case of age-dependent concentration-response functions, a 5-year age segment; in other cases, the total age range to which the function is applicable), $Frac_{age}$ is the fraction of the population belonging to the analysed age group, *Incidence* is the baseline incidence of the analysed health condition, and *c* is the pollutant concentration, with c_{base} referring to the baseline concentration (current ambient concentration). $RR_{(c, age)}$ is the function giving the risk ratio of the analysed health outcome at the given concentration for the given age group compared with clean air. In the case of a log-linear, non-age-specific concentration-response function, the RR function becomes: $RR(c) = RR_0\ c{-}c_0\ \Delta c_0\ when\ c > c_0,\ 1\ otherwise$, where RR_0 is the risk ratio found in epidemiological research, Δc0 is the concentration change that RR_0 refers to, and c_0 is the assumed no-harm concentration (in general, the lowest concentration found in study data).

Data on the total population and population age structure were taken from Global Burden of Disease results for 2019 (IHME, 2020). The spatial distribution of population within the country, as projected for 2020, was based on the Gridded Population of the World v4 (CIESIN, 2018).

Following the update of the WHO Air Quality Guidelines in 2021, which now recognize health harm from NO_2 at low concentrations, we use the mortality risk function for NO_2 based on the findings of Huangfu & Atkinson (2020) and include impacts down to 4.5 µg/m^3, the lowest concentration level in studies that found increased mortality risk (Table 1).

Adult deaths and disabilities were estimated using the Global Burden of Disease (IHME, 2020) risk functions.

Deaths of small children (under 5 years old) from lower respiratory infections linked to $PM_{2.5}$ pollution were assessed using the Global Burden of Disease risk function for lower respiratory diseases (IHME, 2020). For all mortality results, cause-specific data were taken from the Global Burden of Disease project results for 2019 (IHME, 2020).

Health impact modelling projects the effects of pollutant exposure during the study year. Some health impacts are immediate, such as exacerbation of asthma symptoms and lost working days, whereas other chronic impacts may have a latency of several years. Concentration-response relationships for emergency room visits for asthma and work absences were based on studies that evaluated daily variations in pollutant concentrations and health outcomes; these relationships were applied to changes in annual average concentrations.

The annual average baseline concentrations of $PM_{2.5}$ and NO_2 were taken from van Donkelaar et al. (2016) and Larkin et al. (2017), respectively. Since the no-harm concentration for SO_2 is very low and the risk function is linear with respect to the background concentration, there was no need for data on SO_2 background concentrations.

The development of the health impacts into the future took into account projected changes in population, population age structure and mortality by age group, based on the UNPD (2019) World Population Prospects Medium Variant. This factors in the expected reduction in baseline infant mortality and increase in deaths from chronic diseases in older adults as a part of the population and epidemiological transitions and improvements in health care.

Table 1. *Input parameters and data used in estimating physical health impacts.*

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	Khreis et al. 2017	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	Sapkota et al. 2012	Chawanpaiboon et al. 2019
20-65	Work absence	$PM_{2.5}$	1.046 (1.039-1.053)	10 µg/m^3	N/A	WHO 2013	EEA 2014
0-4	Deaths from lower respiratory infections	$PM_{2.5}$	IHME 2020		5.8 µg/m^3	IHME 2020	IHME 2020
25-99	Deaths from non-communicable diseases and lower respiratory infections	$PM_{2.5}$	IHME 2020		2.4 µg/m^3	IHME 2020	IHME 2020
25-99	Disability caused by diabetes, stroke and chronic respiratory disease	$PM_{2.5}$	IHME 2020		2.4 µg/m^3	IHME 2020	IHME 2020
25-99	Premature deaths	NO_2	1.02 (1.01-1.04)	10 µg/m^3	4.5 µg/m^3	Huangfu & Atkinson 2020; NRT from Stieb et al. 2021	IHME 2020
25-99	Premature deaths	SO_2	1.02 (1.01–1.03)	5 ppb	0.02 ppb	Krewski et al 2009	IHME 2020

Numeric values in the column "Concentration-response function" refer to odds ratio corresponding to the increase in concentrations given in the column "concentration change." Literature references indicate the use of a non-linear concentration-response function. No-harm threshold refers to a concentration below which the health impact is not quantified, generally because the studies on which the function is based did not include people with lower exposure levels. Data on concentration-response relationships do not exist for all geographies, so a global risk model is applied to all cities. Incidence data are generally unavailable at the city level so national averages have to be applied.

Economic Valuation

Air pollution both increases the risk of developing respiratory and cardiovascular diseases, and increases complications and deaths from them, significantly lowering the quality of life and economic productivity of people affected and increasing healthcare costs. Economic losses as a result of air pollution were calculated using the methods outlined in Myllyvirta (2020). The valuation of deaths was updated to the values derived by Viscusi and Masterman (2017) which are based on labour market data, and pay particular attention to applicability in middle- and low-income countries. The valuation of different health outcomes used in the study is shown in Table 2.

The Global Burden of Disease project has quantified the degree of disability caused by each disease into a “disability weight” that can be used to compare the costs of different illnesses. The economic cost of disability and reduced quality of life caused by these diseases and disabilities are assessed based on disability weights, combined with the economic valuation of disability used by the UK environmental regulator DEFRA (Birchby et al., 2019), and adjusted by GNI PPP for South Africa (Table 2). The deaths of young children are valued at twice the valuation of adult deaths, following the recommendations in OECD (2012).

The valuation of future health impacts is based on the premise that the long-term social discount rate is equal to the long-term GDP growth rate, and the economic loss associated with different health impacts is proportional to the GDP, resulting in a constant present value of health impacts over time.

Table 2. *Input parameters and data used to estimate economic costs of health impacts.*

Outcome	Valuation at world average GDP/GNI per capita, 2017 international dollars	Valuation in South Africa, current USD	Valuation in South Africa, current ZAR	Reference
work absence (sick leave days)	85	35	514	EEA 2014
number of children suffering from asthma due to pollution exposure (increased prevalence)	1,077	438	6,486	Brandt et al. 2012
deaths	2,637,000	1,069,000	15,810,000	Viscusi & Masterman 2017
deaths of children under 5	5,273,000	2,138,000	31,630,000	OECD 2012
asthma emergency room visits	232	95	1,399	Brandt et al. 2012
preterm births	107,700	43,850	648,500	Trasande et al. 2016
years lived with disability	28,480	11,550	170,800	Birchby et al. 2019

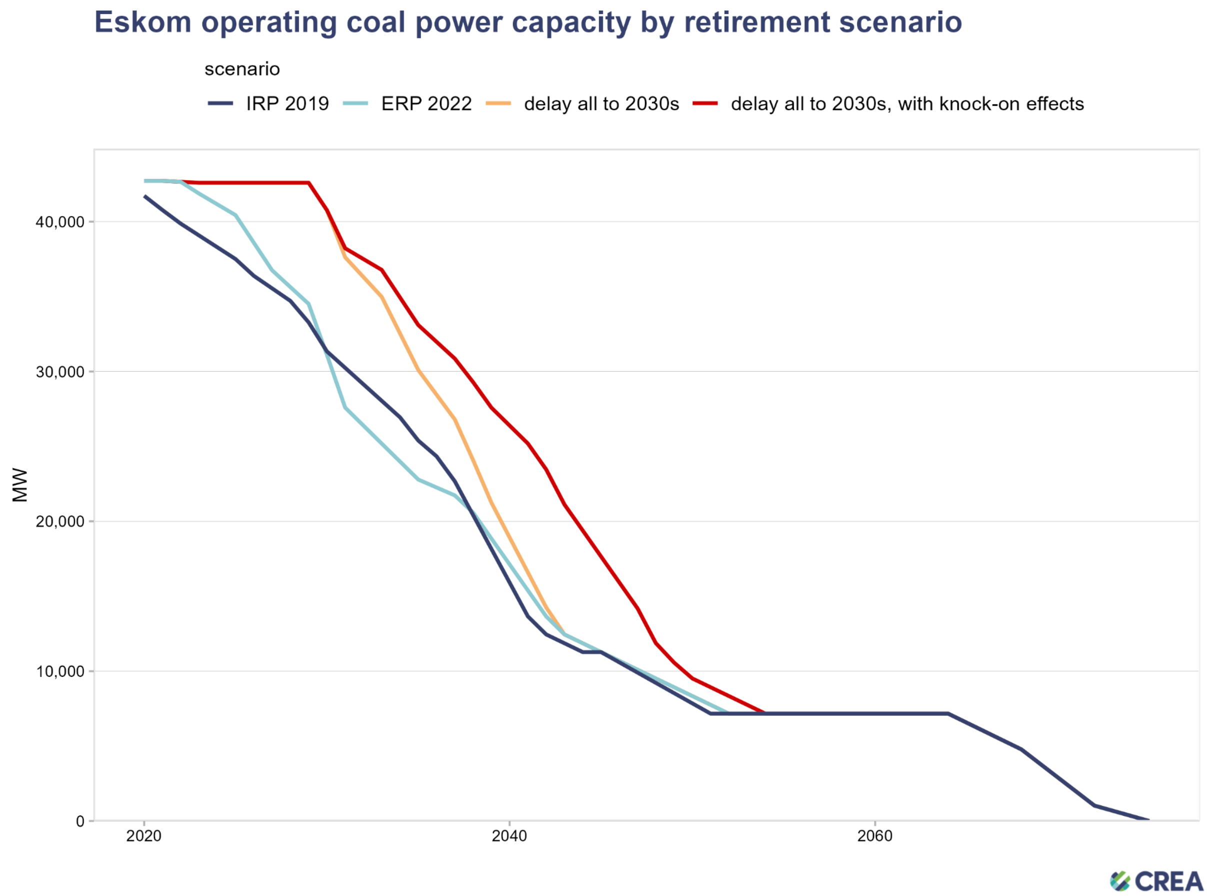

Figure 4. *Eskom operating coal power capacity by retirement scenario. (CREA, 2023).*

Results

As Komati is the only Eskom coal power plant to have been closed down, if not yet decommissioned, the health benefits from eliminating the air pollutant emissions from the plant are highly relevant. We estimate that in 2020–2023, the closure of Komati has already avoided 220 deaths from air pollution (95% confidence interval: 130 – 350) and economic costs of R4.9 billion (95% confidence interval: 2.9 – 7.7). Other avoided health impacts include 760 asthma emergency room visits, 190 new cases of asthma in children, 360 preterm births, 0.2 million days of work absence, and 260 years lived with disability, of which 120 due to chronic obstructive pulmonary disease, 110 due to diabetes, and 30 due to stroke.

If all coal power plant decommissioning scheduled to begin by 2030 was delayed until after 2030, the air pollutant emissions from prolonged operation of the plants would have a major impact on public health in South Africa. The projected health impacts include 15,300 deaths (95% confidence interval: 9,200 – 24,000), of which 6,200 due to exposure to PM2.5, 3,500 due to exposure to NO2, and 5,700 due to exposure to SO2. Of the deaths caused by PM2.5 exposure, 550 are attributed to chronic obstructive pulmonary disease, 570 to diabetes, 620 to ischaemic heart disease, 1,500 to lower respiratory infections, 370 to lung cancer, and 370 to stroke.

Other projected health impacts include 52,000 asthma emergency room visits, 9,300 new cases of asthma in children, 22,000 preterm births, 13.0 million days of work absence, and 18,000 years lived with disability, of which 8,600 due to chronic obstructive pulmonary disease, 8,000 due to diabetes, 1,900 due to stroke. We estimate the total economic costs of the health impacts at R340 bln (USD 18,000 mln).

The actual impacts would likely be larger, as the delay could have knock-on effects. Unless Eskom is able to manage much higher annual rates of decommissioning in the 2030s than targeted in the IRP and ERP, the closure of plants currently scheduled for decommissioning in the 2030s will have to be delayed as well. This further delay would increase the health impacts to 32,000 deaths (95% confidence interval: 20,000 – 49,000), of which 13,000 due to exposure to PM2.5, 6,100 due to exposure to NO2, 13,000 due to exposure to SO2. The deaths related to PM2.5 include 400 deaths of children under 5 due to lower respiratory infections. Other projected health impacts include 100,000 asthma emergency room visits, 15,000 new cases of asthma in children, 42,000 preterm births, 27.0 million days of work absence, and 38,000 years lived with disability, of which 18,000 due to chronic obstructive pulmonary disease, 17,000 due to diabetes, and 4,000 due to stroke. The total economic costs would amount to a projected R720bln (USD 38,000 mln).

Of the deaths caused by PM2.5 exposure, 1,700 are attributed to chronic obstructive pulmonary disease, 1,800 to diabetes, 1,900 to ischaemic heart disease, 4,700 to lower respiratory infections, 1,200 to lung cancer, 1,200 to stroke.

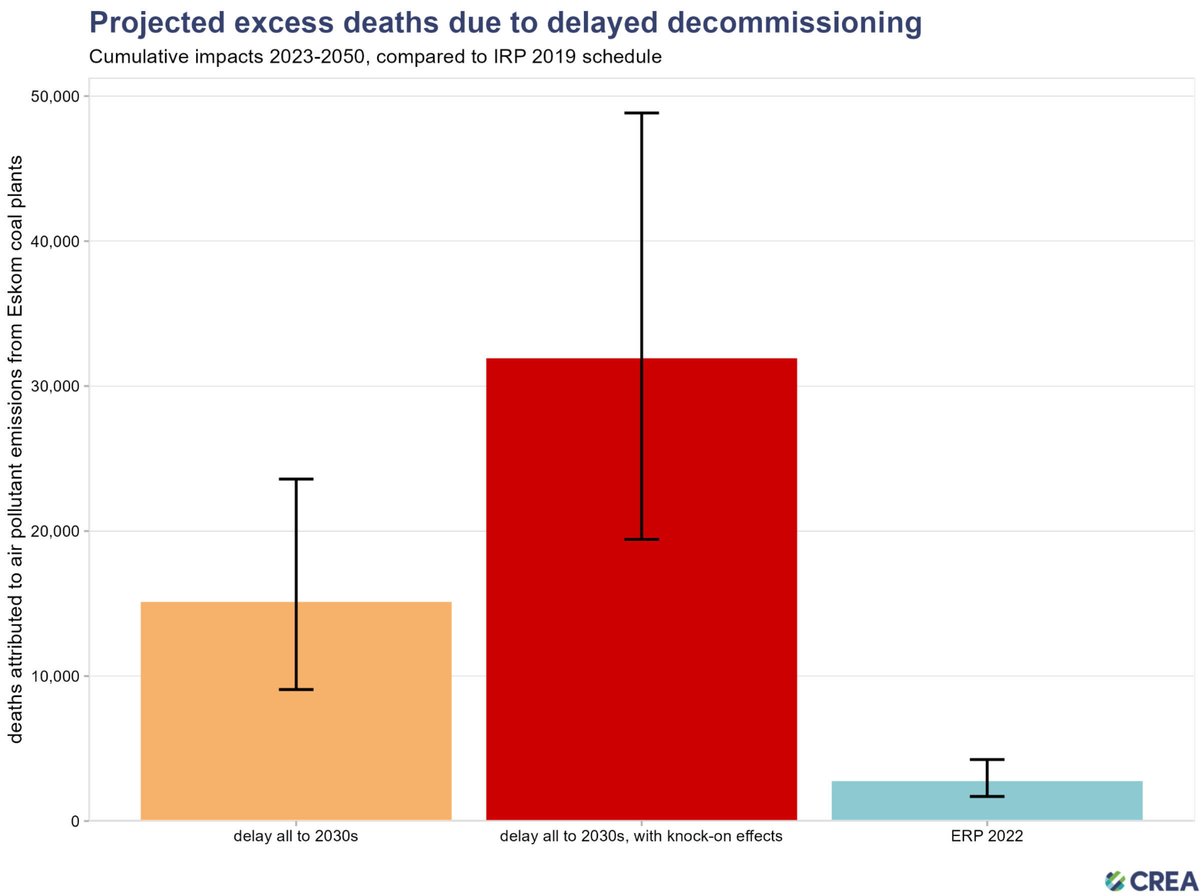

Figure 5. *Projected excess deaths due to delayed decommissioning. (CREA, 2023).*

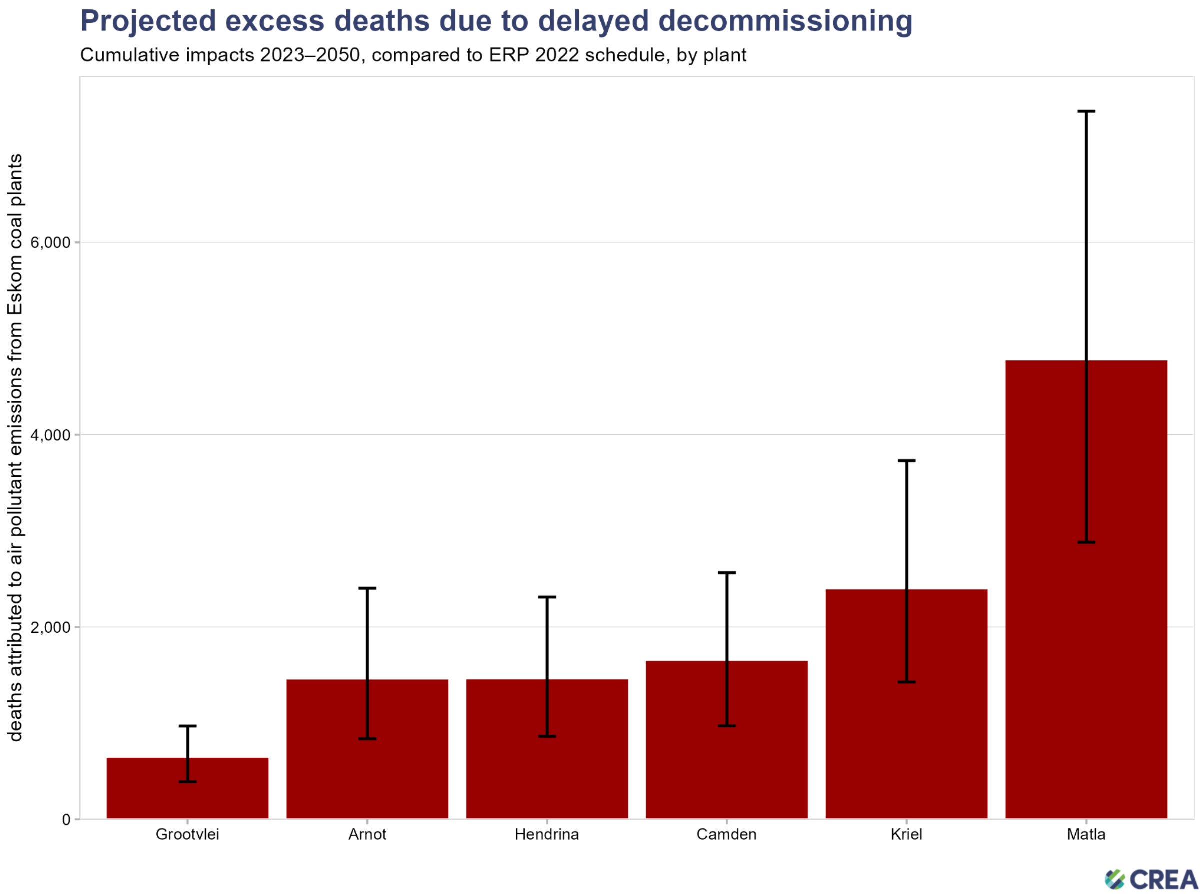

Figure 6. *Projected excess deaths due to delayed decommissioning. (CREA, 2023).*

Table 3. *Projected health impacts in different scenarios.*

Outcome	Cause	Pollutant	ERP 2022	delay all to 2030s	delay all to 2030s, with knock-on effects
deaths	all causes	all	2,780 (1,710 – 4,290)	15,300 (9,210 – 23,900)	32,300 (19,700 – 49,500)
deaths	all causes	PM2.5	830 (523 – 1,150)	6,220 (3,800 – 8,700)	12,900 (7,910 – 17,900)
deaths	chronic obstructive pulmonary disease	PM2.5	110 (69 – 147)	826 (507 – 1,110)	1,720 (1,060 – 2,300)
deaths	diabetes	PM2.5	104 (37 – 170)	857 (266 – 1,470)	1,780 (566 – 2,980)
deaths	ischaemic heart disease	PM2.5	122 (84 – 155)	925 (630 – 1,180)	1,920 (1,310 – 2,450)
deaths	lower respiratory infections	PM2.5	311 (226 – 417)	2,270 (1,620 – 3,050)	4,740 (3,400 – 6,330)
deaths	lung cancer	PM2.5	77 (51 – 110)	560 (367 – 815)	1,170 (766 – 1,700)
deaths	stroke	PM2.5	74 (36 – 98)	559 (269 – 747)	1,160 (561 – 1,550)
deaths	all causes	NO2	578 (276 – 1,230)	3,460 (1,650 – 7,350)	6,110 (2,920 – 13,000)
deaths	all causes	SO2	1,380 (914 – 1,910)	5,660 (3,760 – 7,870)	13,300 (8,850 – 18,500)
deaths of children under 5	lower respiratory infections in children	PM2.5	31 (20 – 48)	224 (144 – 342)	401 (258 – 611)
asthma emergency room visits	asthma	PM2.5	7,340 (4,340 – 10,300)	51,800 (30,600 – 72,700)	104,000 (61,800 – 146,000)

new cases of asthma in children	asthma	NO2	1,570 (309 – 3,780)	9,300 (1,830 – 22,300)	15,400 (3,030 – 37,100)
preterm births		PM2.5	3,090 (1,500 – 3,280)	21,800 (10,600 – 23,100)	42,300 (20,500 – 44,900)
work absence (mln sick leave days)		PM2.5	1.87 (1.59 – 2.15)	13.10 (11.20 – 15.10)	27.30 (23.20 – 31.30)
years lived with disability	all causes	PM2.5	2,360 (1,020 – 3,930)	18,500 (7,460 – 31,800)	38,300 (15,600 – 65,200)
years lived with disability	chronic obstructive pulmonary disease	PM2.5	1,150 (653 – 1,590)	8,580 (4,820 – 12,000)	17,800 (10,000 – 24,900)
years lived with disability	diabetes	PM2.5	965 (264 – 1,940)	7,970 (1,910 – 16,700)	16,500 (4,060 – 34,000)
years lived with disability	stroke	PM2.5	254 (99 – 400)	1,920 (727 – 3,060)	4,000 (1,510 – 6,350)
total economic cost, bln R	all	all	61.10 (37.50 – 92.60)	345.00 (206.00 – 526.00)	721.00 (438.00 – 1,080.00)
total economic cost, mln USD	all	all	3,240 (1,990 – 4,910)	18,300 (11,000 – 27,900)	38,300 (23,200 – 57,400)

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