Health impacts of coal fired power plants in South Africa

Clients: Groundwork (South Africa), Health Care Without Harm

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Summary

This report provides estimates of the health impacts and associated economic costs of current emissions of air pollutants from coal fired power stations in South Africa. Results are provided both as a total for all power plants, and disaggregated to individual power stations.

The analysis is based on earlier work for Greenpeace International by Lauri Myllyvirta, and work by the present author for OECD under the CIRCLE (Costs of Inaction and Resource Scarcity) Study. Myllyvirta's analysis was adopted following review of available materials, as it was found to have undertaken a robust implementation of the impact pathway approach, representing the state of the art in this field of work. The work for OECD was adopted as it is also based on full impact pathway analysis, albeit at a coarse scale) and provides results that account for conditions specific in some important respects to South Africa. The OECD work has also been widely reviewed internationally.

Results demonstrate that air pollution has a broad spectrum of effects on health, including mortality and cardiovascular and respiratory illness. The total quantified impact from the coal fired power plants considered in this analysis is valued at $int2.4 billion annually, 20% of the total $int12 billion/year national damage quantified in the OECD CIRCLE study. These costs accumulate year on year, which is clearly of great concern for plant that have lifetimes in the region of several decades.

These results do not provide a full account of the effects of coal and other fossil-derived pollutants on health for two reasons. Firstly, they omit a range of impacts that have been reported in the academic literature, but for which response-functions are yet to be widely accepted, including sub-lethal effects of stroke, treatment costs and morbidity linked to lung cancer, and effects linked to low birth weight and impaired cognitive development in children. Secondly, they are focused only on coal fired power generation, and hence do not include other industrial and non-industrial sources of pollution.

Outputs of this analysis are intended to inform the current debate on energy policy in South Africa by providing a means of accounting for the external costs of power generation from coal.

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About the Author

Dr Michael Holland has been involved in the quantification of the impacts of air pollution from power systems since 1990, when he worked at the heart of the influential EC-US Fuel Cycles Study funded by the European Commission, EU Member States and the US Department of Energy. Following completion of the initial study in 1995 this work continued in Europe as the ExternE Study until 2005. Since 1996 Mike has provided cost-benefit analysis of air quality and industrial policies for a variety of organisations including not only the European Commission, but governments in the UK, France, Sweden, China and a number of other countries. He has also provided analysis for international organisations including the Organisation for Economic Cooperation and Development (OECD) and the World Bank.

1   Introduction

1.1   Objectives

The objective of this paper is to provide a first estimate of the health impacts and related social costs of emissions of air pollutants from existing coal fired power stations in South Africa.

This information needs to be considered by energy planners in South Africa. Without assessment of the 'external costs' of energy technologies, planning decisions can be biased towards technologies that are not optimal for society, through the burdens placed on for example health, agriculture, water supplies and so on. These decisions are critical to future development, as they will affect the country for 40 or more years into the future. In other parts of the world, for example Europe, North America and increasingly in developing countries such as China, quantification of the health impacts of air pollution linked to energy use is commonplace in the planning process.

1.2   The pollutants of interest and their health impacts

The evidence that air pollution at levels found in South Africa has a serious adverse impact on health is substantial, with the epidemiological literature on the subject running to many thousands of papers. Attention has focused especially on the role of fine particles (commonly abbreviated to $PM_{2.5}$, 'particulate matter with an aerodynamic diameter of less than 2.5 micrometres').

Analysis[1] has considered the impacts of particles emitted directly into the atmosphere (primary particles) and 'secondary' particles formed in the atmosphere following release of other pollutants, particularly sulphur dioxide (SO_2) and oxides of nitrogen (NOx). Experience in Europe, North America and various other places around the world demonstrates that the health impacts of these pollutants per unit emission are substantial, with the total burden on society being equal to many thousands of deaths and billions of $.

The World Health Organization (WHO) publishes air quality guidance including suggested legislative limit values to assist countries in defining their own air quality policies[2]. Over time, the guidelines have tightened, reflecting increased awareness about the severity of air pollution effects. Key conclusions from the WHO's work on air pollution are as follows:

- Air pollution is a major environmental risk to health. By reducing air pollution levels, countries can reduce the burden of disease from stroke, heart disease, lung cancer, and both chronic and acute respiratory diseases, including asthma.

- The lower the levels of air pollution, the better the cardiovascular and respiratory health of the population will be, both long- and short-term.

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[1] Cost benefit analysis of EU air quality policies (Cost-benefit Analysis of Final Policy Scenarios for the EU Clean Air Package) is available at: http://ec.europa.eu/environment/air/pdf/TSAP%20CBA.pdf. Similar analysis for the US Environmental Protection Agency (USEPA) is available at: https://www.epa.gov/clean-air-act-overview/benefits-and-costs-clean-air-act.

[2] WHO guidelines: Ambient (outdoor) air quality and health: http://www.who.int/mediacentre/factsheets/fs313/en/.

- The "WHO Air quality guidelines" provide an assessment of health effects of air pollution and thresholds for health-harmful pollution levels.

- In 2014, 92% of the world population was living in places where the WHO air quality guidelines levels were not met.

- Ambient (outdoor air pollution) in both cities and rural areas was estimated to cause 3 million premature deaths worldwide in 2012.

- Some 88% of those premature deaths occurred in low- and middle-income countries, and the greatest number in the WHO Western Pacific and South-East Asia regions.

- Policies and investments supporting cleaner transport, energy-efficient housing, power generation, industry and better municipal waste management would reduce key sources of urban outdoor air pollution.

- Reducing outdoor emissions from household coal and biomass energy systems, agricultural waste incineration, forest fires and certain agro-forestry activities (e.g. charcoal production) would reduce key rural and peri-urban air pollution sources in developing regions.

- Reducing outdoor air pollution also reduces emissions of CO_2 and short-lived climate pollutants such as black carbon particles and methane, thus contributing to the near- and long-term mitigation of climate change.

- In addition to outdoor air pollution, indoor smoke is a serious health risk for some 3 billion people who cook and heat their homes with biomass fuels and coal.

A good review demonstrating the breadth of impacts, and how they affect health throughout the life course was provided last year by the Royal College of Physicians[3] in the UK.

Epidemiological studies have not identified thresholds to air pollution. A notable study by Crouse et al[4], published in 2012, found no evidence for thresholds even in remote areas of Canada, where concentrations of $PM_{2.5}$ are of the order of just a few ug/m^3.

Although this paper is focused on impacts linked to primary and secondary $PM_{2.5}$ exposure, the use of coal leads to the release of other pollutants into the atmosphere, with toxic metals such as lead and mercury being of special note. Emissions of mercury and lead are established as having impacts on neurodevelopment, leading to reduced IQ in the population that persists from youth to old age. Linked to this effect is a reduction in the productivity of the labour force. These effects are not considered further in this report.

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[3] Every breath we take: the lifelong impact of air pollution. The Royal Colleges of Physicians and of Paediatrics and Child Health (2016) https://www.rcplondon.ac.uk/projects/outputs/every-breath-we-take-lifelong-impact-air-pollution
[4] Crouse DL, Peters PA, van Donkelaar A, Goldberg MS, Villeneuve PJ, Brion O, et al. 2012. Risk of nonaccidental and cardiovascular mortality in relation to long-term exposure to low concentrations of fine particulate matter: a Canadian national-level cohort study. Environ Health Perspect 120:708–714; doi: 10.1289/ehp.1104049.

2 Methods

2.1 Overview of methods

The impacts of air pollution are modelled using the 'impact pathway approach' (IPA) of the EC-US Fuel Cycles and ExternE Studies[5]. The IPA simply describes a logical path from activity (such as demand for transport or energy), through the quantification of impacts (mortality, hospital admissions, etc.) to a monetised estimate of pollutant damage for each health endpoint-pollutant combination, as illustrated in Figure 2-1.

<div style="border:1px solid; padding:1em; text-align:center;">

1. Activity (e.g. demand for electricity)
↓
2. Emission (e.g. tonnes of $PM_{2.5}$, NOx and SO_2)
↓
3. Dispersion and atmospheric chemistry
(e.g. including formation of secondary aerosols such as ammonium sulphate, $\mu g.m^3$)
↓
4. Exposure of the general population (people. $\mu g.m^3$)
↓
5. Exposure of population at risk from a specific effect
(people at risk. $\mu g.m^3$)
↓
6. Incidence of the health effect under analysis linked to the pollutant under investigation
(e.g. hospital admissions)
↓
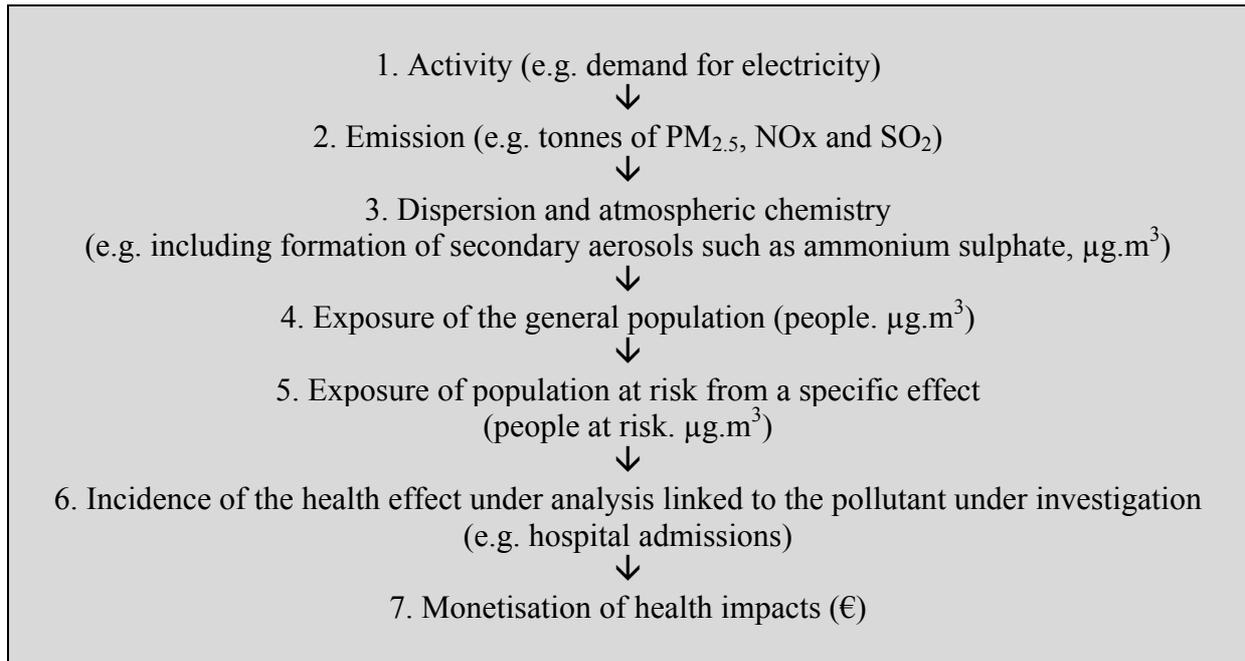7. Monetisation of health impacts (€)

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Figure 2-1. Representation of the impact pathway for hospital admissions associated with exposure to fine particles arising from emissions of coal related air pollutants.

The quantification at stages 5 and 6 in the figure takes the following (simplified) form:

$$I = C_i \times P_a \times P_r \times R \times CRF \qquad \textit{Equation 1}$$

Where
- I = Impact (e.g. number of cases, days of ill health, etc.)
- . C_i = Pollutant concentration for pollutant *i*
- P_a = Fraction of the population within the age group considered relevant for a specific impact (e.g. hospital admissions amongst those aged over 65 years)
- P_r = Fraction of the population at risk within this age group (e.g. asthmatics)
- R = Incidence rate (e.g. cases per 1000 population at risk)
- CRF = Concentration response function (change in incidence per unit concentration for those at risk)

Monetisation may address a number of elements, including the medical costs incurred through ill health, loss of productivity amongst workers and aversion to premature death and being ill (pain, suffering, inconvenience, etc.). Earlier studies focused only on effects on the

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[5] The publications of the ExternE study are available at: http://www.externe.info/externe_d7/?q=node/4.

'productive economy', but this is generally regarded now as being inadequate on the grounds that it implies that there is no other value in good health.

In recent years the Global Burden of Disease (GBD) initiative of WHO and the UK Institute for Health Metrics (IHMe) has provided some insight on the magnitude of impacts of air pollution in all countries of the world [6]. This work has importantly investigated the question of how the response functions used in the more industrialised countries of Europe and North America can be applied elsewhere, for example in locations where pollution levels may be significantly higher (e.g. China and India) or the underlying health of the population may be different, for example through reduced access to health care or through differences in the spectrum of disease prevalence. The GBD work provided the basis for analysis by OECD under the CIRCLE (Costs of Inaction and Resource Scarcity) Project [7].

2.2 Previous analysis in South Africa

2.2.1 Vivid Economics [8]

The Vivid Economics study of South African energy system externalities adopts external cost estimates generated in the UK by Defra (the government Department for Environment, Food and Rural Affairs), with values converted to the South African economic situation using methods recommended by OECD [9]. The Defra data have the appearance of being particularly detailed for PM emissions, as they are broken down by source type. However, the limitations of the Defra data are not immediately apparent:

1. They consider impacts over only a limited range (within the UK, ignoring impacts in neighbouring countries). This is important here given that South Africa is four times larger than the UK, and that the burden of emissions from the UK on neighbouring countries is significant.
2. The range of impacts considered by Defra is very restrictive, being limited to mortality and hospital admissions. The number of hospital admissions concerned is insufficient to describe the level of illness in the population likely to be sufficient to generate the mortality burden. WHO has recommended a much more extensive analysis of effects on morbidity (illness).
3. The valuation of mortality impacts is very conservative compared to the OECD recommendations (here taken as the best estimate for mortality).

All three factors would bias towards underestimation of damage costs. With respect to [1], however, this would be countered by the reduced population density of South Africa relative to western Europe.

The underlying health state of the South African population is different to that of the regions for which the Defra-selected response functions were developed, which are based on exposures of people in North America and (mostly western) Europe. Given the high incidence of HIV/AIDS in sub-Saharan Africa relative to the countries where the

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[6] IHMe's work is described at http://www.healthdata.org/gbd. WHO's activities are described at http://www.who.int/topics/global_burden_of_disease/en/.
[7] The economic consequences of outdoor air pollution. http://www.oecd.org/env/indicators-modelling-outlooks/circle.htm.
[8] Energy system externalities in South Africa. Vivid Economics. http://www.vivideconomics.com/publications/energy-system-externalities-south-africa.
[9] Mortality Risk Valuation in Environment, Health and Transport Policies. http://www.oecd.org/environment/mortalityriskvaluationinenvironmenthealthandtransportpolicies.htm

epidemiology studies have been performed, the reliability of the Defra functions may not be high.

A further question concerning the Vivid analysis relates to the treatment of PM emissions. The Defra data are specific to emissions of $PM_{2.5}$ (in some documentation they are described as being for PM, and in some for PM_{10}, but the underlying calculations are based on response functions calibrated against $PM_{2.5}$). Unlike the other factors considered, this potential error in application would lead to overestimation of damage costs if the unit damage costs are applied to TSP or PM_{10} as $PM_{2.5}$ makes up (by definition) only a part of TSP and PM_{10}.

2.2.2   Lauri Myllyvirta for Greenpeace International [10]
The Myllyvirta paper provides estimates of emissions beyond limit values for PM, SO_2, NOx and mercury, to 2050. Dispersion modelling specific to South Africa takes account of local conditions (e.g. rainfall and ammonia emissions – ammonia plays an important role in the atmospheric chemistry of both SO_2 and NOx through the conversion of the primary pollutants to ammonium sulphate and ammonium nitrate, the effects of which are considered through response functions for fine particles). Response functions for pollutants other than mercury are based on the Global Burden of Disease study (2010), for which methods are designed specifically to take account of variation in health status in different regions of the world (to the extent that data permit). The application of OECD methods for quantifying the VSL to apply to air pollution related deaths also follows state of the art.

A limitation of the paper arises because of the omission of impacts on morbidity. The availability of functions and incidence data makes this problematic in many assessments. However, the OECD CIRCLE study overcame this difficulty by scaling morbidity impacts against deaths, drawing on results from countries that are, comparatively data rich. At one level this approach may be considered to assume that access to healthcare is uniform across the world, when it clearly is not. However, this limitation is countered from the perspective that health impacts that are untreated are likely to have worse, and possibly substantially worse, outcomes than those that are treated. The assumptions made in the CIRCLE study are therefore considered more likely to underestimate the burden to society than to overestimate it.

2.3   Approach adopted here
The approach adopted here is based around the Myllyvirta study rather than the work of Vivid Economics, as Myllyvirta took more precise account of conditions in South Africa, using original modelling to quantify impacts rather than the extrapolation adopted by Vivid. Review of the methods used by Myllyvirta for this report finds that they are close to state of the art. Use of the GBD analysis, and investigation of pollutant dispersion and chemistry using 2 different models are particularly noteworthy.

For the initial aggregate estimates of impacts for all plant combined, analysis has taken Myllyvirta's mortality estimates and quantified morbidity pro rata with the results for South Africa generated by the OECD CIRCLE Study. An indication of the relative strength of

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[10] Health impacts and social costs of Eskom's proposed non-compliance with South Africa's air emission standards.
http://www.greenpeace.org/africa/Global/africa/publications/Health%20impacts%20of%20Eskom%20applicat ions%202014%20_final.pdf.

different impacts in the analysis is provided in which summarises results for South Africa from one of the scenarios run for the CIRCLE Study, based on 2010 conditions.

Table 2-1. Summary of 2010 results from the CIRCLE study for OECD, for South Africa, to demonstrate the relative importance of different impact types.

	Cases, etc.	Costs, $int, millions			
		Welfare	Healthcare	Productivity	Total
Deaths	11,355	10,761	0	0	10,761
Chronic Bronchitis (adults, cases)	14,103	274	53	0	328
Bronchitis in children aged 6 to 12	48,347	10	0.80	0	11
Equivalent hospital admissions	12,065	2.2	12	0	14
Restricted Activity Days (all ages)	20,148,510	673	0	0	673
Asthma symptom days (children 5-19yr)	480,169	7.3	0	0	7
Lost working days	5,054,383	0	0	239	239
Totals		**11,728**	**66**	**239**	**12,033**

The results in the table demonstrate that in economic terms, the analysis will be dominated by mortality. However, to ignore morbidity would be to ignore significant impacts, and costs to the healthcare system and to productivity in the labour force.

An initial decision was taken to consider disaggregation to individual facilities from three factors:
- Differences in the amount of pollution released from each plant (shown in the next section).
- The differential impact of PM, SO_2 and NOx, drawing on European analysis used in a study for the European Environment Agency[11]. SO_2 is found to be 42% as harmful as $PM_{2.5}$ and NOx, 16% as harmful, according to the average of results across 38 European countries.
- Differences in the population density around each site (necessarily over extended distances to account for the long range dispersion of pollutants and the time taken for atmospheric chemistry to convert SO2 and NOx to sulphate and nitrate aerosol)

Linear scaling is applied. It is acknowledged that the quality of analysis could be improved by carrying out the assessment from scratch. However, in the interests of providing first estimates to inform the current process, these methods are considered appropriate for the time being.

Review of the impacts of differences in location of the plant around South Africa concludes that this factor is likely to have a very limited effect. The map on the next page [12] shows the plant to be concentrated in and around Mpumulanga Province in the North East of the country, corresponding to the country's main coal deposits. This also corresponds to an area

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[11] Costs of air pollution from European industrial facilities 2008-2012.
http://www.eea.europa.eu/publications/costs-of-air-pollution-2008-2012
[12]
http://www.eskom.co.za/Whatweredoing/ElectricityGeneration/PowerStations/Documents/EskomGenerationDivMapREV81.pdf

of high population density for the country (Figure 2-3 and Table 2-2). The highest concentrations of pollution linked to Eskom's activities are naturally also linked to this area (Figure 2-4 from Myllyvirta's paper). Table 2-2 shows that although population density varies greatly between the provinces (from 3/km^2 to 726/km^2), the range becomes much smaller once Provinces that are some way distant from the coal plant are excluded, and once (for obvious reasons) averaging is carried out across neighbouring Provinces to account for long distance transport of pollutants. On this basis, a scaling against Provincial population density is not considered necessary for the purpose of this paper.
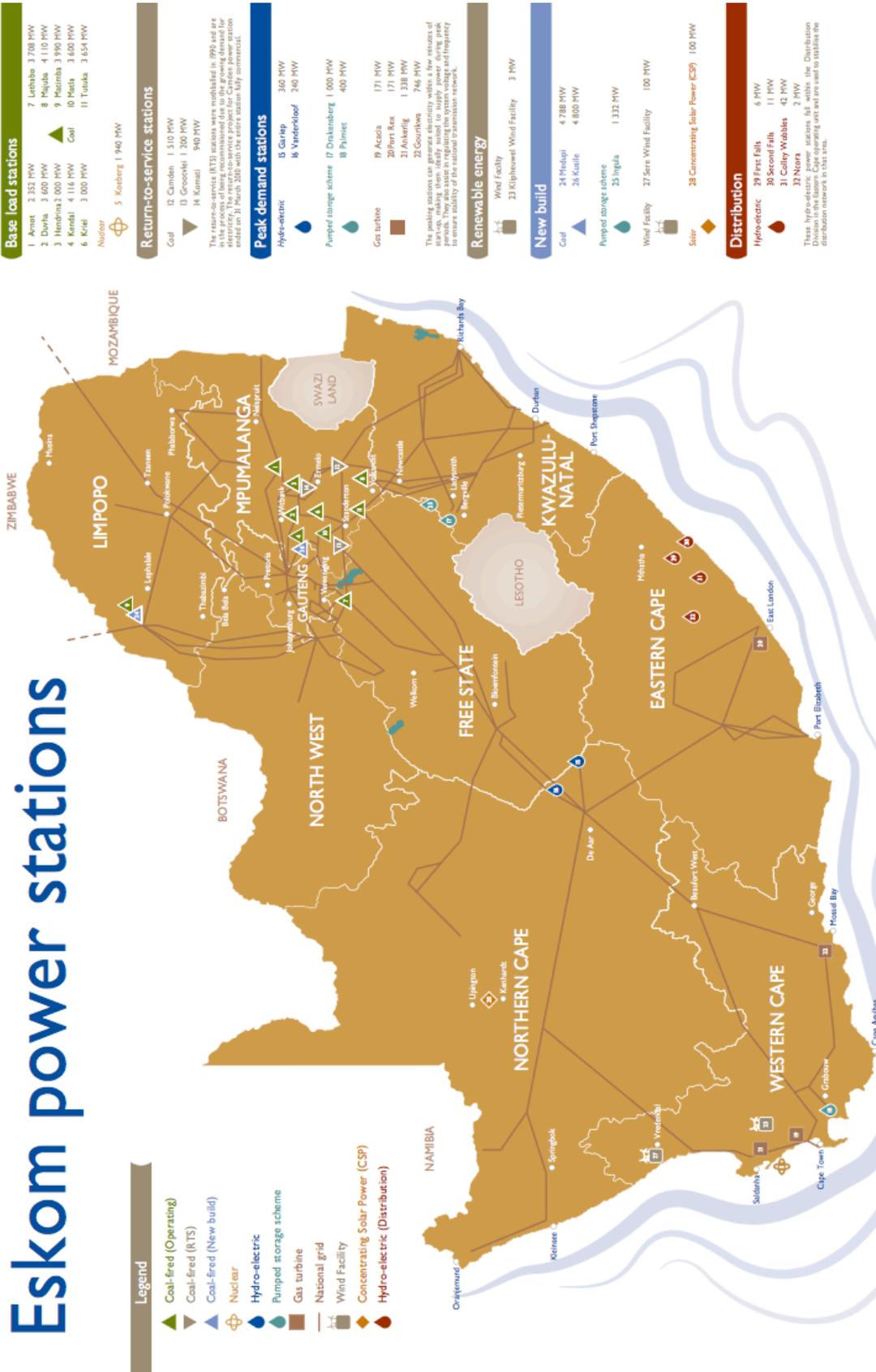
Figure 2-2. Map of Eskom's power plants. The coal fired power plants of interest here are shown by the green and grey triangles, and are concentrated in and around Mpumalanga Province.
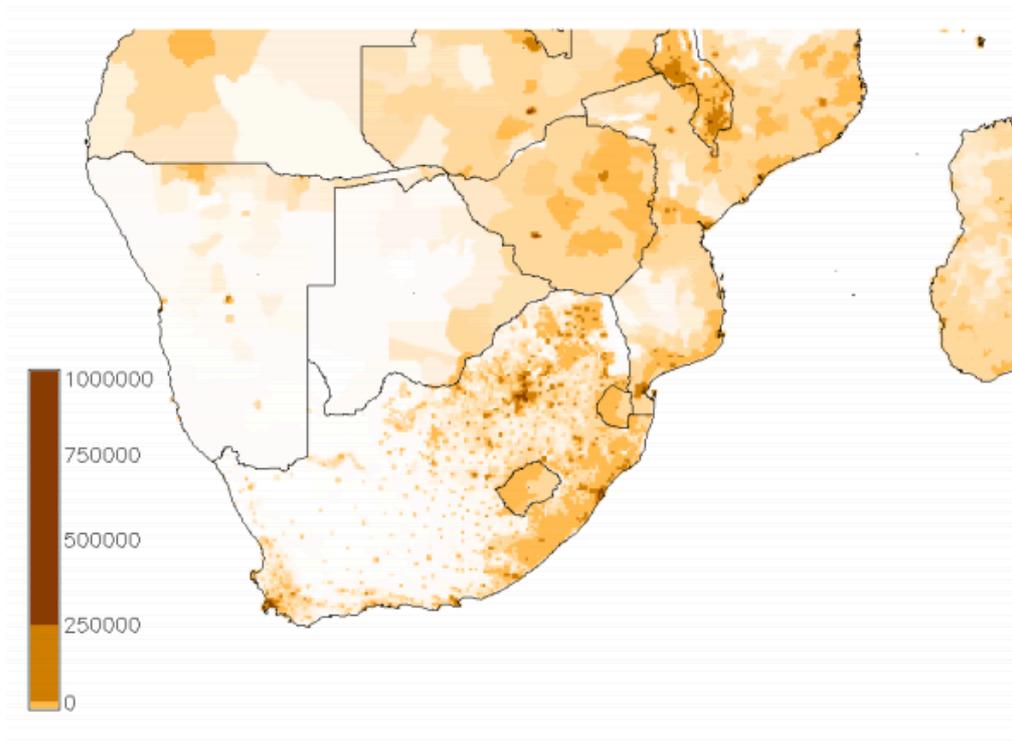
Figure 2-3. Population counts at 0.1x0.1 degree resolution (GPWv3 projections for 2010) (from Myllyvirta, 2014)

Table 2-2. Population density in the Provinces of South Africa and of Lesotho and Swaziland

|	Area km^2	Population	Population density people/km^2
Eastern Cape	168,966	6,916,200	41
Free State	129,825	2,817,900	22
Gauteng	18,176	13,200,300	726
KwaZulu Natal	94,361	10,919,100	116
Limpopo	125,754	5,726,800	46
Mpumalanga	76,495	4,283,900	56
North West	104,882	3,509,953	33
Northern Cape	372,889	1,185,600	3
Western Cape	129,462	5,822,734	45
Neighbouring countries most affected			
Lesotho	30,355	2,067,000	68
Swaziland	17,364	1,119,000	64
Population density accounting for neighbouring provinces and countries in Provinces hosting coal plant			
Free State + neighbours	995,949	44,899,953	45
Gauteng + neighbours	455,132	29,538,853	65
Limpopo + neighbours	325,307	26,720,953	82
Mpumalanga + neighbours	461,975	38,067,000	82
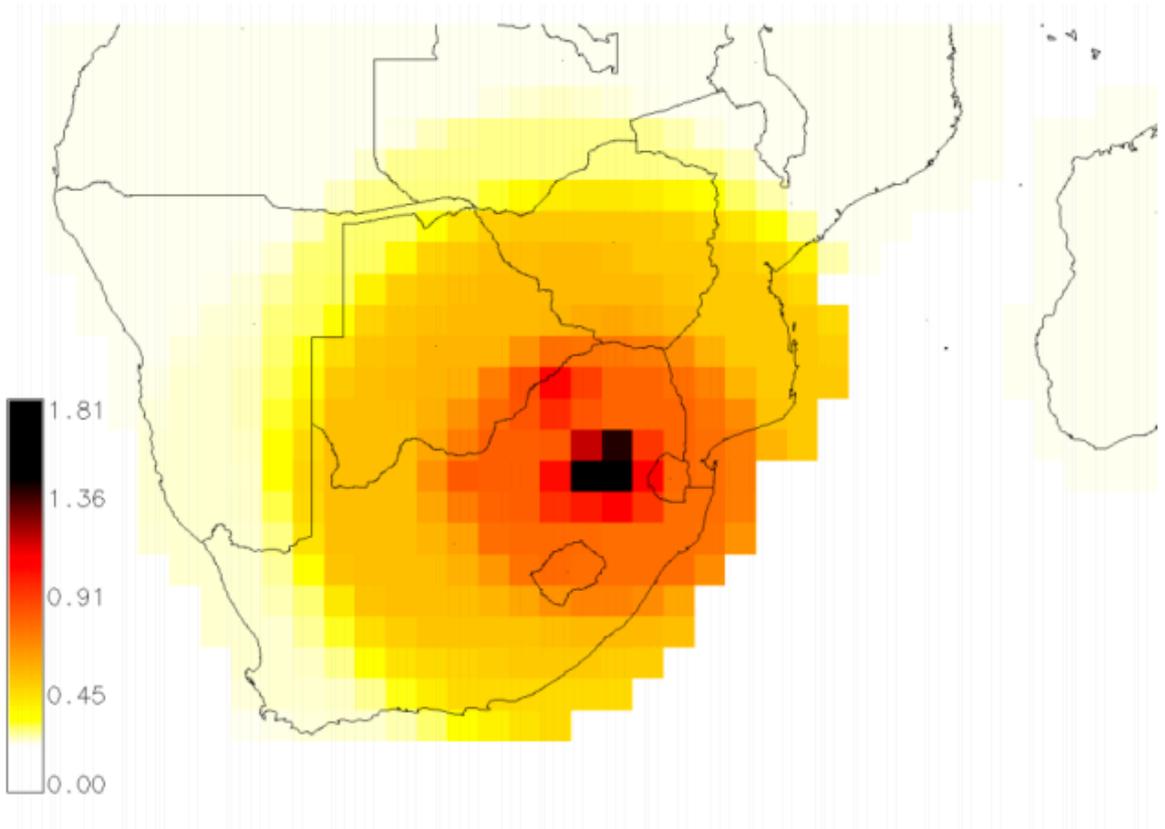
Figure 2-4. Predicted annual average PM$_{2.5}$ contributions by plants covered by Eskom's applications for postponement from meeting permitted emission limits (results of Zhou et al model, from Myllyvirta, 2014)

3 Results

3.1 Emissions

Myllyvirta's analysis took as its baseline the following data on emissions from the current fleet of South African coal fired power plants. The same data are adopted here.

Table 3-1. Emissions of NOx, SO$_2$ and PM$_{10}$ from South African coal fired power stations (from Myllyvirta, 2014).

Power station	Stack	Current emissions, tonnes / year		
		NOX	SO$_2$	PM$_{10}$
Arnot	Stack 1	25,692	38,637	1,495
Arnot	Stack 2	25,691	38,637	1,495
Camden	Stack 1	10,345	21,325	1,041
Camden	Stack 2	10,345	21,325	1,041
Camden	Stack 3	10,345	21,325	1,041
Camden	Stack 4	10,345	21,325	1,041
Duvha U1-3	Stack 1	39,638	68,618	4,548
Duvha U4-6	Stack 2	39,638	68,618	4,548
Grootvlei	Stack 1	12,376	23,929	4,084
Grootvlei	Stack 2	12,376	23,929	4,084
Hendrina	Stack 1	24,089	56,871	1,273
Hendrina	Stack 2	24,089	56,871	1,273
Kendal	Stack 1	45,772	109,019	5,144
Kendal	Stack 2	45,772	109,019	5,144
Kriel	Stack 1	50,272	56,167	7,610
Kriel	Stack 2	50,272	56,167	7,610
Komati	Stack 1	11,150	11,462	1,253
Komati	Stack 2	11,150	11,462	1,253
Lethabo	Stack 1	54,026	98,105	6,725
Lethabo	Stack 2	54,026	98,105	6,725
Majuba	Stack 1	68,904	87,582	1,245
Majuba	Stack 2	68,904	87,582	1,245
Matimba	Stack 1	33,796	154,631	2,452
Matimba	Stack 2	33,796	154,631	2,452
Matla	Stack 1	56,520	89,082	6,773
Matla	Stack 2	56,520	89,082	6,773
Medupi	Stack 1	30,691	224,308	2,046
Medupi	Stack 2	30,691	224,308	2,046
Tutuka	Stack 1	52,332	89,216	7,494
Tutuka	Stack 2	52,332	89,216	7,494
Totals		**1,051,895**	**2,300,554**	**108,448**

3.2 Estimated total impact of coal fired generation in South Africa

The estimated total quantifiable impact of coal fired power generation in South Africa on health is shown in Table 3-2. The estimate of deaths is taken from the Myllyvirta paper. Estimated morbidity effects and valuations are extrapolated relative to the number of deaths using results from the OECD CIRCLE study.

Table 3-2. Annual health impacts linked to coal fired generation in South Africa.

	Cases, etc	Value, $int, millions
Equivalent attributable deaths		
Lung cancer	*157*	
Ischaemic heart disease	*1,110*	
Chronic obstructive pulmonary disease	*73*	
Stroke	*719*	
Lower respiratory infection	*180*	
Total equivalent attributable deaths	**2,239**	**2,121.94**
Chronic Bronchitis (adults, cases)	2,781	64.64
Bronchitis in children aged 6 to 12	9,533	2.19
Equivalent hospital admissions	2,379	2.79
Restricted Activity Days (all ages)	3,972,902	132.72
Asthma symptom days (children 5-19yr)	94,680	1.44
Lost working days	996,628	47.05
Total costs		**2,372.78**

3.3 Allocation of impacts to individual plant

Using the methods outlined above, accounting for variation in the emissions of pollutants from each plant, and the variation in the harmfulness for health of emissions of $PM_{2.5}$, SO_2 and NOx respectively, the estimated total health burden described in Table 3-2 has been allocated across the individual power stations.

It should be noted that care has been taken with the wording of impacts, particularly for mortality, where reference is made to 'equivalent attributable deaths' rather than simply 'deaths', following from the discussion provided by the UK's Committee on the Medical Effects of Air Pollutants (COMEAP) [13]. A reference to 'deaths' might imply that a number of specific individuals, and only those individuals are affected, and perhaps even that those individuals would be traceable. The view of COMEAP, supported here, is that air pollution acts alongside a number of other agents to bring forward the time of death. An individual whose cause of death is given as 'cardiovascular disease' would be likely to have developed this disease from exposure to a number of stressors, including air pollution, smoking, diet, lack of proper exercise and so on. COMEAP concluded that the total number of people likely to be affected by air pollution in some way would be larger than the estimated number of deaths, but that the estimate would indicate the 'equivalent' mortality burden of air pollution.

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[13] COMEAP: mortality effects of long-term exposure to particulate air pollution in the UK. https://www.gov.uk/government/publications/comeap-mortality-effects-of-long-term-exposure-to-particulate-air-pollution-in-the-uk.

Whilst it is useful to understand these issues, they do not make the impact of pollution on mortality any the less real: the fact remains that a large number of epidemiological studies have found links between mortality and air pollution, and reducing pollution wold benefit the health of the population substantially, with the health costs of air pollution from coal fired generation totalling $int2.37 billion annually in South Africa.

Table 3-3. Health impacts and associated costs ($int, millions) allocated to individual power stations.

	Total equivalent annual death	Chronic Bronchitis (adults, cases	Bronchitis in children aged 6 to 1:	Equivalent hospital admission	Restricted Activity Days (all ages	Asthma symptom days (children 5-19yr	Lost working day:	Total costs, $int, million:
Arnot	79	98	335	84	139,569	3,326	35,012	83.36
Camden	84	104	357	89	148,980	3,550	37,373	88.98
Duvha U1-3	143	178	609	152	253,845	6,050	63,679	151.61
Grootvlei	58	72	247	62	103,011	2,455	25,841	61.52
Hendrina	105	130	445	111	185,467	4,420	46,525	110.77
Kendal	210	261	894	223	372,400	8,875	93,419	222.41
Kriel	141	176	602	150	250,866	5,979	62,931	149.83
Komati	28	35	120	30	50,188	1,196	12,590	29.97
Lethabo	204	253	868	217	361,646	8,619	90,721	215.99
Majuba	177	219	752	188	313,579	7,473	78,663	187.28
Matimba	262	326	1,117	279	465,404	11,091	116,749	277.96
Matla	192	238	817	204	340,278	8,109	85,361	203.23
Medupi	364	453	1,552	387	646,706	15,412	162,230	386.24
Tutuka	192	239	818	204	340,963	8,126	85,533	203.64
Totals	**2,239**	**2,781**	**9,533**	**2,379**	**3,972,902**	**94,680**	**996,628**	**2,373**

4   Discussion

4.1   Air pollution and health

The effects of air pollution on health are widely recognised, for example by the World Health Organization, OECD, USEPA and the European Commission. Coal fired power generation is recognised the world over as a major source of this pollution.

It is estimated here that the total quantifiable economic cost of air pollution from coal fired generation in South Africa is in the region of $int2.37 billion annually. This is made up of impacts in terms of early death, chronic bronchitis, hospital admissions for respiratory and cardiovascular disease and a variety of minor conditions leading to restrictions on daily activity, including lost productivity.

4.2   Sensitivity of the population

It is important to consider whether all people are equally affected by air pollution, or whether some are likely to be worse affected than others for the same exposure. Some insight on this issue is provided in Figure 4-1, taken from work for the European Commission by Miller et al[14], in the context of the development of European pollution legislation. Results are for men and women in different European countries where there is a significant variation in life expectancy (the two graphs show the same dataset, but test linear (left hand side) and curved (right hand side) fits to the data). Countries with the longest life expectancies appear the lower right hand side of each figure, whilst those with the shortest life expectancies appear towards the upper left hand side (the point with the lowest life expectancy, a little over 60 years, is for Russian men). The conclusion from these figures is that air pollution most affects those whose underlying health condition is worst, and hence that any improvement in air quality will most benefit those who are most disadvantaged.
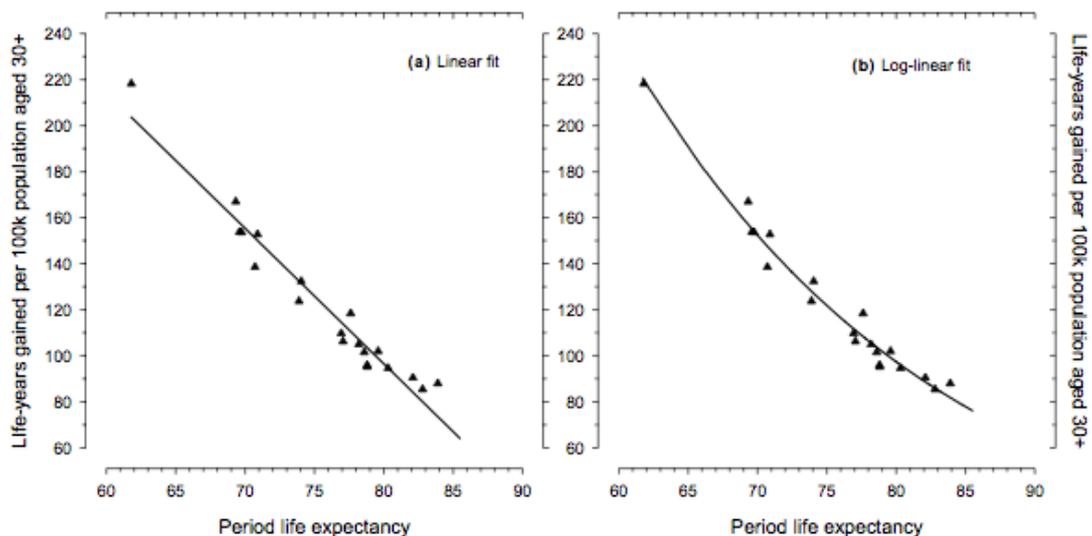

Figure 4-1. Linear and log-linear relationships between life expectancy and life years gained per 100,000 people in the population aged over 30 years for a 1 ug/m^3 reduction in PM$_{2.5}$ exposure. Points represent men and women in 10 European countries.

[14] Health Impact Assessment for the National Emissions Ceiling Directive (NECD) – Methodological Issues. http://www.iom-world.org/media/71685/IOM_TM1103.pdf

The RCP report referenced earlier [3] highlights how an additional burden, such as air pollution, can have a substantial impact on the population, by considering the sensitivity of the lung function of a population of individuals to an increase in pollution (Figure 4-2). Lung function is normally distributed in the population. Most people will not fall below some disease threshold. However, the imposition of an additional stress agent, such as air pollution, can shift the distribution to the left, leading to a large increase in disease within the population as a whole.
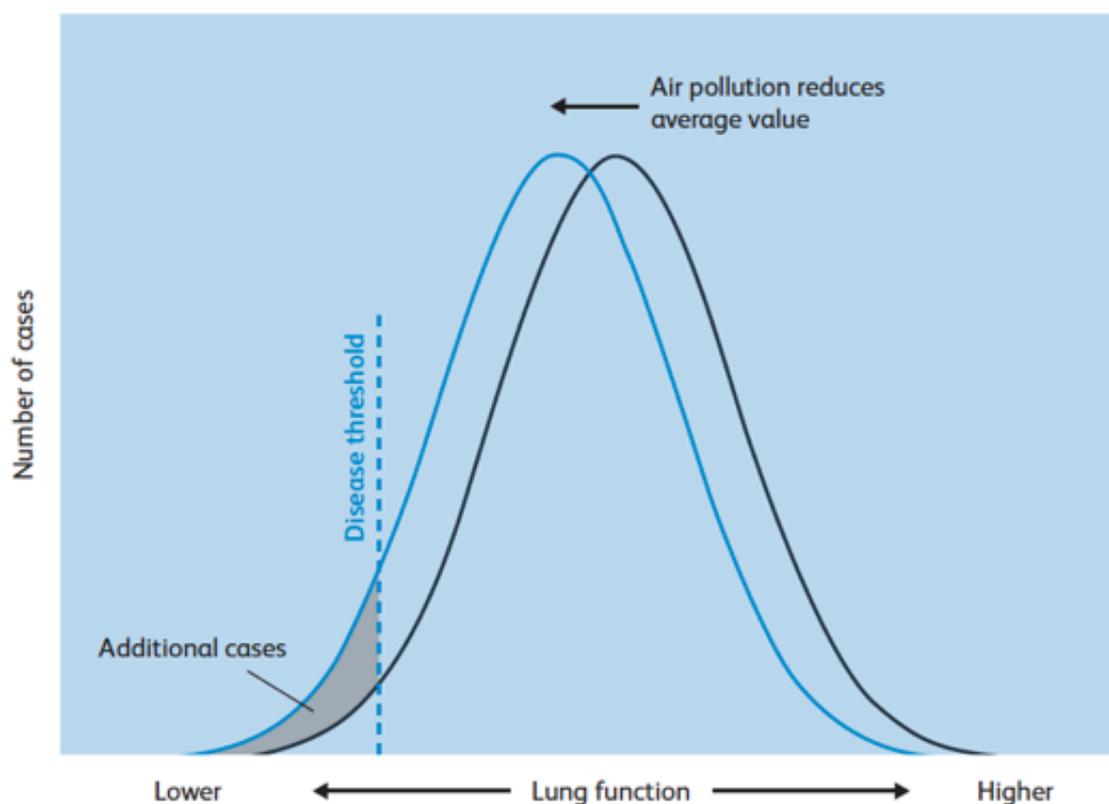

Figure 4-2. A small change in the average value of lung function leads to a far greater number of people falling below the disease threshold (shaded). From RCP (2016).

4.3   The impact of coal on health elsewhere

The European Environment Agency has published an assessment[15] of the health impacts of all (>14,000) industrial installations that report to the European Pollutant Release and Transfer Register (E-PRTR). Analysis, summarised in Figure 4-3, shows that half of all damage is caused by only 147 facilities of the 14,000 (around 1%). Closer investigation of the underlying results shows that most of these 147 facilities are coal fired power stations, and includes many with rather advanced technologies for flue gas pollutant abatement.

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[15] Costs of air pollution from European industrial facilities 2008-2012.
http://www.eea.europa.eu/publications/costs-of-air-pollution-2008-2012
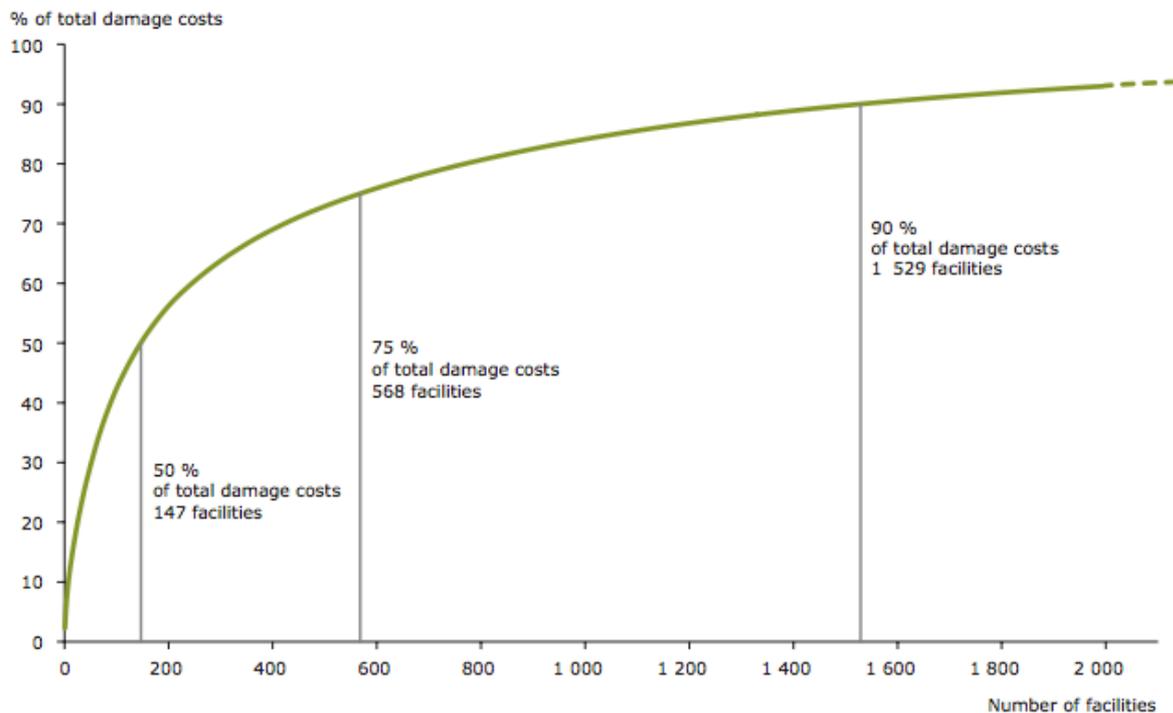
Figure 4-3. Results from the European Environment Agency demonstrating how the impacts caused by industrial emissions can be dominated by a small number of highly polluting facilities. Source: EEA (2014).

4.4   Final remarks

This report provides estimates of the health impacts of coal fired power plants in South Africa. Building on earlier work, it is concluded that these impacts provide a substantial burden on health, leading to premature death and increased illness quite widely within the population. Impacts may well be most severe on the more disadvantaged members of society (Figure 4-1 and surrounding discussion). The view that the impacts of coal are significant is matched by observations elsewhere (Figure 4-3).

These results demonstrate the importance of factoring in these external costs of coal on health into future energy planning for South Africa.