



ground**Work**

The Health Impact of Coal

**The responsibility that coal-fired power stations bear for
ambient air quality associated health impacts**

20 May 2014

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Introduction

Within the Mpumalanga Highveld, reportedly one of the worst air quality areas in the world, there are 22 collieries concentrated around eMalahleni (formerly known as Witbank), and over the last 100 years of coal mining, a complicated “coal dynamic” has been imposed on the area (Munnik et al 2009). “This dynamic includes the mining itself, the generation of electricity in 14 coal-fired power stations, some of which are serviced by captive collieries, heavy industry using coal to produce steel and alloyed products, coal hauling by truck, and a culture of indoor coal burning for heating and cooking in seasonally cold areas, now recognised as a major health hazard” (Munnik et al 2009).

Local studies on health impacts of pollution indicate that poor communities reliant on burning coal or other fuels in their homes, experience increased disease burden with 24% of childhood (under five years old) deaths due to acute respiratory infections were estimated to be from indoor air pollution (Norman 2007b). However, more recently, with an increase in industrial activity, mining, coal-fired power stations returning to service and new ones being built and

the related increase in transport vehicles (emitting various pollutants into the air) the health of people living in the Mpumalanga Highveld has significantly deteriorated (Scorgie 2012, Myllyvirta 2014, Centre for Environmental Rights (CER) 2014, Burt et al 2013). Environmental health studies in urban areas of South Africa have estimated that outdoor or ambient air pollution caused 1.1% of child (under five years old) mortality due to acute lower respiratory infections (Norman et al 2007a). For this study, our main focus is on ambient air quality.

The recognition of part of the Highveld as an Air Priority Area for air quality (HPA) by government in 2007 should have galvanised action to reduce emissions in this area. However, in 2013, Eskom applied to the Department of Environmental Affairs (DEA) for exemptions for a number of its coal-fired power stations from air pollution standards meant to reduce pollution levels and improve the people's health. (CER 2014, Strategic Environmental Management Solutions 2013).

Drawing on available academic peer reviewed literature, government statistics¹ and other reports, this desktop study attempts to understand the contribution that the coal industry and Eskom make to the health risk of the people of the Mpumalanga Highveld, to highlight the costs of such a health burden and to compare health risks with other South African cities, namely Tshwane and Cape Town.



Figure 1: Positions of the monitoring stations (in orange) relative to the power stations (in purple) for the Highveld².

¹ Although international literature provides clear linkages between pollution and health impacts, there is a considerable challenge in assigning responsibility for health impacts to particular source emitters. This report used peer reviewed South African research which had attributed proportions of emissions to particular sources, and then used this model with recent mortality statistics and emissions data to derive illustrative health impacts. The report looked at particular health impacts for example, respiratory mortality of children under 5 and at cardiovascular related deaths as illustrative of the health impacts. The report is therefore necessarily conservative and indicative, and considerable detailed health measurement and monitoring is necessary to ascertain the full impact of Eskom and associated coal industrial processes on ambient quality, and the people's health.

² From Strategic Environmental Solutions 2013 pg 7

How much pollution is produced?

Table 1 provides an estimate of the amount of pollutants emitted into the air in South Africa in 2002 (Scorgie 2012), and the proportion attributed to Eskom.

Pollutant	Total emissions tons/annum	% due to electricity generation, industrial processes and domestic fuel	% due to electricity generation only (Eskom)
PM ₁₀	98901	81%	65%
SO ₂	2153917	98%	71%
NO ₂	1253229	78%	55%

More than ten years later, the amount of pollution that Eskom is emitting has increased considerably due to the additional coal-fired power stations that have been returned to service (Myllyvirta 2014). Figure 2a shows the annual tons of pollutants, nitrogen dioxide (NO₂), and sulphur dioxide (SO₂) emitted from Eskom's coal power generation fleet (Myllyvirta 2014) today (in orange) compared with the emissions if the RTS power plants had not been re-commissioned (in blue). Figure 2b compares the PM₁₀ emissions over the same timeframe.



Figure 2a and 2b: The increase in emissions from NO₂, SO₂ and PM₁₀ over an approximate ten year timeframe (tons/annum).

As can be seen from the graph, Eskom has increased its emissions of NO₂, SO₂ and particulates (PM₁₀)³ by 44%, 22% and 74% respectively, and the trend is likely to continue upwards as those new coal-fired power stations under construction and the proposal of a third new coal-fired power station will further add to the pollution load of the country (derived from the figures above).

Within the Mpumalanga Highveld, the estimated increase in emissions for different pollutants is shown in Figure 3, and of these emissions, 12% of PM₁₀, 73% of NO₂ and 82% of SO₂ are respectively attributed to power generation in the area⁴.

³ a mixture of very small particles and liquid droplets less than 10 micro-millimetres

⁴ DEA (undated). Highveld Priority Area Air Quality Management Plan Executive Summary. DEA. Pretoria.[document is undated but it was released for public comment in 2011]

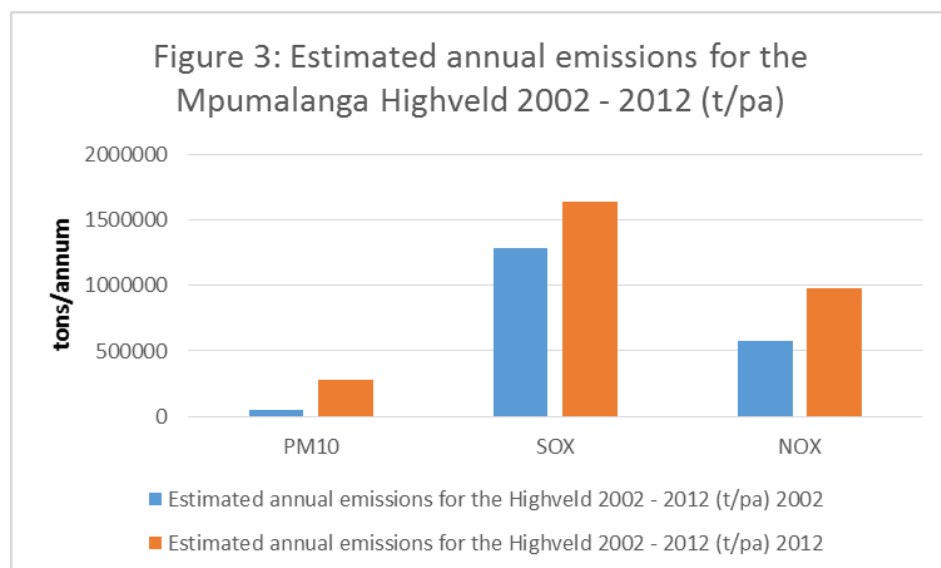


Figure 3: The increase in PM₁₀ SO₂, and NO₂ emissions over the last 10 years⁵ in the Highveld⁶.

In addition, it is estimated that during 2010, 19.8 tons of mercury was emitted by Eskom's coal-fired power stations, estimated at 77% of total mercury emissions in the country (Roos 2011). Figure 4 shows the historical estimates of mercury emissions (Roos 2011⁷). However, Roos's estimates are at variance with Leaner et al (2008) estimating a total of 30 tons for the year 2008, and Myllyvirta (2014⁸) estimates of 26973 kg, and Scott (2011) estimating 39.4 tons for 2009, which he estimates to be a 45% increase from 2000. The mercury emissions estimates for the coal power stations need to be considered as having a low degree of confidence and further work is needed to quantify the mercury emissions with a fair degree of accuracy.

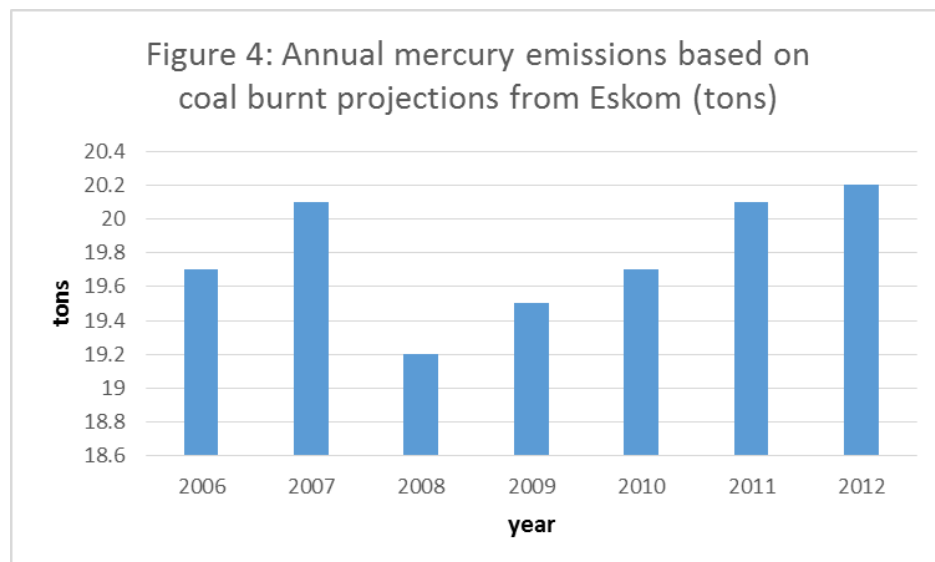


Figure 4: Mercury emissions from Eskom coal-fired power stations 2006-2012 (Roos 2011).

⁵ One of the limitations of this report is the difficult of aligning different sets of data in time. Population data, health data and pollution data are not necessarily captured over the same timeframes, and conclusions drawn from such data must necessarily be regarded as indicative rather than absolute. The quality of the available data also adds to this uncertainty.

⁶ Data for this figure taken from HPA air quality plan and Scorgie 2012.

⁷ Roos. B. 2011. Mercury Emissions from Coal-fired Power stations in South Africa,. University of Johannesburg,

⁸ Myllyvirta 2014

The DEA ground level monitoring in HPA includes mercury and results indicate it is $<0.00005 \mu\text{g}/\text{m}^3$ (DEA 2012)⁹, well below the World Health Organisation (WHO) guideline of $0.02 \mu\text{g}/\text{m}^3$. However, mercury emissions from coal-fired power stations are estimated to account for about 75% of anthropogenic sources in South Africa (Scott 2011), and reducing mercury emissions in this sector will therefore improve the environmental health nationally. With 12 Eskom power stations located within the HPA, mercury reductions in the power sector will benefit HPA communities, redressing some of the injustices they bear due to their heavy environmental burden from other pollutants.

Air currents, wind speed and the height of the power station stacks are all complicating factors which researchers need to take into account when attempting to understand the extent to which power station emissions contribute to ground level pollution. Various studies (Barnes 2014, Norman 2007, Qasim et al 2014) have shown that while life style, wealth and energy poverty (e.g. people forced to use polluting fuels because they are unable to afford access to clean energy) contribute to individual health risk from *indoor* pollutants. However, when it comes to *outdoor* air quality, in South Africa, one's location is also an important determinant of health risk.

Air quality is impacted by a range of pollution sources, and emissions interact with local weather conditions, including the diurnal air flows that can result in stack emissions being brought to ground level during certain times of the day (Bhugwandin 2013¹⁰). SO_2 diurnal variation graphs at all Eskom monitoring stations show a build-up of SO_2 in the early morning, climbing from 07h00, peaking just before midday, and dropping off sharply to back ground levels by 22h00. There is also a smaller peak in the afternoon around 18h00 associated with household coal fires for cooking and heating. The day time high concentrations are typical of high level stack emissions that are brought to the ground due to strong daytime convective turbulence experienced in the Mpumalanga Highveld (Bhughwandin 2013). An example is depicted in Figure 5.

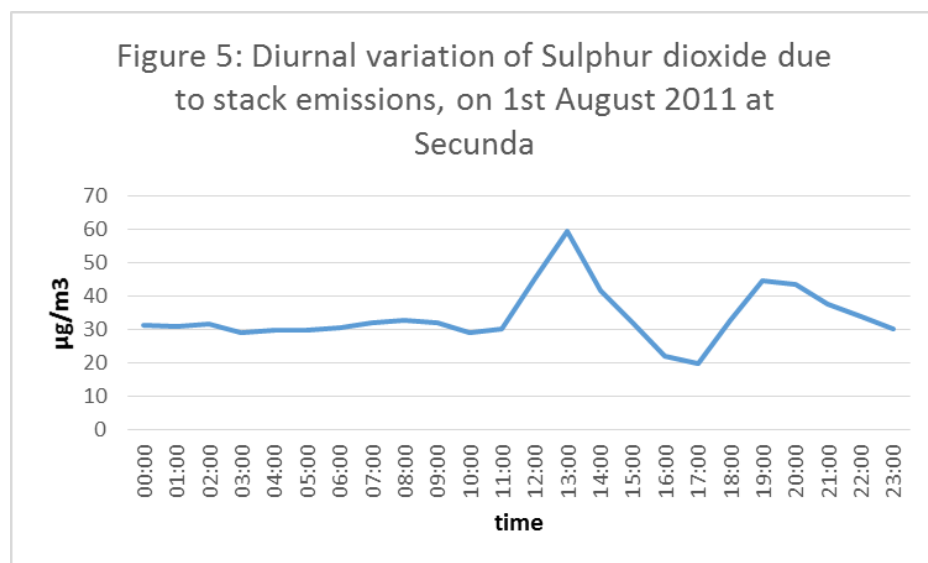


Figure 5: The SO_2 emissions diurnal variation for August 2012 (data from DEA air quality report 2012).

Complex modelling that includes such diurnal variations enables an apportionment of pollution levels to particular sources (Scorgie 2012).

⁹ DEA monitoring data report for June 2012 - <http://www.deat.sianalytics.co.za/index.php?id=reports> EMISSIONS 2008 to 2013 (accessed 5th April 2014)

¹⁰ Bhugwandin K., 2013. The integration of measured, modelled and remotely sensed air quality data and its'impact on the Highveld. Thesis submitted. School of Geography, Archaeology and Environmental Studies, University of the Witwatersrand, Johannesburg.

Ground level ambient air quality in the HPA

The industrial, mining, power generation and domestic coal-fired heating activities on the Mpumalanga Highveld have significantly altered the atmospheric sulphur budget (Bhugwandin 2013). In a study that aimed to improve the air quality predictions for air quality models, Bhugwandin (2013) described how atmospheric dispersion models can be used to determine if proposed or existing industrial plants will comply with air quality standards.

In most countries around the world, governments regulate ambient air quality, through ambient air quality standards, set to protect human health, and the broader ecosystem, and air quality management plans are put in place to manage this. Based on epidemiological studies, the World Health Organisation (WHO) has amended its recommended air quality guidelines, over time, in order to reduce the risk to human health. South Africa air quality standards were gazetted in 2009 with relevant standards for SO₂ and NO₂ and PM₁₀ (DEA 2009), and are shown in Appendix A, together with the WHO recommended standards for comparison. South African air quality standards for PM_{2.5} were gazetted in 2012.

The DEA has implemented monitoring of air quality at ground level, with a focus on areas estimated to be a high health risk. In 2007, the DEA declared the Highveld Priority Area (HPA), and relevant air quality data are released to the public on a monthly basis from the DEA.

Over the last five years, pollution levels appear to be increasing for PM₁₀, while for SO₂, some improvement appears to have taken place for most areas except Secunda. Also of note is that while the annual average for PM₁₀ was above the legal standard for three monitoring stations in 2012, South African legal standards also lag behind the WHO recommendation of 20 µg/m³. The implication is that South Africans in the HPA are experiencing extremely poor air quality, with pollution levels above even the weak South African air quality standards for PM₁₀.

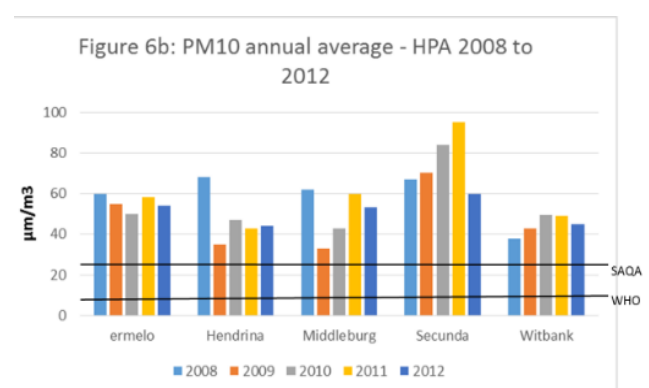
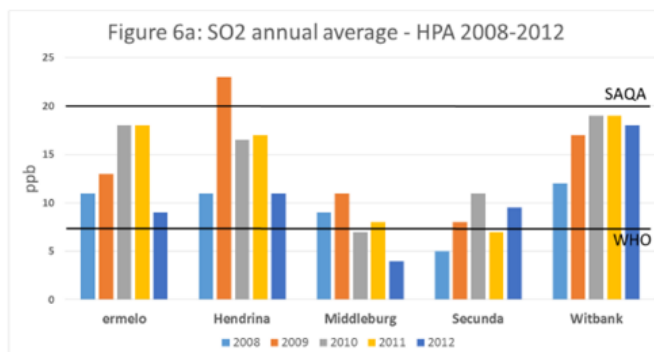


Figure 6a-b: The annual average pollution level trends from 2008 to 2012 for SO₂ and PM₁₀ in the HPA.

However, annual averages do not necessarily reveal the whole picture as there are particular seasonal variations due to atmospheric changes. The HPA pollutant levels are higher in winter because of atmospheric diurnal patterns as mentioned earlier.

Figure 7 Average levels of pollutants for two monitoring stations in the HPA – 2008-2012

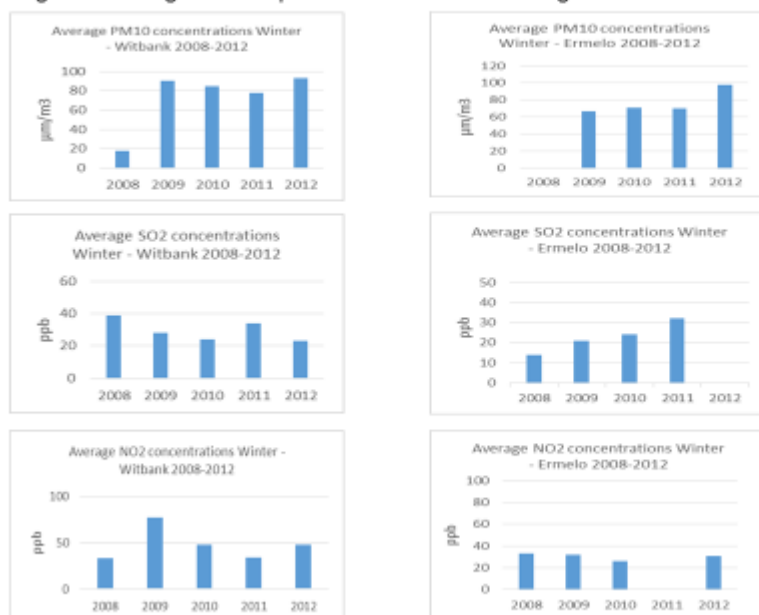
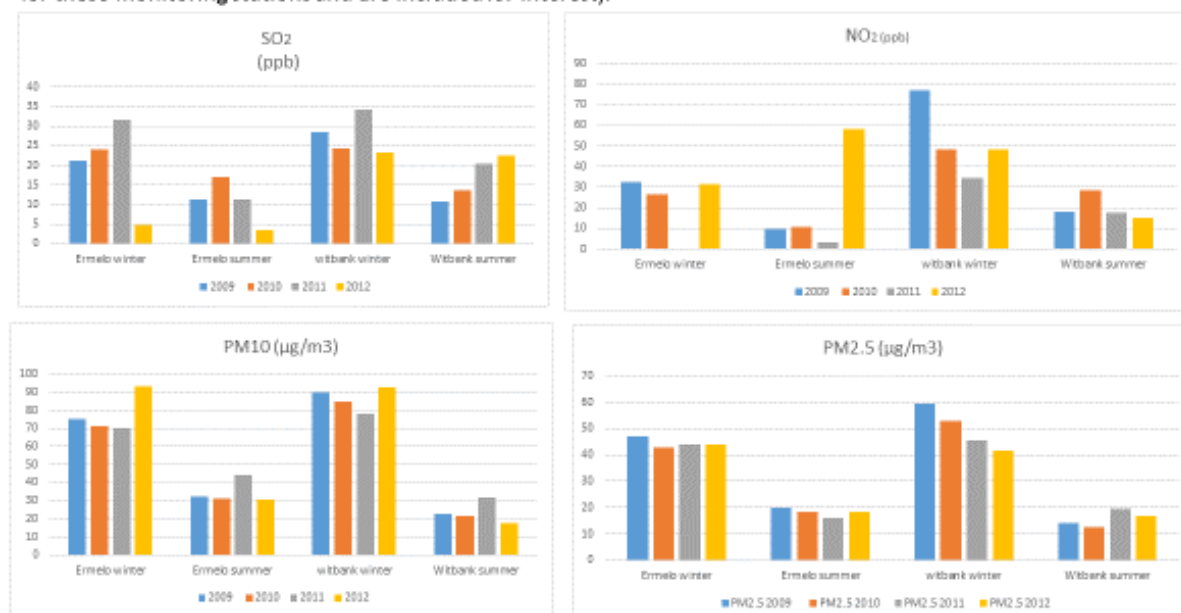


Figure 7: The winter pollution levels for the Witbank and Ermelo monitoring station, from 2008 to 2012.

Using the HPA data for years 2010, 2011, 2012 (DEA), Figure 8 shows the average daily concentrations of three pollutants, SO₂, NO₂, and PM₁₀, for three months of summer (December, January and February), compared to winter (June, July and August) for Witbank and Ermelo monitoring stations. As can be clearly seen in the graphs, winter pollution levels are much higher than summer levels, and there is no overall improvement that is clearly discernible. For example, apart from 2011, it appears that pollution levels are dropping for Witbank winter SO₂, whereas summer SO₂ levels are increasing. Further analysis is necessary to understand the cause of this.

Figure 8: Seasonal variations of pollutants 2009 to 2012. (PM_{2.5} data are also available for these monitoring stations and are included for interest).

South African air quality standards are weaker than the WHO recommendations, and are exceeded regularly, further adding to the health burden of the people of the HPA. For example, the annual average of PM₁₀ and SO₂ appear to be within the guidelines, yet Table 2 shows that people are exposed to increased levels of pollutants, well in excess of the approved exceedances standards. Appendix A provides a summary of the air quality standards and number of allowed exceedances.

Table 2 below provides an indication of the number of actual exceedances per pollutant compared to the air quality standard in the HPA (drawn directly from the HPA Air Quality Management Plan (AQMP)).

Table 2. Exceedances at HPA sites based on monitoring data (HPA AQMP 2011)

		NO ₂ 1-hr (88)	O ₃ 8-hr (71)	PM ₁₀ 24-hr (4)	SO ₂ 24-hr (4); 1-hr (88)
Emalahleni LM	Kendal 2	1	58		34 (43)
	Phola	0		3	2 (27)
	Witbank	37	9	9	4 (51)
	Witbank 2		17	25	1 (11)
Steve Tshwane LM	Columbus			26	1 (14)
	Komati 2			3	1 (2)
	Hendrina	1	22		
	Middelburg	71	66	7	1 (4)
Govan Mbeki LM	Middelburg 2		1	7	0 (1)
	Sasol Club	1		0	0 (25)
	Langensvacht	1		0	2 (78)
	Bojesspruit				2 (27)
Mokaligwa LM	Elandsfontein	0	73	3	4 (33)
	Leandra				8 (14)
	eMbaleni	2	4	39	0 (1)
	Camden	0	24	1	0 (4)
Puley Ka Seme LM	Emelo	1	73	22	21 (10)
	Amersfoort				4 (87)
	Majuba 1				
	Majuba 2				
Lekwa	Verkykloep	0	46	0	1 (7)
	Standerton	4	10	29	1 (6)
Dipaleseng	Balfour		29	8	0 (4)

Row 1: The averaging period for the relevant pollutant's standard is represented below the pollutant and following, the Allowed frequency of exceedance in brackets. Stations in grey blocks represent new monitoring data for the period 2008-2009. Red circles indicate exceedances greater than Permitted frequency of allowed exceedances.

How polluted is the Mpumalanga Highveld compared to other parts of the country?

In a detailed study Scorgie (2012) examined and compared the amount of three different pollutants in different parts of the country. This comparison of the amounts of pollutants emitted for different conurbations is shown in Figure 9, showing that Mpumalanga emits disproportionate amounts of polluting emissions, namely 79% of the PM₁₀ emissions, 84% of the SO₂ and 83% of the NO₂, while a city like Tshwane contributes only 7% of the PM₁₀, 1% of the SO₂ and 2% of the NO₂.

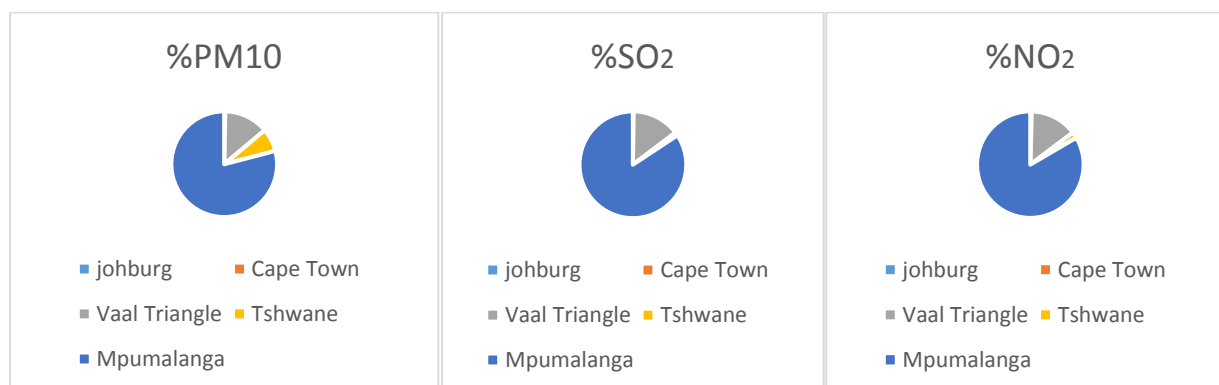


Figure 9: The proportion of different pollutants attributed to different conurbations in the country (Scorgie 2012).

The large proportion of the emissions in Mpumalanga are due to coal related pollutants, particularly Eskom's coal fleet (Scorgie 2012). Refer to Figure 1 showing the location of Eskom's coal-fired power stations within the Mpumalanga area.

Health burden of coal related emissions

Indoor air quality is impacted by burning of fuels inside the home. Many electrified households continue to burn paraffin, coal or wood indoors at times (DoE 2012), placing an unacceptable burden on these households. Government programmes of electrification and the introduction of cleaner coal burning techniques can reduce indoor air pollution and associated health impacts. It is then commonly understood that ambient air quality will then improve. However, such programmes fail to address the underlying cause of this indoor pollution, namely that people have no access to clean affordable energy.

However, air quality derives from various industrial, transport and other processes in addition to indoor fuel use and attributing health risk to particular pollutants is complex (Bhugwandin 2013). This report examined the sources of ambient air pollution and how they further increase the health burden of communities in the HPA.

Modelled ambient air quality and associated health impacts were used to calculate the proportion of health impacts that could be attributed to particular sources, for example, domestic coal burning, power generation and coal use in the industrial sector (Scorgie 2012).

Figures 10, 11 and 12 show the proportion of health impacts attributed to particular sectors for Mpumalanga Highveld, Tshwane and Cape Town. The health impact includes the impact of NO₂, SO₂, PM₁₀ pollutants.

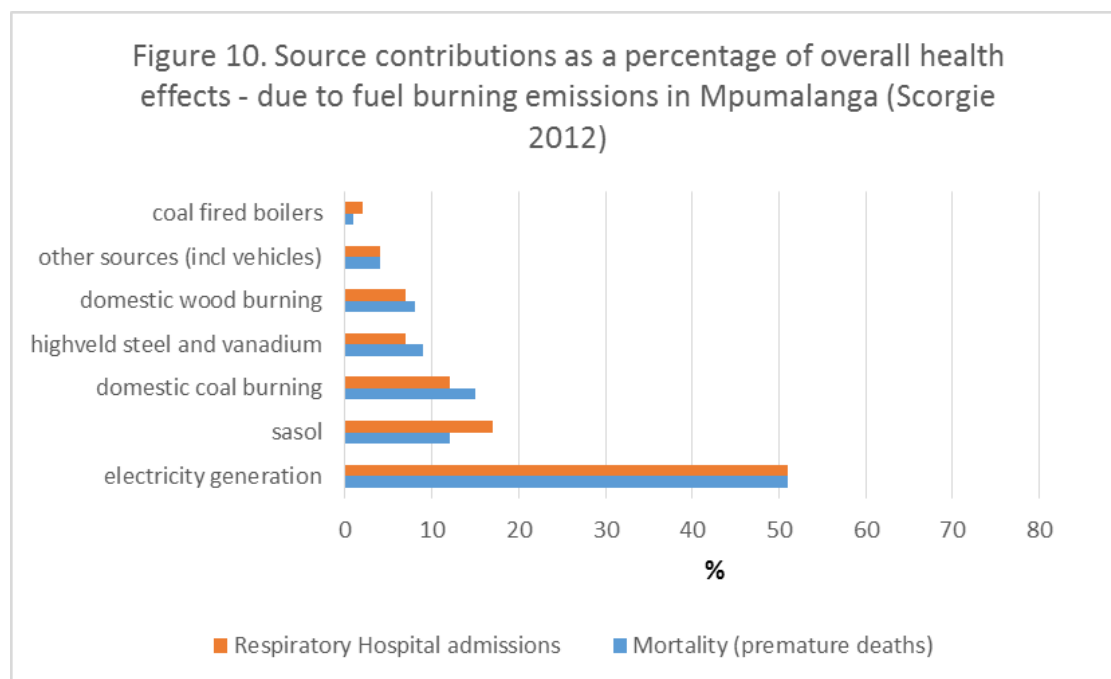


Figure 11. Source contributions as a percentage of overall health effects - due to fuel burning emissions in Tshwane (Scorgie 2012)

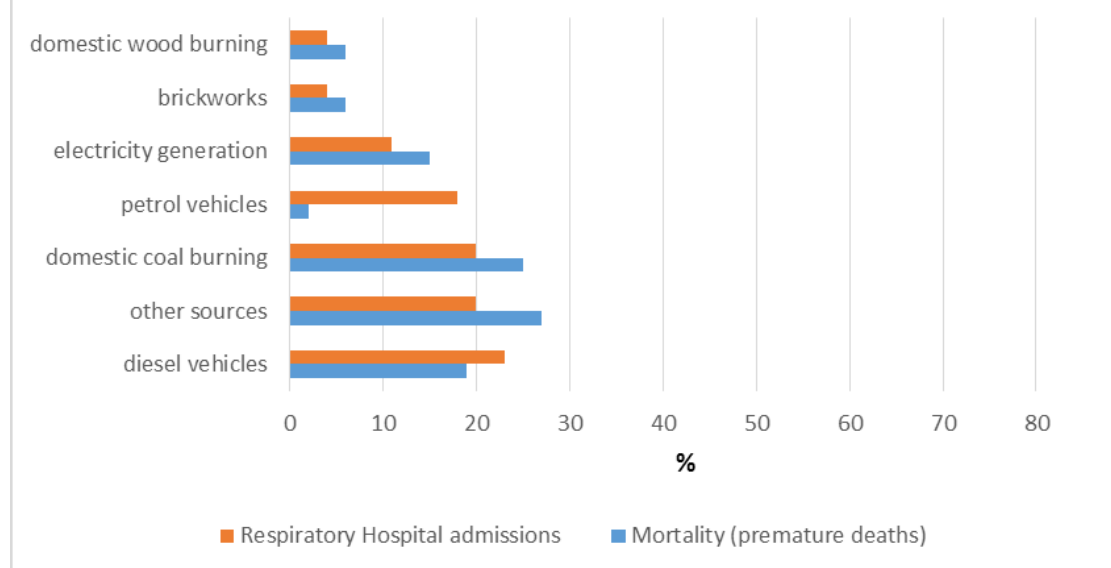


Figure 12. Source contributions as a percentage of overall health effects - due to fuel burning emissions in Cape Town (Scorgie 2012)

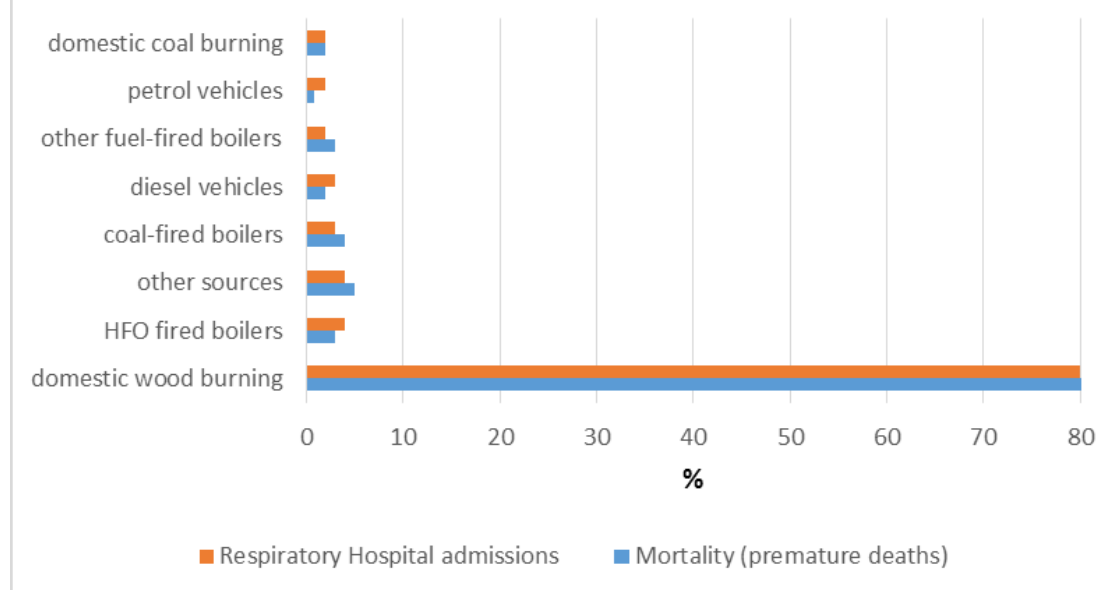


Figure 10 shows that in the HPA, although the outdoor air pollution from the burning of coal indoors has a considerable impact on people's health, its effect is dwarfed by the impact from coal-fired electricity generation. For this province, the ambient air quality related health risk from Eskom's emissions is three times greater than the health risk from indoor coal combustion. As a result, 51% of all hospital admissions and mortalities in the HPA are due to outdoor air pollution related respiratory illness can be attributed to Eskom's emissions.

Electricity generation is not a significant contributor to outdoor air quality related health risks in the other areas. Figure 11 shows that domestic coal burning in Tshwane has a greater impact on health risk than electricity generation, and in Cape Town, the majority of the health risk from fuel burning emissions comes from domestic wood burning.

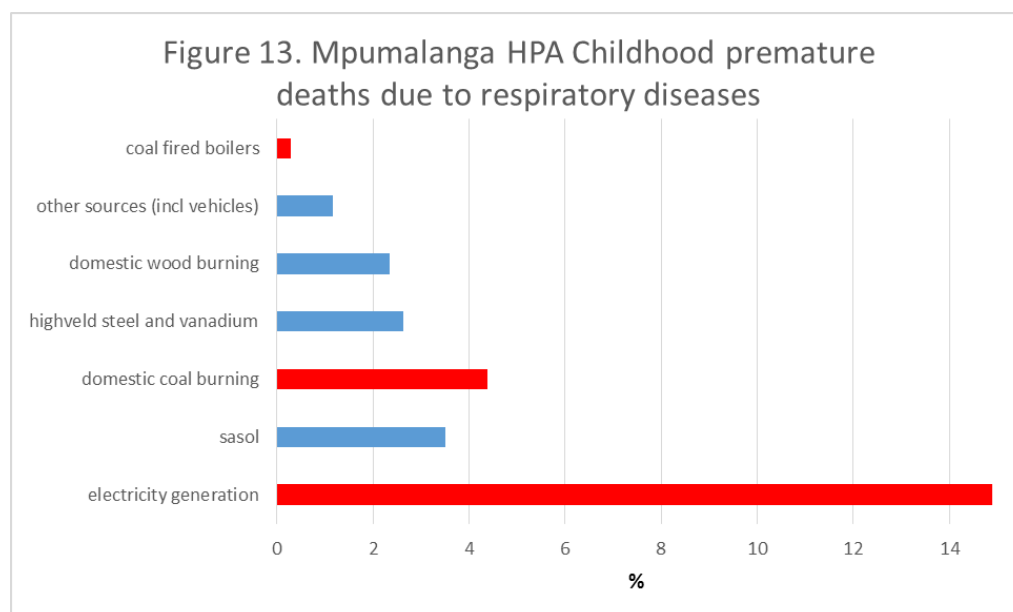
This study has concentrated on children's respiratory health risk. Children and infants are among the most susceptible to outdoor air pollution, as their lungs continue to develop in childhood, and because children play outdoors more than adults, they are more susceptible to the health impacts of ambient air pollution. (Kim et al 2004)

Many households use multiple sources of energy, particularly for cooking and spatial heating (DoE 2012). In Mpumalanga, 26% of households rely on coal as an energy source. This is nearly four times the national average of 7% (DoE 2012). So the children of Mpumalanga not only face the outdoor health burden from Eskom's electricity generation but they are also four times more likely to suffer from indoor air pollution caused by burning coal.

Health impacts due to poor ambient air quality on the Mpumalanga Highveld

The population within the HPA for 2013 was estimated at 3.9 million, based on 2007 estimates^{11 12} and extrapolations from population census data (Statistics South Africa 2011¹³). In 2010, respiratory diseases were responsible for 5249 deaths¹⁴ in Mpumalanga (Stats SA 2010¹⁵, DEA 2011), and for the HPA, in the years 2006 to 2009 the total number of children who died prematurely of respiratory diseases was 2656 (StatsSA 2012a¹⁶).

Using this data, and applying the disease attribution percentages from Figures 10,11 and 12 it is possible to estimate the childhood mortality that can be attributed to coal, and specifically to coal-fired power stations. Figures 13, 14 and 15 provide the estimated numbers of childhood deaths for the Mpumalanga HPA, compared to Tshwane and Cape Town¹⁷.



¹¹ Mid-year population estimates for Mpumalanga are 4 128 000 (2013) [total popn. 5298 million], (statistics South Africa 2013. Statistical release PO302. Mid-term population estimates 2013).

¹² DEA media statement of August 2008 claimed that the HPA population is 3.6 million people
https://www.environment.gov.za/mediastatement/mabudafhasi_airquality_monitoringstations

¹³ Statistics South Africa 2011. Census 2011, provinces at a glance (calculated popn. of Mpumalanga as 3,78 mill in 2007)
<http://www.statssa.gov.za/Census2011/Products/Provinces%20at%20a%20glance%2016%20Nov%202012%20corrected.pdf>

¹⁴ 2010 Deaths per district municipality Ehlanzeni 1809, Ger Sibande 1861, Nkangala 1579 (excluding TB) -

¹⁵ Stats SA 2010. Statistical release P0309.3. Mortality and causes of death in South Africa, 2010: findings from death notification.

¹⁶ STATSA 2010 – childhood mortality report pg 65

¹⁷ An urban factor has been applied to the data to align the provincial child health burden numbers with the conurbation pollution data.

Figure 14. Tshwane Childhood premature deaths due to respiratory diseases

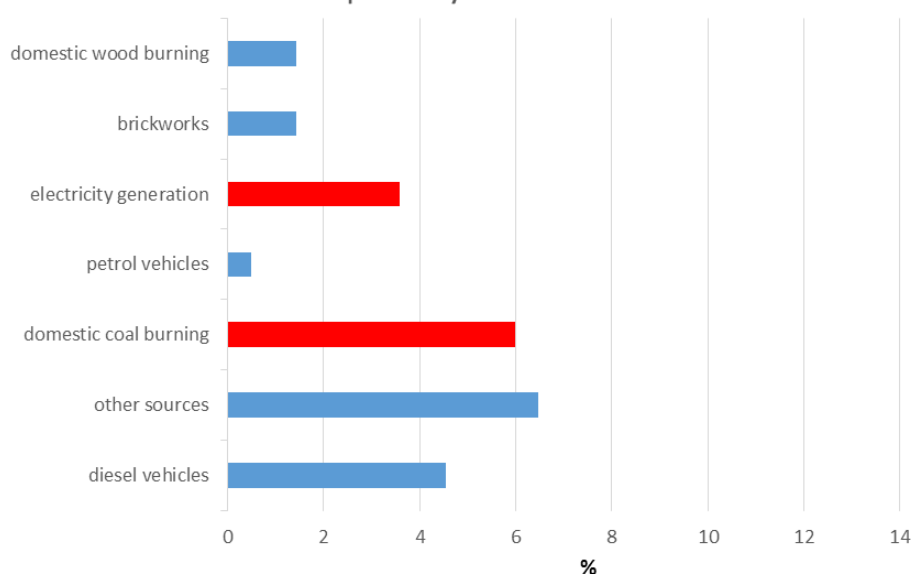
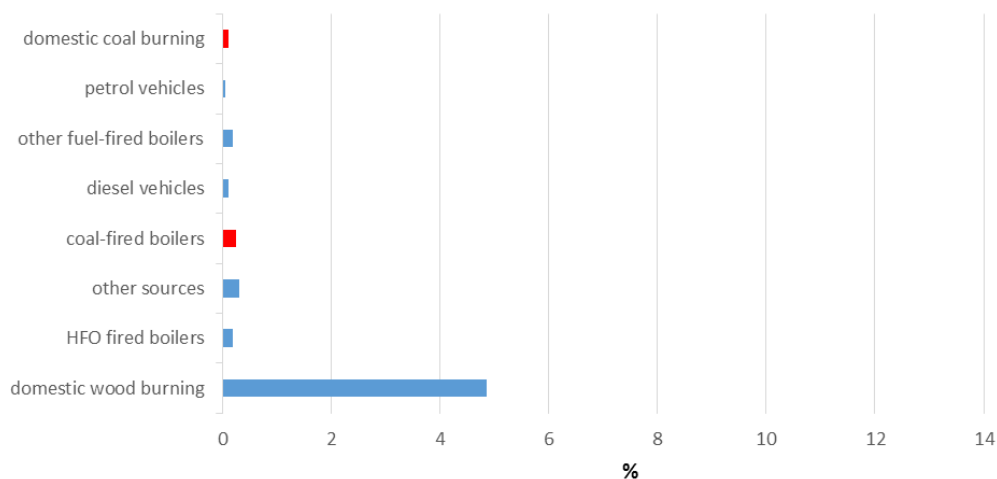
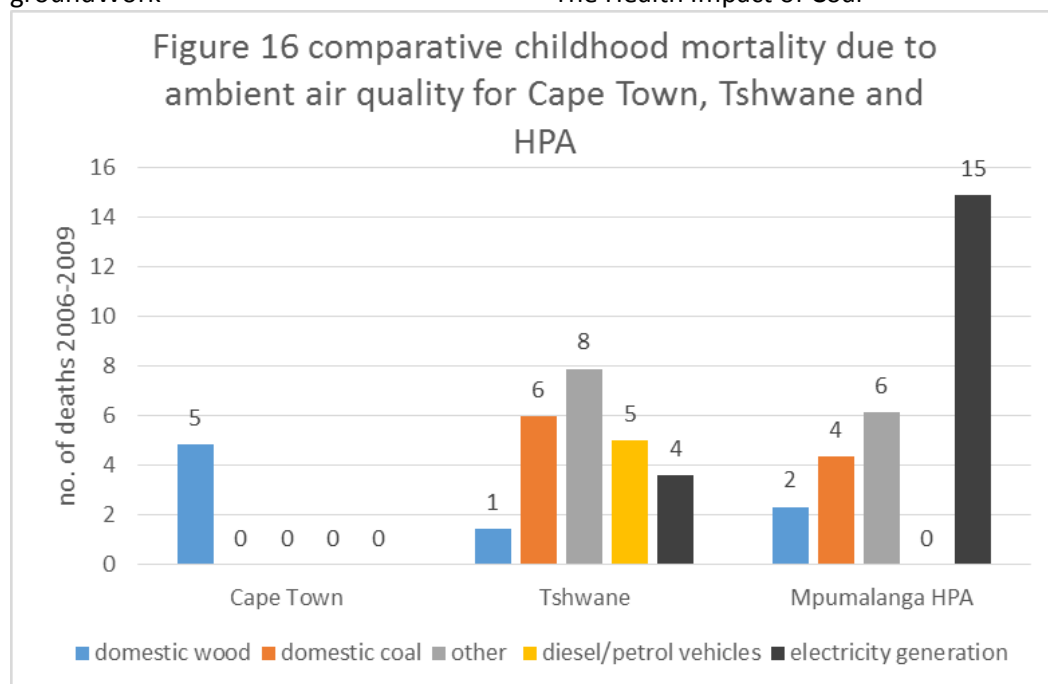


Figure 15. Cape Town Childhood premature deaths due to respiratory diseases



The results shown in Figure 13, 14 and 15 follow those of Figure 10, 11 and 12. For Cape Town, with almost no coal sourced emissions, domestic wood burning contributes most to poor ambient air quality and poses the highest health risk to children (Figure 15). In Tshwane, although coal-fired electricity generation contributes to poor air quality and childhood mortality, children face a higher health risk from domestic coal use that causes poor ambient air quality. However, Figure 13 indicates that in Mpumalanga, while domestic coal burning does contribute to outdoor air pollution and related childhood deaths, this is considerably less than that from coal-fired electricity generation.

Extrapolating from Figure 13, for every child that might die from outdoor air pollution related diseases due to household coal use and industrial coal-fired boilers, more than three children each year would die from Eskom produced pollution in the HPA.



Applying these percentages to the number of deaths for 2006 to 2009 for the different regions, Figure 16 clearly shows that Eskom's electricity generation is responsible for proportionally more premature child deaths due to respiratory illness in Mpumalanga than in Tshwane or Cape Town.

Cardiovascular impacts

The levels of PM₁₀ in eMalahleni in winter have remained about 80 µg/m³ from 2009 to 2012, about 30 µg/m³ above the South African ambient air quality standard. Applying a USA Environmental Protection Agency (EPA) report's (Burt 2013) findings to South Africa, this would mean that an additional 1.5% to 7.2% increase in cardiovascular disease for the HPA due to air pollution. Diseases of the circulatory system were given as the cause of death for 82906 South Africans in 2010, and various forms of cardiovascular disease caused 5256 deaths in Mpumalanga in 2010 (StatsSA 2010¹⁸).

Assuming that 3.7% of those deaths were due to air pollution (CSIR 2009), with 65% of ambient air pollution deaths associated with coal (Scorgie 2012), Figure 17, 18 and 19 shows the proportion of cardiovascular disease attributed to the coal industry, and to Eskom, for the HPA compared to Tshwane and Cape Town. A significant proportion of air pollution related cardiovascular diseases can be attributed to Eskom in the HPA.

¹⁸ StatsSA death report appendix K and appendix M8

Figure 17: Premature deaths due to cardio-vascular disease - HPA

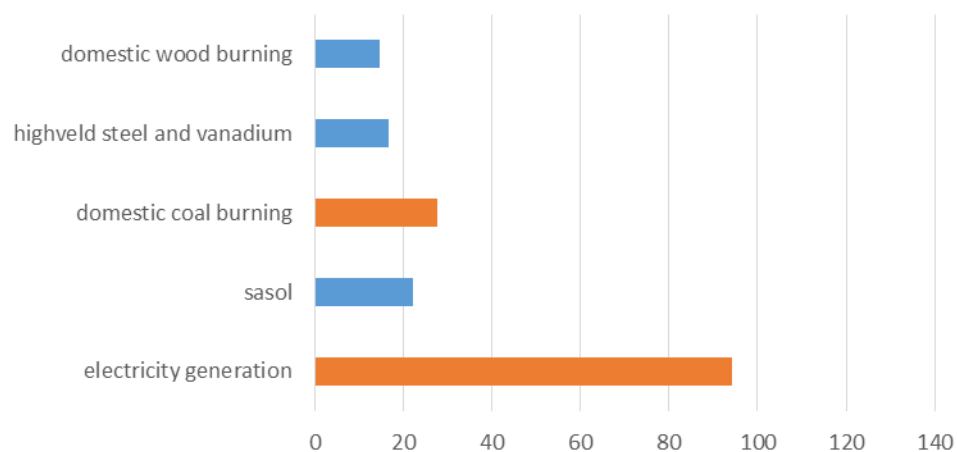
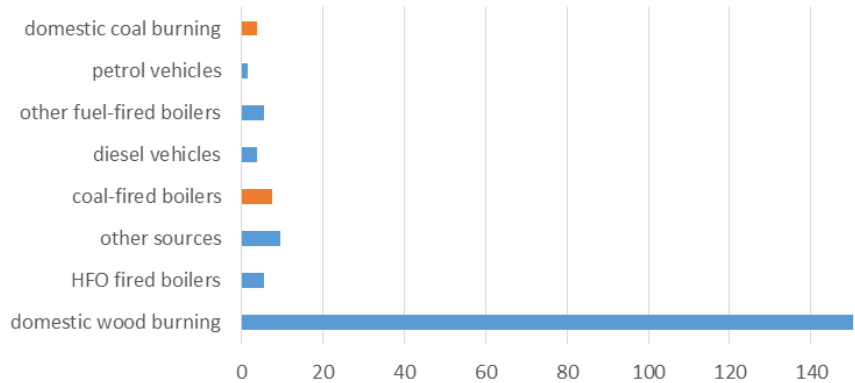
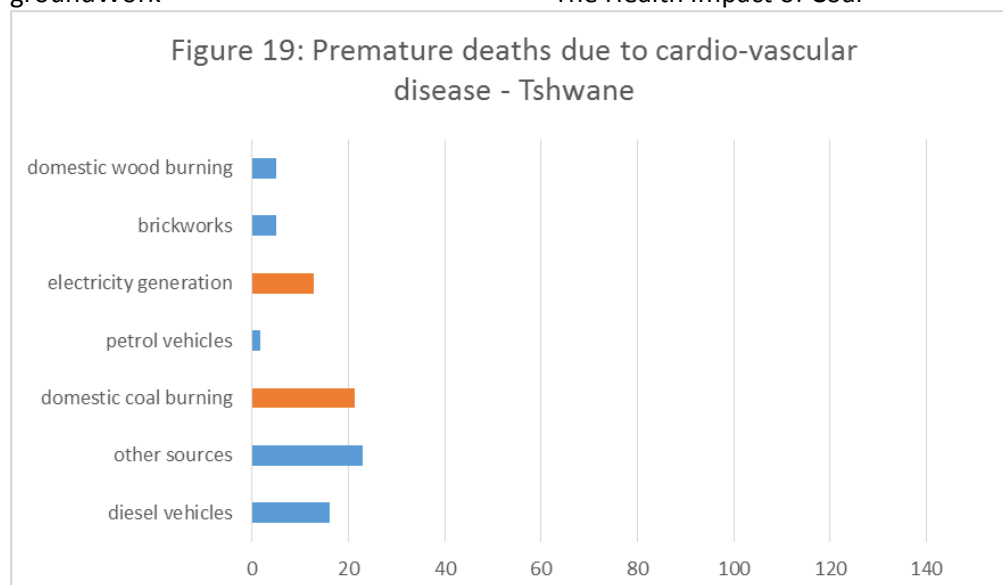


Figure 18: Premature deaths due to cardio-vascular disease - Cape Town





Reducing the PM₁₀ levels to that recommended by WHO (20 µg/m³) could reduce the health risk for Mpumalanga HPA.

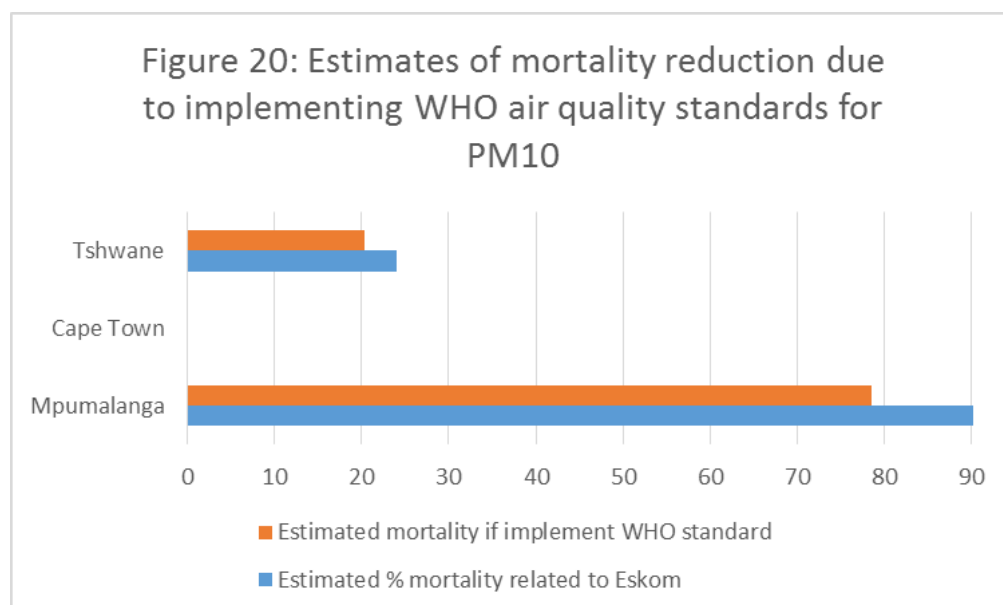


Figure 20: The estimated reduction in coal related cardiovascular disease health burden associated with the implementation of the WHO air quality standard for PM₁₀ for Tshwane, Cape Town and HPA.

Figure 20 illustrates that because in the HPA, electricity generation contributes a large proportion of ambient air quality related health impacts, reducing particulates related to electricity generation has a proportionally larger benefit for people within the HPA. As indicated in Figure 10, in the HPA, for every two people who die from ambient air pollution related disease, Eskom's electricity generation fleet can be regarded as responsible for one of them.

Because our particulate levels are higher than the WHO guideline of 10 µg/m³ (see Figure 8) we can estimate that for every 10 µg/m³ reduction in PM_{2.5} levels, eight to 18% of lives lost due to cardiovascular deaths could be saved, in other words, an estimated 14 to 33 people (derived from Burt 2013). These people should have lived if the WHO PM_{2.5} air quality standard was applied in South Africa¹⁹.

¹⁹ Burt 2013. In the USA, every 10 µg/m³ increase in PM_{2.5} resulted in an 8-18% increase in cardio-vascular deaths (pg 7).

Over the last five years, in the HPA, an estimated 70 to 165 people's lives could have been saved through implementing the WHO air quality standards.

Life expectancy

For those countries with a moderate life expectancy (using 1965 as a baseline year), research indicates that coal burning reduced life expectancy by 2.5 and 3.5 years in India and China respectively (Burt et al 2013). Evidence from the Chen (2013) study supports this.

In South Africa, life expectancy in Mpumalanga is 50.3 for males, and 51.6 for females, below the national life expectancy of 53.3 for males and 55.2 for females²⁰. According to the Mpumalanga health budget of 2012, although HIV/AIDS still remains the major cause of death, with 770 deaths per day during the 2010/2011 financial year, one of the causes of a decline in life expectancy was cardiovascular disease²¹. Although ambient air quality due to coal emissions no doubt contributes to the reduced life expectancy, it is not possible to show the exact extent in this short study.

Health and wellbeing

Given the multiple stressors that impact on human lives, it is difficult to calculate the contribution of each stressor to the health and welfare of people, and researchers tend to focus on mortality and its causes. However, some estimates have been calculated for the impact of air pollution on human *wellbeing*. Scorgie (2012) calculated how the level of air pollution might impact on daily activities using a measure called Minor Restricted-Activity Days (MRADs), defined as occurring "when individuals reduce most usual daily activities and replace them with less-strenuous activities or rest, but do not miss work or school"(EPA 2009)²².

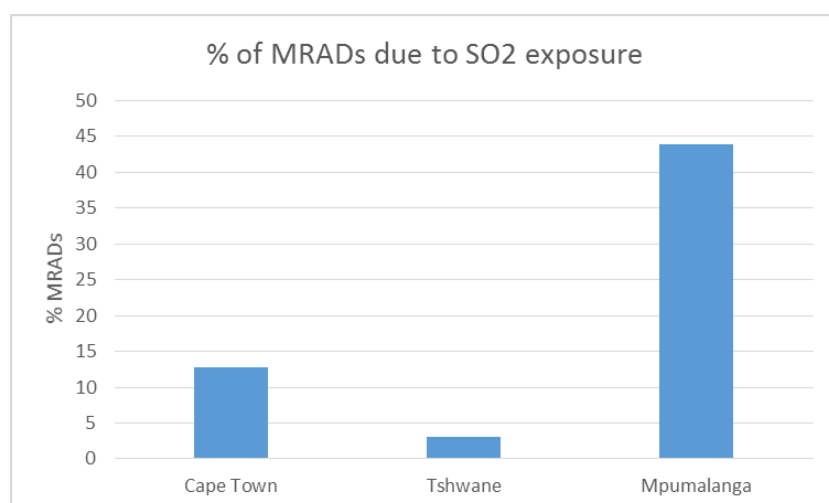


Figure 21: The three locations and relative MRADs – associated with SO₂ exposures (derived from Scorgie 2012).

If we compare the three areas, we see that, as anticipated, lower levels of coal related pollutants in Cape Town and Tshwane lead to less coal related health impacts. Mpumalanga has 44% of SO₂ related MRADs in the country (Scorgie 2012)²³, with half of those attributable to coal generation (refer to Figure 10). If we take the total number of incidences

²⁰ <http://www.mpumalanga.gov.za/media/speeches/health/budget.htm>

²¹ Mpumalanga Policy and budget speech for the Department of Health 2012/2013

²² EPA 2009. SAB/HES review draft – November 2009. Chapter 2 – Estimation of human health effects and economic benefits. http://www.epa.gov/cleanairactbenefits/dec09/IEc_Second_Prospective_Health_Benefits_Chapter.pdf

²³ Scorgie 2012. Pg 129

of air pollution related MRADs in the country, then one in five (20%) are due to electricity generation activities in Mpumalanga.

Mercury

Long term occupational exposure to mercury may affect the kidney and the central nervous system negatively. Mercury is emitted from coal combustion, and is then deposited into the environment (for example through leaching from fly ash dumps), finding its way into the water system, and from there, it is concentrated up the food chain, finding its way into crops and livestock, or into humans through for example, people eating fish contaminated with mercury (WHO 2007). The health impacts can include development effects such as low intelligence levels and delayed neurodevelopment in children. (Burt et al 2013.) According to the WHO (2013), a guideline value for ambient air would be $0.2\mu\text{g}/\text{m}^3$ ²⁴ for inhalation by the general public.

Estimates for mercury related health impacts related to coal burning in South Africa have suggested that current emissions are associated with the loss of 45000 IQ points each year (Myllyvirta 2014).

According to an EPA study, mercury toxicity in the USA could affect 10 to 15% of children born each year, and the EPA states that when there have been outbreaks of methyl mercury poisoning, "some mothers with no symptoms of nervous system damage gave birth to infants with severe disabilities, it becomes clear that the developing nervous system of the foetus may be more vulnerable to methyl mercury than in the adult nervous system"²⁵.

American studies estimate that a 1.6 point drop in IQ could cost US \$31 800 in a person's lifetime earnings (Trasande et al 2005)²⁶. The application of this equation to the estimated 45000 IQ points lost each year (2014) could potentially lead to lost earnings of R894 million impacting the earning potential of 28125 people.

Water

The use of water in pollution abatement technologies on coal-fired power stations raises additional challenges for water quality. Removing mercury and other pollutants from the power station emissions, means that there is an increase of mercury in by products such as fly ash and waste from coal washing and this raises the risk that the mercury could potentially leach back into the environment, rendering the pollution abatement mechanisms futile (Roos 2011).

In a water scarce country, Eskom's electricity generation uses large amounts of water. Human basic water allocation is 25 litres per day and Eskom uses about 1.38 litres of water to produce 1 kWh of electricity (EMG 2011). Eskom would use one citizen's allocation of water to produce sufficient electricity (about 18kWh) to light a 100 watt bulb for 180 hours.

Acid mine drainage (AMD) from coal mines amounts to 62Ml/d, with estimated costs of clean up for the eMalahleni area minimally at R126 million (Munnik 2009)²⁷, and estimates are that this would raise the price of water to between

²⁴ WHO European Centre for environment and Health, Bonn. 2013. Review of evidence on health aspects of air pollution – REVIHAAP Project: Technical Report Page 127. http://www.euro.who.int/_data/assets/pdf_file/0004/193108/REVIHAAP-Final-technical-report-final-version.pdf

²⁵ <http://www.epa.gov/mercury/effects.htm>.

²⁶ <http://www.cbsnews.com/news/study-iq-loss-from-mercury-costly/>). And <http://www.ncbi.nlm.nih.gov.ezproxy.uct.ac.za/pmc/articles/PMC1257552/>

²⁷ Clean up costs for AMD are much more for the country but this is an illustrative example

40 and 50 $\mu\text{g}/\text{m}^3$ ²⁸), while other reports indicate a threefold increase in water pricing, and capital outlay of R300 million for one water purifying plant (McCarthy 2011²⁹).

Solving the problem, reducing the health burden

For the HPA, in the years 2006 to 2009 the total number of children who died prematurely of respiratory diseases was 2656 (StatsSA 2012a³⁰), 29 due to outdoor air pollution, with a conservative estimate that at least 15 of those children's deaths would be attributable to Eskom coal power stations.

A recent study in China highlighted significant differences between two communities that were of comparable socio-economic status but one was exposed to high levels of airborne particulate matter through the use of coal-fired boilers in town, whereas the other was not. Researchers (Chen et al 2014) found that exposure to high levels of particulates 184 $\mu\text{g}/\text{m}^3$ led to an increase in cardiorespiratory causes of death (resulting in a 14% increase in overall mortality) and a reduced life expectancy at birth of about three years. While the HPA area experiences high PM_{10} and $\text{PM}_{2.5}$ levels (refer to Figure 8), for example, in winter in eMalahleni the PM_{10} levels almost double the South African air quality standard of 50 $\mu\text{g}/\text{m}^3$ (DEA 2011 air quality data). However, overall, the levels of particulates are much less than that found in the China case study.

Although not necessarily at a level that demonstrably increases mortality at the same rate as in the China case study, particulates that are smaller than 2.5 microns travel deeper into the bronchial passages and lungs causing increased negative health impacts. These can include decreased lung function, asthma, for example, every 10 $\mu\text{g}/\text{m}^3$ increase in $\text{PM}_{2.5}$ is associated with a 1 to 3.5% decrease in measured lung function (Burt et al 2013). The USA EPA also found a 0.5 to 2.4% increase in cardiovascular disease (evidenced by an increase in emergency department visits and hospital admissions) for each 10 $\mu\text{g}/\text{m}^3$ increase in $\text{PM}_{2.5}$ (Burt et al 2013). The WHO has estimated that reducing annual average PM_{10} levels from around 70 $\mu\text{g}/\text{m}^3$ to 20 $\mu\text{g}/\text{m}^3$ would reduce the air pollution related mortality by around 15%³¹.

For sulphur dioxide emissions, research indicates that even at low concentrations (less than 10ppb 24 hour average), there is an increased risk of death from heart and lung conditions. For every 10 ppb decrease, the risk of death could be reduced by 0.4 to 2% (Burt et al 2013). Implementing flue-gas desulfurization in the HPA, particularly to reduce winter pollution, could potentially save many lives. Nationally, Eskom is estimated to be responsible for 6% of the overall coal related health risk (relating to ambient air quality), but in Mpumalanga, 50% of the ambient air quality related health risk is attributed to Eskom (Scorgie 2012). Extrapolating from this, it would appear that Mpumalanga bears eight times the health related pollution risk than the national average.

Although this study did not assess the health risk of ozone, it is important to note that nitrogen oxides from fossil fuel combustion (vehicles and power stations contribute) undergo chemical reactions, producing pollutants such as ozone, nitrous oxide and nitrogen dioxide. These pollutants increase respiratory disease, increase susceptibility to viral and bacterial infections, and potential lead to emergency hospital visits particularly asthma (Burt et al 2013).

Table 3 indicates the numbers of reductions in health burden that are potentially achievable Using an example of two interventions, the reductions in health impact are, measured in reduced number of people affected (Scorgie 2012).

²⁸ The Impact of Acid Mine Drainage in the Witwatersrand on the Mining Industry in Mpumalanga, Free State, Limpopo, North West and Northern Cape Provinces (undated), Richard Holden - TCTA). For more AMD information - <http://archive.constantcontact.com/fs106/1101623328228/archive/1114670814995.html>

²⁹ McCarthy TS. The impact of acid mine drainage in South Africa. S Afr J Sci. 107(5/6), Art. #712, 7 pages. doi:10.4102/sajs.v107i5/6.712

³⁰ STATSA 2010 – childhood mortality report pg 65

³¹ WHO, 2014. Ambient (outdoor) Air quality and Health factsheet No 313, updated March 2014.

intervention	Respiratory hospital admissions due to PM ₁₀ , SO ₂ , NO ₂	Cardiovascular hospital admissions due to PM ₁₀ exposure	Chronic Bronchitis (PM ₂₀ related)	Total number of people
Desulphurisation of all power stations	-1520	1.9	301	-1217
Electrification	-7946	-65.5	-8405	-16416

Assuming that the ultimate goal is zero pollution, and acknowledging that an incremental approach to improving health would logically adopt the most cost effective measures first, Leiman (2007) identified the reduction of indoor domestic fuel emissions as having the greatest impact on the health of people at the least cost to the economy. However, the relative contribution of domestic fuel burning towards ambient air quality also needs to be taken into account.

The proportional contributions to human health from domestic fuel emissions varies from area to area, as indicated in Figure 10 and 11 above. Improving ambient air quality through removing the use of domestic coal in both Tshwane and Mpumalanga could reduce health impacts by 20%. However, in Mpumalanga, closing down power station and stopping their emissions would improve ambient air quality and result in a health improvement of more than twice as much as addressing domestic coal burning³². But doing the same actions in Tshwane would only yield a 15% health improvement.

An illustrative example would be if 100 children were likely to die prematurely due to poor ambient air quality in Tshwane, you could potentially save 15 lives through addressing coal-fired power station emissions, but you could save 20 lives if you addressed domestic coal related ambient air pollution. However, if there are a similar potential 100 premature children's deaths in Mpumalanga due to ambient air quality, 20 could be saved through addressing domestic coal but 50 deaths could be prevented through addressing coal-fired power station emissions. The extent of exposure to health risks is thus dependent on location.

A Department of Energy (DoE) residential energy survey found that many households are reliant on multiple energy use, particularly the poorer households, and Figure 23 shows the provincial distribution of coal for household energy use (DoE 2012).

³² Please note that these results apply to ambient air quality health impacts and are in addition to the significant and obvious health benefits from improving indoor air quality.

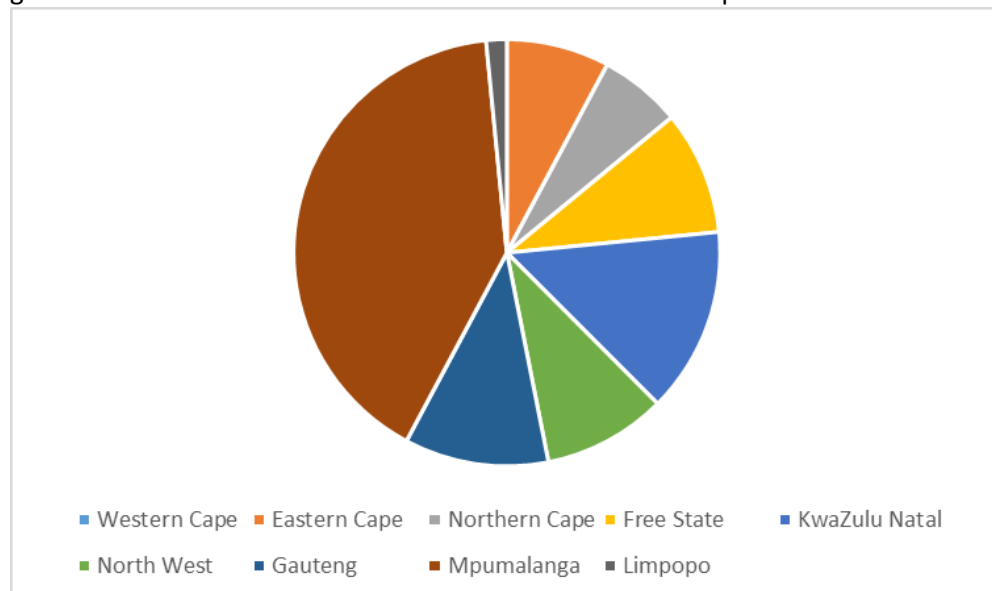
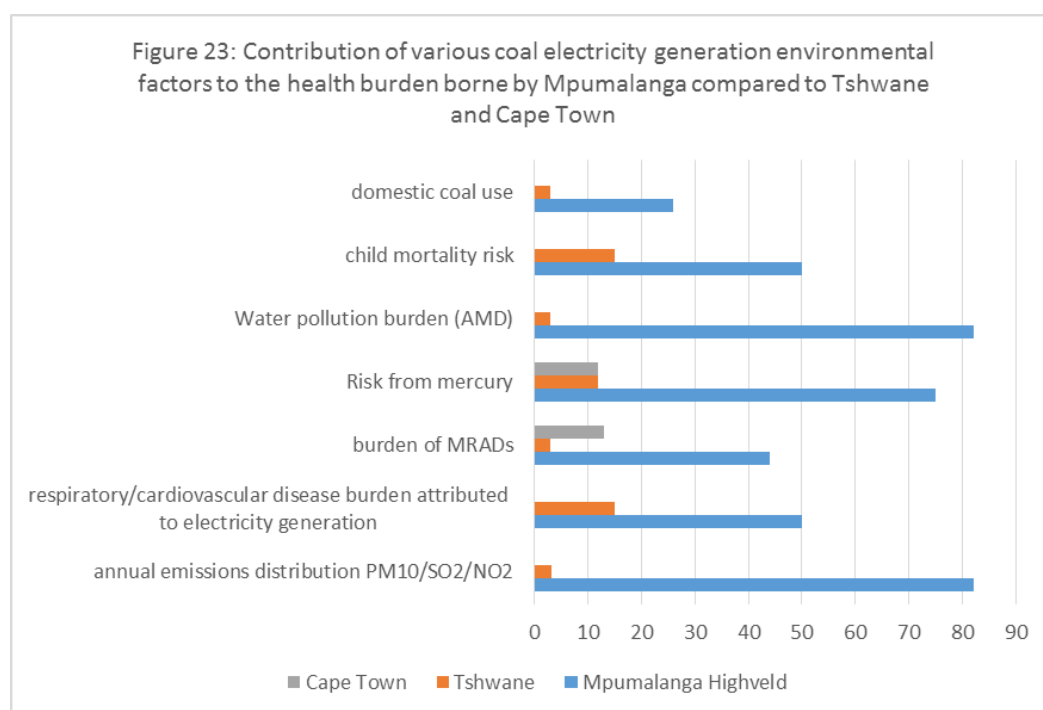


Figure 22: The percentage of households in each province using coal for domestic use (DoE 2012).

If you are in Mpumalanga, the health risk from coal-fired power stations is three times that of ambient air quality risk of burning domestic coal, while in Tshwane, ambient air quality impacts from household coal burning pose a greater risk to health than emissions from power station stacks.

Overall health burden for the Mpumalanga Highveld person

Throughout this report different environmental factors have been assessed for the estimated impact on the health and wellbeing of the people of Mpumalanga HPA, and compared with Tshwane and Cape Town. Figure 23 provides an indication of how Mpumalanga experiences a disproportional burden of negative health impacts, due to coal related air pollution.



Economic impacts

In theory, a conventional cost benefit analysis can be used to determine the pollution reduction measures that the state should implement, but often, the key question posed by economists is how to determine how much pollution should be endured.

In Figure 24 (Leiman et al 2007), the level of emissions decrease from the left side of the diagram while the abatement measures increase from the right hand side.

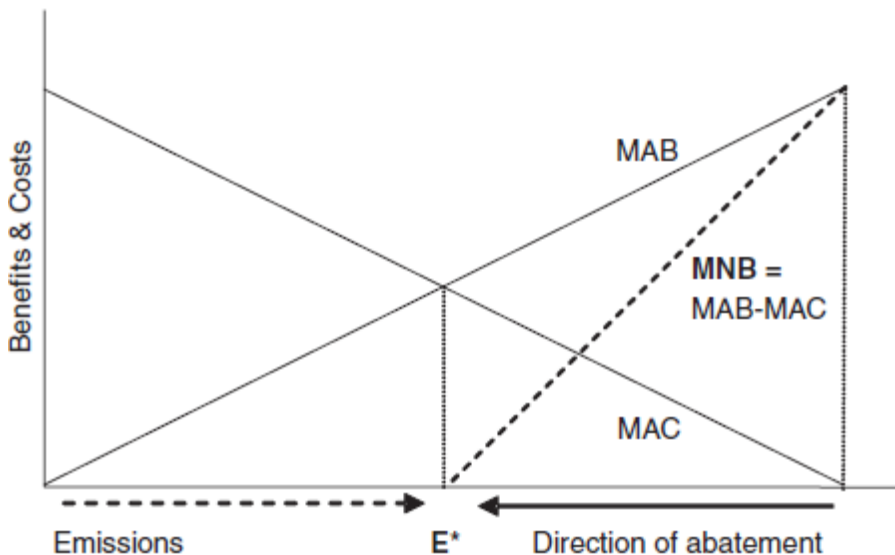


Figure 24: A diagrammatic representation of the optimal level of pollution abatement.

At the beginning of such a pollution abatement programme, the emissions will be high and the marginal cost of abatement (MAC) will be correspondingly high. As emissions levels decline, it should cost less per unit of abatement. On the right hand side, similarly, the benefits (quantified as the avoided health costs due to cleaner air) will be high when pollution levels are high, and will reduce as the air gets cleaner. At some point E, the cost of implementing a further unit reduction of pollutants, will cost more than the health care costs that would be incurred due to the emission related ill health. For economists, this is known as the optimal level of pollution (Leiman 2007).

Environmental health advocates and affected people would lobby for E to move to the right, while governments and polluting industries would argue that limited financial resources or technical limitations would restrict such a right movement, often citing that the health benefit does not justify the cost involved.

The financial quantification of the abatement costs appears a relatively less complex exercise. For example, Eskom claimed that to implement pollution abatement across all its power stations would cost between R105 and R404 billion. However, this was contested by CER who argued for a figure of R146 billion (CER 2013).

The marginal benefit costs are complex and also difficult to quantify. Conventionally, lives in developing countries are regarded as of less financial worth (Leiman et al 2007) (using the value of life insurance policies for example). With a knowledge of salaries, it would be possible to determine the cost of a day off work due to illness for those employed. However, given that workers earn less than management, this type of calculation would suggest that management's health is more valuable than ordinary workers due to the differential in their salaries. Those that are involved in providing unpaid services (cooking, cleaning, child care, looking after the aged and sick – mainly women) must also be costed. The cost of medical care provided by hospitals and clinics can also be calculated. However, again, taking the current South African public health services budgets as a proxy is likely to underestimate those air pollution costs as it is generally accepted that public health services are inadequate to meet patients' needs.

Scorgie (2012) estimated that external health related costs associated with coal across her study sites was about R3.5 billion with power generation responsible for only 6% of external costs overall, whereas Myllyvirta (2014) estimated that the cost to society is R230 billion including premature deaths from exposure to pollutants such as PM_{2.5} and mercury.

External costs of coal-fired electricity in the USA were calculated at 17.8 US cents per kWh cost production, while in Europe, studies indicated 1.6 to 5.8 euro cents/kwh, with an acknowledgement that 95% of external costs are regarded as health related (Burt et al 2013).

A 2003 study estimated that the costs of externalities for Eskom power were 4.4 cents/kWh, and totalled R7.3bn, of which air pollution and health were about 16% (Spalding-Fechter 2003³³). Interestingly, this study calculated the cost of benefits from electrification would be R958 million (13% of net externality costs) and subtracted this benefit cost from the overall externalities costs.

Depending on methodologies (largely contentious), a range of external cost values have been calculated related to health impacts. This report has not reviewed the acceptability of different methodologies but has included a range of estimates derived from international studies. The rationale for taking this approach is to illustrate the diversity of estimates, and to hopefully take into account best practice and healthiest air quality standards.

This study therefore drew accepted a principled position that health should be improved and pollution reduced and narrowly examined the cost of implementing pollution abatement technologies, contrasting this with internationally referenced external cost estimates.

Table 4: A range of estimates of benefit and costs, calculated using the various approached outlined by different reports.

	USA EPA (2010)	Myllyvirta (2014)	Eskom	Burt et al (2013)	Munnik (2009)	Scorgie (2012)
Method	Electricity generation direct costs to 2020		FGD for whole fleet	Ratio of 1:25 of abatement costs	10% increase on elec. cost	Eskom 6.5% of R3.5bn
Calculated cost	R 100 bn	R30 billion	R200 bn ³⁴	R 150 billion ³³	R 21 billion ³⁵	R 210 million

In the USA, the EPA calculated that for every dollar spent on reducing air pollution, US \$25 were saved in health care costs due to the reduction in premature deaths, and respiratory diseases (Burt et al 2013³⁶). An EPA study that found

³³ Spalding Fechter R., Matibe 2003

³⁴ Eskom estimation for whole fleet – 2007 prices - <http://mg.co.za/article/2014-03-13-eskom-spurns-air-quality-controls>

³⁵ Author's calculation

³⁶ Burt E., Orris P., Buchanan S. 2013. Scientific Evidence of Health Effects from Coal Use in Energy Generation – Health care Research Collaborative. University of Illinois at Chicago School of Public Health, Chicago, Illinois, USA

direct costs of cleaning up air pollution related to coal-fired electricity would be \$10bn and that the benefits of clean air programmes could be an equivalent value of US \$6000 per person (EPA 2010)

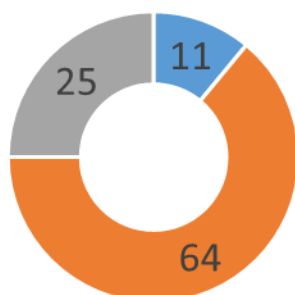
For South Africa, Eskom claims that retrofitting their entire fleet to reduce pollution would cost R200bn³⁷. Applying a 1:25 ratio, this would mean that government would save R5000 billion in health care costs – money that could be directed towards early childhood development for example or increasing rates of electrification.

This study is necessarily illustrative in nature and figures presented here are indicative, based on available data. This study was not able to include additional health costs due to ozone related to power station emissions, for example. Overall a conservative approach has been adopted in estimating numbers of affected people whose health could be directly linked to coal-fired power station emissions, and the gaps in available data indicate an urgent need for further research on the ground.

Environmental justice - Who is paying the cost right now?

The benefit of Eskom's electricity is largely not experienced by those that are suffering from the pollution emitted from the coal-fired power stations. Nationally, the residential share of total electricity demand is 20% and is concentrated in the hands of the wealthy. As shown in Figure 24, Low income households make up 25% of the population, but only use 2.4 % of the electricity, whereas high income households are less than half in number but use 14 times as much (adapted from Tait & Winkler, 2012). Many of those poorer people live in Mpumalanga.

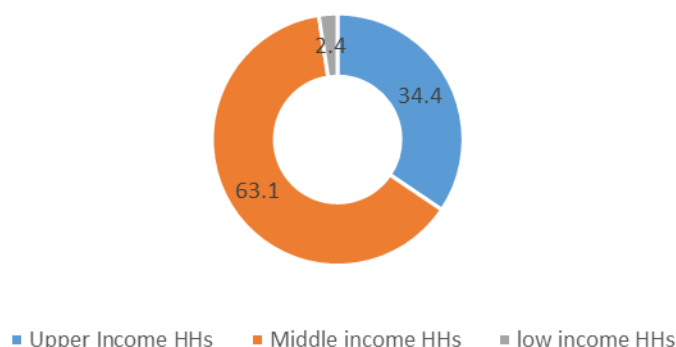
Figure 24a: Percentage of households in different income groups (from Tait and Winkler 2012)



■ Upper Income HHs ■ Middle income HHs ■ Low income HHs

³⁷ Eskom estimation for its whole fleet – 2007 prices - <http://mg.co.za/article/2014-03-13-eskom-spurns-air-quality-controls>

Figure 24b: Percentage of electricity usage per household income group (from Tait and Winkler 2012)



58% of South African households earn less than R2300 per month, and in Mpumalanga, approximately 580 000 households earn less than R1600 per month (Stats SA 2011³⁸).

Indoor pollution due to coal use imposes a health burden on many HPA people, and in addition, the large contribution that Eskom's coal-fired power stations make towards worsening ambient air quality imposes increased health risks (Figure 8). Mpumalanga children are paying for Eskom's refusal to implement pollution abatement measures.

In order to effect a just transition away from dirty, unhealthy and expensive fossil fuels, our electricity mix needs to shift from coal-fired electricity towards renewable energy³⁹, while existing coal-fired power stations must implement pollution abatement measures. Implementing 10000GWh of renewable energy would reduce Eskom's coal-fired power generation emissions by 6.4%, while implementing 37000GWh would reduce emissions by 19% (Scorgie 2012), implementing sulphur reduction technologies would reduce sulphur emissions by 5.2% (Scorgie 2012). With no intervention, increasing numbers of children risk premature death, whereas direct action to address pollution due to coal-fired power station emissions would result in a healthier generation of Highveld children.

In conclusion, government programmes of electrification, and fuel efficient stoves⁴⁰ are addressing indoor pollution to some degree, and logically, this will then address outdoor pollution in affected areas. However, as this report demonstrates, in areas like the HPA, at least 50% of the outdoor air pollution is due to Eskom power stations, and addressing indoor pollution will have little impact on the ambient air quality health risk borne by affected communities. Conservative estimates indicate that investing in reducing pollution, improving ambient air quality, leading to an improvement in people's health, is economically a more sustainable development choice, and leads to additional jobs that are part of a just transition towards a healthier society.

Liziwe McDaid

³⁸ Stats SA 2011. Copy of Households by income band by metro and province, Stats Sa

³⁹ Various job studies (IDC, Institute for Security Studies) indicate that renewable energy could create an estimated 130 023 long-term jobs, with an additional 67 977 long-term jobs in energy efficiency and resource efficiency (Borel-Saladin 2013).

⁴⁰ For example, Basa Njengo Magogo

Appendix A

Appendix A. Ambient Air Quality national standards for criteria pollutants – South Africa compared to WHO (WHO 2005).

Averaging Period	Concentration	Frequency of Exceedance	Compliance Date
National Ambient Air Quality Standards for Sulphur Dioxide SO₂			
24 hours	125 µg/m ³ (48ppb)	4	immediate
1 year	50 µg/m ³ (19ppb)	0	immediate
WHO 2005			
24 hours	20 µg/m ³		
National Ambient Air Quality Standards for Nitrogen Dioxide NO₂			
1 hour	200 µg/m ³ (106ppb)	88	immediate
1 year	40 µg/m ³ (21ppb)	0	immediate
WHO			
National Ambient Air Quality Standards for Particulate matter (PM₁₀)			
24 hours	120 µg/m ³	4	Immediate 31 Dec. 2014
24 hours	75 µg/m ³	4	1 January 2015
1 year	50 µg/m ³	0	Immediate 31 Dec. 2014
1 year	40 µg/m ³	0	1 January 2015
WHO ⁴¹			
24 hour	50 µg/m ³		
1 year	20 µg/m ³		
National Ambient Air Quality Standards for Particulate Matter (PM_{2.5})⁴²			
24 hours	65 µg/m ³	4	Immediate – 31 Dec 2012
24 hours	40 µg/m ³	4	1 Jan. 2016- 31 Dec. 2029
24 hours	25 µg/m ³	4	1 January 2030
1 year	25 µg/m ³	0	Immediate – 31 Dec 2012
1 year	20 µg/m ³	0	1 Jan. 2016- 31 Dec. 2029
1 year	15 µg/m ³	0	1 January 2030
WHO			
24 hour	25 µg/m ³		
1 year	10 µg/m ³		

⁴¹ The new WHO guidelines (World Health Organization, 2005) are documented primarily for the protection of human health. The 10-minute guideline of 500 µg/m³ published in 2000 remains unchanged, but the daily guideline is significantly reduced from 125 µg/m³ to 20 µg/m³ (in line with the precautionary principle). An annual guideline is not deemed necessary, since “compliance with the 24-hour level will assure lower levels for the annual average

⁴² Department of Environment Affairs 2012. NEM: AQA 2004. National Ambient Air Quality Standard for Particulate Matter with Aerodynamic Diameter less than 2.5 micron metres (PM_{2.5}). Government Gazette 29 June 2012 no.35463 pg 7

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