DELWP Economics working paper to inform the Independent Expert Panel on Interim Targets

Summary

Exposure to common air pollutants are associated with a range of health impacts including effects on respiratory and cardiovascular conditions, and premature mortality. This paper summarises the available evidence on the health costs associated with localised outdoor air pollution in Victoria from fossil fuel use in the electricity and transport sectors:

- Air pollution from the electricity sector cost Victoria an estimated $420 to $600 million in the year 2017 ($2018 prices).

- Air pollution from the transport sector cost Victoria an estimated $660 million to $1.5 billion in the year 2005 ($2018 prices).

In addition to estimating the total health cost of air pollution, it is also of value to consider the potential for avoided health costs under potential future GHG emissions abatement actions in Victoria. The future health costs avoided through emissions reductions will depend on the strength and timing of action, and on the specific policies put in place. For example, a study in 2018 estimated the potential for avoided health costs of air pollution from use of zero emissions and autonomous vehicles of up to $735 million in 2046.

Background and purpose

In addition to greenhouse gas (GHG) emissions[1], the combustion of fossil fuels directly emits primary air pollutants which impact on air quality, the environment and human health. Secondary pollutants are also produced from photochemical reactions between some pollutants in the atmosphere, and also impact on human health. For example, ozone (O_3) is formed when volatile organic compounds (VOCs) and nitrous oxides (NO_x) react in sunlight.

Exposure to common air pollutants – such as sulfur dioxide (SO_2), oxides of nitrogen (NO_X), and fine particulate matter with an aerodynamic diameter smaller than 2.5μm and 10μm ($PM_{2.5}$ and PM_{10}) – are associated with a range of health impacts. There is a large body of evidence that shows a clear association between increases in $PM_{2.5}$ exposure and effects on respiratory and cardiovascular conditions, and premature mortality[2]. Exposure to PM_{10}, SO_2, and NO_x has also been found to exacerbate cardiac conditions, asthma and other respiratory symptoms and diseases[3].

Evidence also shows that even at concentrations below the current air quality standards, air pollution is still associated with adverse health effects[4]. For some pollutants (e.g. $PM_{2.5}$ and PM_{10}) there is no established level (threshold[5]) at which there are no observable impacts on human health – i.e. there is no 'safe' level of exposure.

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[1] According to the *Climate Change Act 2017,* greenhouse gas emissions means emissions of carbon dioxide, methane, nitrous oxide or sulphur hexafluoride; or a hydrofluorocarbon or a perfluorocarbon that is specified in regulations made under the *National Greenhouse and Energy Reporting Act 2007* of the Commonwealth.

[2] World Health Organisation (WHO) (2016) *Ambient air pollution: A global assessment of exposure and burden of disease.*

[3] Environment Protection Authority Victoria (2018). *Air Pollution in Victoria – A summary of the state of knowledge.*

[4] Ibid.

[5] A threshold is a level of exposure below which there are assumed to be no associated health effects. Thresholds tend to exist at the individual level, however substantial evidence indicates there is no threshold at the population level. I.e. even at low background concentrations, some vulnerable people are exposed to concentrations that adversely affect health. – Department of Environment and Conservation NSW (2005).

Victoria's most common ambient (or outdoor) pollutants that may also cause localised air pollution include carbon monoxide (CO), SO_2, NO_x, O_3, $PM_{2.5}$ and PM_{10}. Of these, fine particulate matter ($PM_{2.5}$) and ozone are of greatest concern for impacts on human health and the environment. For $PM_{2.5}$ this is due to the pollutant's ongoing presence in ambient air, and the numerous sources which contribute to its presence; for O_3 this is due to the potential for the presence of the pollutant to increase in the future with growing populations and increasing temperatures[6].

Predictions for a drier, hotter climate means Victoria is likely to experience worsening heat waves and harsher bushfire seasons, which together with projected population increases, pose challenges to Victoria's future air quality. Climate change is predicted to impact future air quality by altering the meteorological variables that influence the development, chemical transformation, transport dispersion and deposition of air pollutants[7]. Climate change may also indirectly increase natural sources of PM by increasing fire weather, dust storms and affecting the production and dispersion of aeroallergens such as pollens and moulds[8].

Actions to reduce GHG emissions often reduce co-emitted air pollutants, bringing co-benefits for air quality and human health[9]. This paper summarises the available evidence to estimate the health costs associated with localised air pollution in Victoria, from fossil fuel use in the electricity and transport sectors.

The next section of this paper provides estimates of the total current health cost of air pollution in Victoria in 2018. For the electricity sector, these estimates have been calculated using damage costs from the existing literature, and cover the air pollutants SO_2, NO_x, $PM_{2.5}$ and PM_{10}. The various damage costs have been combined with air pollutant emissions and electricity generation data from the National Pollutant Inventory (NPI) and the Clean Energy Regulator (CER) to calculate the estimated health costs of air pollution. Given the lack of Australian specific damage costs, a number of damage costs from various studies have been considered, and a range of health cost estimates have been produced.

For the transport sector, some studies in the existing literature have calculated the health costs of air pollution in the Australian context, and where necessary these figures have been adjusted to estimate the health costs of air pollution in Victoria or Melbourne.

It is important to note that as ozone is a secondary pollutant, the reduction of NO_x through GHG emissions abatement opportunities will likely influence O_3 generation and may provide further health benefits. Damage costs for ozone are not readily available in the existing literature[10], and so the health costs of ozone are not quantified in this paper. This is a potentially significant gap and means the health cost estimates could be quite conservative.

Estimates of total sector-specific health costs to Victoria

In Victoria, the main sources of air pollution are motor-vehicles, power generating industries, and smoke from bushfires, planned burns and wood heaters[11]. The electricity and transport sectors are the two largest emitters of GHG emissions – respectively contributing 52 per cent and 16.2 per cent shares of total Victorian GHG emissions in 2016[12].

For power generation, health costs mostly fall on local populations – in Victoria this means the health costs associated with the electricity sector are concentrated in the Latrobe Valley region. For transport, health costs are

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[6] World Health Organisation (WHO) (2016).

[7] Ibid.

[8] Dean & Green (2018) *Climate change, air pollution and human health in Sydney, Australia: A review of the literature.* Environmental Research Letters, 13.

[9] West et. al. (2013) *Co-benefits of mitigating global greenhouse gas emissions for future air quality and human health,* Nature Climate Change 3, 885-889 (2013).

[10] It is difficult to quantify these health benefits given the secondary nature of O_3 and the uncertainty of its generation in Victoria.

[11] Environment Protection Authority Victoria (2018).

[12] Victorian Government (2018) *Victorian Greenhouse Gas Emissions Report.*

largely concentrated in urban areas – e.g. the Greater Melbourne region, with greater population density near major roads where pollutant concentrations are higher.

Damage costs

Various studies around the world looking at the health costs of air pollution have adopted models which allow direct valuation based on air pollutant emissions. These 'damage costs' are commonly generated using an impact pathway approach[13], which produce stated costs per tonne of pollutant or per megawatt hour (MWh) of electricity generated.

These costs are derived using monetary valuations of mortality and morbidity impacts. Mortality impacts are based on estimates of how much society is willing to pay to reduce the risk of death – which is known as the 'value of statistical life'. The value of statistical life can be estimated from preferences revealed in markets (for example through wage premiums workers receive for higher risk jobs). Morbidity impacts are based on cost of illness estimates which include direct costs of medical treatment (such as hospital, care and drug expenses) and indirect costs (such as the value of output lost due to health-related absences at work).

Damage costs for specific countries or jurisdictions are generated using location-specific inputs and data (such as emissions modelling, population densities, health risk assessments and health costs). Australia, however, currently lacks the required sufficient, readily available data to undertake a full impact pathway process and generate location-specific damage costs. Therefore, it is commonplace in Australian studies to use damage costs derived from overseas locations and adjust these for the Australian context[14].

The lack of Australian produced damage costs reduces the level of confidence we can have in the estimates of the health costs of air pollution for Victoria. It is important to note how integral the health assumptions adopted in these calculations are, and the magnitude of change that different assumptions can make. Therefore, where possible a range of estimates are reported in this paper to reflect the uncertainty of these calculations.

Electricity sector

Based on a review of the existing literature, damage cost values for the electricity sector have been adapted from other jurisdictions for the Australian context. The various damage costs sourced for each pollutant are presented in Appendix A (Table A-1).

Combining the various damage costs with air pollutant emissions and electricity generation data from the National Pollutant Inventory (NPI) and the Clean Energy Regulator (CER), gives estimated health costs of air pollution coming from the electricity sector in Victoria in the order of $600 million (AUD$2018) for the year 2018.

The range of estimates using differing damage costs are presented in Table 1. See Appendix A for a breakdown of these total cost calculations.

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[13] An impact pathway approach is a systematic method for identifying and tracing the effects of air pollution, from changes in emissions through to impacts on outcomes that society values.

[14] PAE Holmes (2013) *Methodology for valuing the health impacts of changes in particle emissions – Final report* – prepared for NSW Environment Protection Authority.

Table 1 Total health costs of electricity sector in Victoria

Source	Year of report	Year of data	Origin of damage cost	Unit (tonnes/MWh)	Pollutants covered [#]	Total health cost (AUD$2018) [*]
Parry et al.[15]	2014	NPI 2016/17 Includes Hazelwood	International	$/tonnes	SO_2, NO_X, $PM_{2.5}$	$422 million
Parry et al. and PAE Holmes (NSW EPA)[16]	2013	NPI 2016/17 Includes Hazelwood	International UK	$/tonnes	SO_2, NO_X, $PM_{2.5}$	$421 million
ATSE[17]	2009	National Electricity Market (NEM) Review 2017/18 Excludes Hazelwood	Europe	$/MWh	SO_2, NO_X, PM_{10}	$587 million
Ward & Power[18]	2015	NEM Review 2017/18 Excludes Hazelwood	US	$/MWh	SO_2^, NO_X, PM_{10}, $PM_{2.5}$	$592 million

[#] As noted by WHO (2014), when estimating the impacts of both PM2.5 and NOx some double counting may occur (likely overlap can be up to 33 per cent) [19]

[*]The total health cost figures here have been derived by applying the damage costs per pollutant from each source to Victoria's generation data. The damage costs applied take into account populations exposed to electricity sector emissions in Victoria or Australia, depending on the study.

^This study draws on US data and acknowledges the differences between US and Australian power stations and emissions intensities – see discussion on Ward & Power (2015) below.

Of the figures presented above, the calculation we have most confidence in comes from using the damage costs presented by Ward & Power (2015). This was the most recent study undertaken, and the study presents damage costs per MWh for each of the (then) four brown coal fired power stations in Victoria (presented in Table 2), which included four of the most concerning pollutants, as discussed earlier.

The total health cost of $592 million presented in Table 1 has been calculated using the most recent generation data for 2017/18[20], and therefore does not include air pollutants from Hazelwood, as it was retired in March 2017.

[15] Parry et al. (2014) *Getting energy prices right: From principle to practice*. International Monetary Fund.

[16] Parry et al. (2014); PAE Holmes (2013).

[17] Australian Academy of Technological Sciences and Engineering (ATSE) (2009). *The hidden costs of electricity: Externalities of power generation in Australia*.

[18] Ward & Power (2015). *Cleaning up Victoria's power sector: The full social cost of Hazelwood power station*. Harvard Kennedy School of Government.

[19] World Health Organisation (2014) *WHO Expert Meeting: Methods and tools for assessing the health risks of air pollution at local, national and international level*, Meeting report, Bonn, Germany, 12-13 May 2014.

[20] NEM Review, Metered generation (As generated), extracted 3 July 2018.

Table 2 Ward & Power total damage cost/MWh for Victorian power stations

Power station	Damage cost ($2018)/MWh
Hazelwood	8.44
Loy Yang A	18.85
Loy Yang B	16.86
Yallourn	11.92

Ward & Power (2015) used modelling that was undertaken for the US National Academy of Science (NAS) in 2010[21] and adapted it to an Australian context. It should be noted that the Ward & Power study includes damage costs for both $PM_{2.5}$ and PM_{10}, taken from the NAS (2010) study. Noting $PM_{2.5}$ is a subset of PM_{10}, the NAS (2010) study explicitly avoids double counting of damages due to $PM_{2.5}$ and PM_{10}[22].

The NAS (2010) study undertook modelling for 406 black coal-fired power stations across the US. To determine those comparable to Victorian power stations (specifically, Hazelwood), Ward & Power (2015) looked at two major determinants of local impact for coal-fired power stations – stack height and local population density. Ward & Power (2015) also recognised that Hazelwood's pollutant emission intensity (excluding CO_2 and NO_x) was, on a per MWh basis, relatively low compared with US power stations, particularly for SO_2 (which accounts for a vast majority of air pollution costs in the US). This is reflected in the central estimates of damage costs chosen by Ward & Power (2015) to be applied to the Victorian context[23]. The central estimates presented in Table 2 are relatively low compared to the median damage cost for US power stations, which was estimated to be $35.86/MWh.

Ward & Power (2015) made assumptions that dose-response[24] and valuation aspects of the NAS (2010) model are applicable to the Australian context, stating there would unlikely be significant differences in health impacts between the US and Australia; and that health effects would have similar valuations with similar per capita incomes and consumer behaviours.

Ward & Power (2015) note that their air pollution cost estimates are rough, and that incomplete data on background air pollutant concentration rates or health complications in Gippsland, means their health impact cost estimates are uncertain. They also note that the NAS model only looks at four pollutants, and other pollutants (such as mercury, lead, arsenic, VOCs) which are also significant public health hazards are not accounted for, and therefore means they are likely to have underestimated the true cost of air pollution.

Transport sector

The key air pollutants of concern coming from transport are $PM_{2.5}$, NO_X and SO_2, as well as particles of PM_{10} (which are generally present as road dust)[25]. Diesel engine emissions are particularly a concern for public health as they

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[21] National Academy of Sciences (NAS) (2010) *Hidden costs of energy: Unpriced consequences of energy production and use*.

[22] The study estimates mortality impacts associated with emissions of $PM_{2.5}$, and the chronic morbidity impacts of PM_{10}. In reporting the morbidity damages due to emissions of PM_{10}, the study nets out the mortality damages due to $PM_{2.5}$. In effect the damages for PM_{10} are expressed as PM_{10}-$PM_{2.5}$ - Refer to NAS (2010), Appendix C Page 428.

[23] The stack height of the Hazelwood power plant was close to the median of US plants. The population density of the Gippsland region is estimated at 6.2 persons per square kilometre (around the 14th percentile of population densities around US plants). Hazelwood's emissions intensity for SO_2 and $PM_{2.5}$ was around the 20th percentile of US power plants, for PM_{10} around the 40th percentile, and for NO_x around the 60th percentile.

[24] The dose-response describes the change in effect caused by differing levels of exposure (doses) to a pollutant.

[25] Victorian Environment Protection Authority (2018).

contain larger quantities of $PM_{2.5}$ and consequently have been classified by the World Health Organisation as carcinogenic[26]. Total estimated health costs of air pollution from the transport sector are summarised in Table 3.

An independent review was undertaken in 2016 by Marsden Jacobs and Pacific Environment Limited (PEL) for the Australian Government Department of the Environment of the *Fuel Quality Standards Act 2000*[27]. In assessing the benefits that have been realised since the introduction of the standards, the review estimated health costs from motor vehicles in Melbourne in 2015 to be approximately $730 million (in 2018 prices). This is the only study from our literature review which has attempted to estimate total health costs from motor-vehicle use relevant to Victoria.

Another study undertaken by the Bureau of Transport and Regional Economics (BTRE) in 2005[28] looked at the economic cost of health impacts of transport emissions in Australia. This study used PM_{10} as a 'surrogate pollutant', aiming to capture the effects of all other pollutants. This study estimated the combined national cost of motor vehicle-related mortality and morbidity was between $1.6 billion and $3.8 billion (central estimate $2.7 billion) in 2000. Currently, Victoria has approximately 26 per cent of Australia's car fleet[29]. Adjusting the national BTRE (2005) estimate for 2018 prices and proportioning the value in line with the number of Victorian vehicles, provides an estimated range of between $660 million and $1.5 billion (central estimate $1.1 billion). This is a simplified approach providing an indicative estimate only, as it ignores other relevant factors such as road use, density, improved vehicle emission standards and population growth.

The BTRE (2005) study also estimated health costs of motor-vehicle related air pollution in Australian capital cities. For Melbourne, these estimates were between $615 million and $1.4 billion (central estimate $1 billion) in 2018 prices, producing a similar range to the calculated Victorian proportion of the Australian wide damage costs reported in the study.

Table 3 Total health costs of transport sector (AUD$2018)

Source	Year of report	Pollutants covered	Scope	Total health cost
Marsden Jacobs & PEL	2016	SO2, NOx, $PM_{2.5}$ CO, VOCS	Melbourne	$730 million
BTRE	2005	PM_{10}	Victoria	$660 million - $1.5 billion
BTRE	2005	PM_{10}	Melbourne	$615 million - $1.4 billion

Potential for avoided health costs

It is well established that many abatement measures that reduce greenhouse gas emissions will also reduce air pollutants, such as SO_2, NO_x, $PM_{2.5}$ and PM_{10}. For example, a recent study from the United States found that regulations targeting power stations and vehicles were effective in reducing both GHG emissions and local air pollutants[30]. It is also well established that measures that reduce both greenhouse gas emissions and air pollutants can generate significant health benefits. For example, the IPCC Special Report on 1.5°C notes that for all the global greenhouse gas emissions reduction pathways it modelled to limit warming to 1.5°C above pre-industrial levels, the improved air quality resulting from projected reductions in many air pollutants would provide direct and

[26] World Health Organisation (2012) *Diesel engine exhaust carcinogenic, International Agency for Research on Cancer (IARC)*, Press Release No. 213.

[27] Marsden Jacob & Pacific Environment Limited (2016) Review of the *Fuel Quality Standards Act 2000* – Prepared for the Australian Government Department of the Environment.

[28] Bureau of Transport and Regional Economics (2005). *Health impacts of transport emissions in Australia: Economic costs*.

[29] Australian Bureau of Statistics (2018) 9309.0 - Motor Vehicle Census, Australia, 31 Jan 2018.

[30] Health Effects Institute (2018). *Impacts of regulations on air quality and emergency department visits in the Atlanta metropolitan area, 1999-2013*.

immediate population health benefits[31]; and the World Health Organisation's COP24 Special Report on Health and Climate Change finds that achieving the Paris Agreement to limit global warming to well below 2°C above pre-industrial levels could save about one million lives worldwide every year by 2050 through reductions in air pollution alone[32].

It follows that as Victoria's GHG emissions in the electricity generation and transport sectors are reduced, we can expect to see large reductions in ambient (or outdoor) pollutants that may also cause localised air pollution, and significant health benefits as a result. Therefore, in addition to estimating the total current health cost of air pollutants, it is also of value to consider the potential for avoided health costs under potential future GHG emissions abatement actions in Victoria.

As an example, a recent study undertaken by Aurecon for Infrastructure Victoria[33] provided advice on the population health and environmental impacts of Zero Emissions Vehicles (ZEV) and Autonomous Vehicles (AV) in Victoria over the next 30 years. The report found that a fleet comprised of ZEVs and AVs can be expected to substantially reduce adverse health impacts from exposure to harmful pollutants. Relative to a business as usual scenario in which petrol and diesel vehicles still make up the majority of the fleet in 2046, Aurecon estimated potential health benefits for different 'fleet transformation' scenarios to particular technologies, driving modes, ownership models, and occupancy models. These estimated potential health benefits ranged between $270 million and $735 million (2018 prices) in 2046.

The Aurecon study notes a few limitations. The study relies heavily on transport modelling of vehicle activity in the selected scenarios, but no verification of the transport modelling was undertaken. The scenarios explored are not necessarily forecasts of the likely Victorian fleet in 2046 – they are hypothetical outcomes for fleet transformation to ZEVs and AVs in Victoria. Additionally, the estimates in this study were based on there being no threshold for the impacts of exposure to NO_x. There is a lot of uncertainty regarding this assumption, and it may mean the health impacts are either under estimated or overstated.

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[31] Intergovernmental Panel on Climate Change (IPCC) (2018), Global Warming of 1.5C: An IPCC Special Report on the impacts of global warming of 1.5C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty, Summary for Policymakers, October 2018, https://www.ipcc.ch/sr15/.

[32] World Health Organisation (2018), COP24 Special Report Health and Climate Change, https://apps.who.int/iris/bitstream/handle/10665/276405/9789241514972-eng.pdf.

[33] Aurecon (2018). *AV/ZEV Environmental & Health Impact Assessment – Final report* – Prepared for Infrastructure Victoria.

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World Health Organisation (2012) *Diesel engine exhaust carcinogenic, International Agency for Research on Cancer (IARC)*, Press Release No. 213.

World Health Organisation (2014) *WHO Expert Meeting: Methods and tools for assessing the health risks of air pollution at local, national and international level,* Meeting report, Bonn, Germany, 12-13 May 2014.

World Health Organisation (2016) *Ambient air pollution: A global assessment of exposure and burden of disease.*

Appendix A

Calculated total health costs for the electricity sector in Victoria

The damage costs of air pollutants from various independent studies are presented in Table A-1. These values are reported in either dollar per tonne of emissions, or per megawatt hour (MWh) of power station generation.

Table A-1 Damage costs ($2018)

Source	Scope	Sector	SO_2	NO_x	PM_{10}	$PM_{2.5}$	Total
			$/ tonne pollutant				
Parry et al.	Australia	Coal	2,696	1,451	N/A	3,382	N/A
		Transport	11,848	2,407		305,977	
PAE Holmes	Melbourne	Transport	N/A	N/A	N/A	216,332	N/A
	Traralgon-Morwell	Transport				53,514	
	Moe-Newborough	Transport				50,098	
			$/ MWh electricity generation				
ATSE	Australia	Energy	9.36	5.17	1.72	N/A	16.26
Ward & Power	Hazelwood	Coal-fired power	5.11	2.88	0.09	0.35	8.44
	Loy Yang A						18.85
	Loy Yang B		N/A	N/A	N/A	N/A	16.86
	Yallourn						11.92

To calculate total health costs for the electricity sector in Victoria, the various damage costs (Table A-1) per tonne of pollutant were applied to emissions data from the National Pollutant Inventory, and the various damage costs per MWh were applied to electricity generation data from the Clean Energy Regulator (for 2016/17 generation) and from the National Electricity Market (NEM) Review (for 2017/18 generation).

The various calculated total health costs for the electricity sector in Victoria from differing damage costs are presented below in Table A-2 – A-7.

Total health costs utilising damage costs per tonne pollutant and 2016/17 NPI emissions data

Table A-2 presents the total health costs for the electricity sector when applying the damage costs from the Parry et al. (2014) study. This study estimated damage costs per tonne of pollutant for SO_2, NO_x and $PM_{2.5}$. It is important to note that this study suggested much lower damage costs for pollutants coming from coal use, than for other emissions at ground-level (i.e. motor vehicles), and that these damage cost values are an Australian national average.

Table A-2 Total health costs from brown coal fired power stations, Victoria (AUD$2018) – Parry et al. damage costs

Pollutant	Hazelwood	Yallourn	Loy Yang A	Loy Yang B	Total
SO2	45,577,593	56,984,798	139,498,979	61,454,934	303,516,304
NOX	36,191,633	22,164,745	30,971,449	20,407,757	109,735,584
PM10	N/A	N/A	N/A	N/A	N/A
PM2.5	2,989,984	2,732,927	742,839	2,100,430	8,566,180
Total	84,759,210	81,882,470	171,213,267	83,963,121	**421,818,068**

Table A-3 again uses the damage costs reported in Parry et al. (2014) for the pollutants SO_2 and NO_x and applies these values to the NPI 2016/17 emissions data. However, for $PM_{2.5}$ pollutants, the damage cost reported in a PAE Holmes (2013) study prepared for the NSW EPA have been applied. The damage costs for $PM_{2.5}$ that are reported in the PAE Holmes study are based on ABS Statistical Urban Areas (SUAs), and so the values utilised in Table A-3 are more specific to the population densities of Traralgon-Morwell and Moe-Newborough, where Victoria's coal-fired power stations are located. It should be noted that the damage costs used in the PAE Holmes study were adjusted from UK data which related to transport. The UK study notes that power plants' emissions have lower damage costs compared to transport, due to the high stack heights. The study estimates this difference results in damage costs equivalent to approximately 5 per cent of the cost per tonne of $PM_{2.5}$ related to transport. Therefore, the figures in Table A-3 for $PM_{2.5}$ have been adjusted to take this into account.

Table A-3 Total health costs from brown coal fired power stations, Victoria (AUD$2018) – Parry et al. & PAE Holmes damage costs

Pollutant	Hazelwood	Yallourn	Loy Yang A	Loy Yang B	Total
SO2 (Parry)	45,577,593	56,984,798	139,498,979	61,454,934	303,516,304
NOX (Parry)	36,191,633	22,164,745	30,971,449	20,407,757	109,735,584
PM10 (Parry)	N/A	N/A	N/A	N/A	N/A
PM2.5 (PAE Holmes)	2,365,303	2,023,954	1,369,949	1,661,599	7,420,805
Total	129,075,284	119,628,627	197,869,412	115,094,662	**420,672,693**

Total health costs utilising damage costs per MWh and 2016/17 CER electricity generation data

Table A-4 presents the total health costs for the electricity sector when applying the damage costs from the ATSE (2009) report. This study covered damage costs for SO_2, NO_x and PM_{10} pollutants, and the damage cost values are an Australian national average which have been adjusted from European damage cost estimates.

Table A-4 Total health costs from brown coal fired power stations, Victoria (AUD$2018) - ATSE

Pollutant	Hazelwood	Yallourn	Loy Yang A	Loy Yang B	Total
SO_2	72,096,882	107,429,298	148,733,620	80,261,850	408,521,650
NO_X	39,843,014	59,368,823	82,194,895	44,355,233	225,761,965
PM_{10}	13,281,005	19,789,608	27,398,298	14,785,078	**75,253,988**
$PM_{2.5}$	N/A	N/A	N/A	N/A	N/A
Total	125,220,900	186,587,728	258,326,814	139,402,160	**709,537,603**

Table A-5 presents total health costs for the electricity sector when applying damage cost values per MWh from the Ward & Power (2015) study. This study included damage costs for SO_2, NO_x, PM_{10} and $PM_{2.5}$ for Hazelwood power station, and total overall damage costs per MWh for the Yallourn, Loy Yang A and Loy Yang B power stations. As discussed in this paper, these damage costs have been taken from a US study and adapted to the Australian context.

Table A-5 Total health costs from brown coal fired power stations, Victoria (AUD$2018) – Ward & Power

Pollutant	Hazelwood	Yallourn	Loy Yang A	Loy Yang B	Total
SO_2	39,384,086				
NO_X	22,189,371				
PM_{10}	655,037				
$PM_{2.5}$	2,702,027				
Total	64,930,521	136,768,967	299,486,397	144,567,797	**645,753,682**

Total health costs utilising damage costs per MWh and 2017/18 NEM-Review electricity generation data (post Hazelwood closure)

Tables A-6 and A-7 present the total health costs for the electricity sector utilising the same damage costs as were used in Table A-4 (ATSE) and Table A-5 (Ward & Power). However, here these damage costs have been applied to more recent generation data for 2017/18 from the NEM-Review. These total costs are lower than the 2016/17 figures, as Hazelwood power station closed in March 2017 reducing generation capacity from Victorian coal-fired power stations by approximately 17 per cent.

Table A-6 Total health costs from brown coal fired power stations, Victoria (AUD$2018) - ATSE

Pollutant	Yallourn	Loy Yang A	Loy Yang B	Total
SO$_2$	95,858,180	158,140,717	84,051,463	338,050,361
NO$_X$	52,974,257	87,393,554	46,449,493	186,817,305
PM$_{10}$	17,658,086	29,131,185	15,483,164	62,272,435
PM$_{2.5}$	N/A	N/A	N/A	N/A
Total	166,490,523	274,665,456	145,984,121	**587,140,100**

Table A-7 Total health costs from brown coal fired power stations, Victoria (AUD$2018) – Ward & Power

	Yallourn	Loy Yang A	Loy Yang B	Total
Total	122,037,698	318,428,298	151,393,657	**591,859,653**