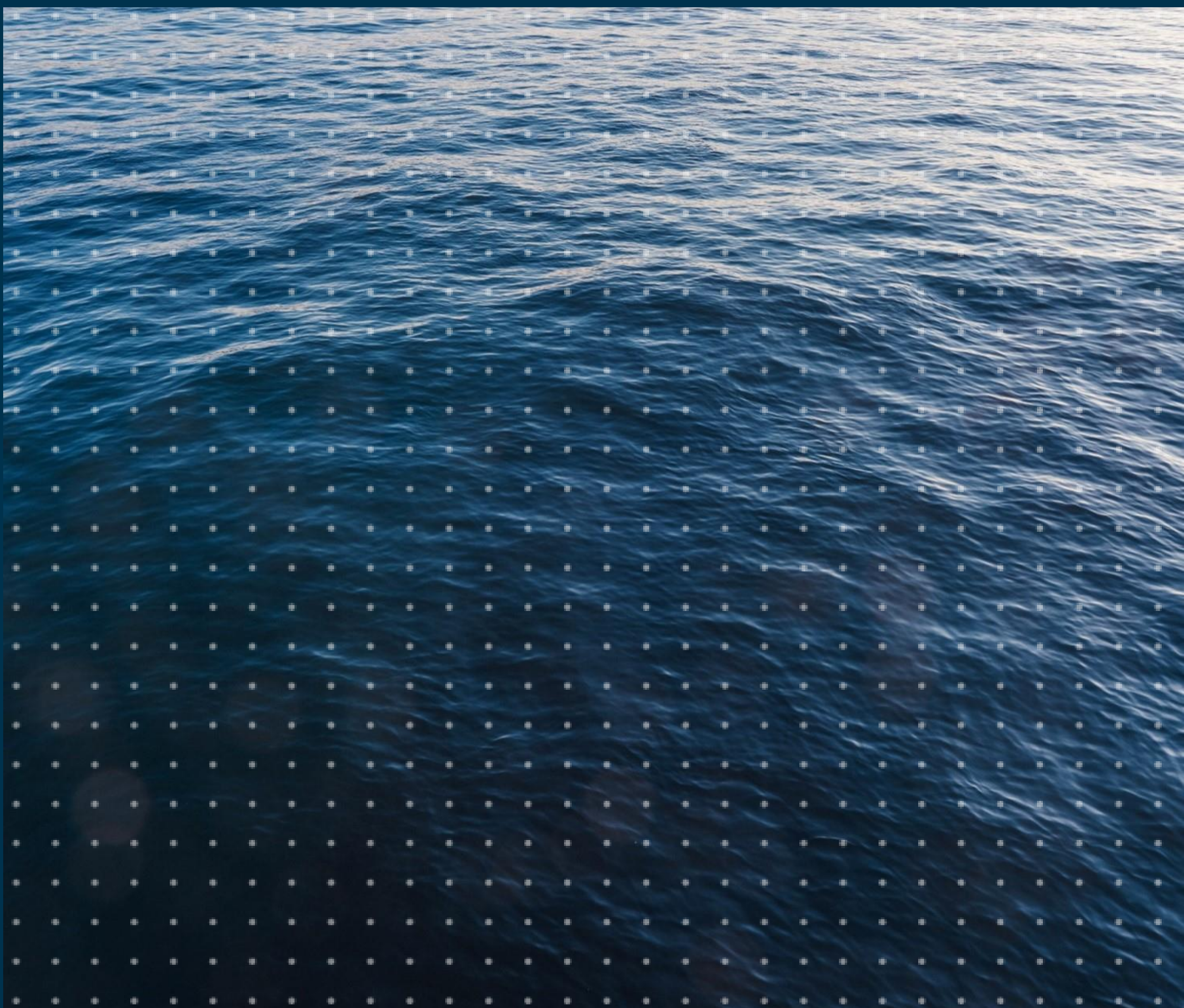
Environment Protection Authority

Regulatory Impact Statement

Proposed Clean Air Regulation 2022



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Executive summary

This document is a Consultation Regulatory Impact Statement (RIS) for the proposed Protection of the Environment Operations (Clean Air) Regulation 2022 (the proposed Regulation), prepared in accordance with the *Subordinate Legislation Act 1989*.

The proposed Regulation continues and improves support of the objectives and implementation of the *Protection of the Environment Operations Act 1997* (POEO Act). It would replace the current Protection of the Environment Operations (Clean Air) Regulation 2021 (the existing Regulation).

While clean air is fundamental to all people's health, air pollution particularly affects the health of children and older people. It also affects the natural environment and the liveability of communities.

The management of air quality in NSW uses an integrated whole-of-government framework that includes regulatory and non-regulatory measures. The goals of the framework are to:

- improve regional and local air quality by meeting the air quality standards set out in the National Environment Protection (Ambient Air Quality) Measure (Air NEPM)
- reduce the population's exposure to air pollution.

The existing Regulation is the key regulatory mechanism in NSW for reducing emissions of harmful pollutants to the air. The Regulation provides regulatory measures for a number of disparate air quality issues. For example:

- residential emissions are controlled by targeting wood smoke and backyard burning
- motor vehicle emissions are addressed through pollution control devices on cars and measures addressing evaporative fuel emissions
- industrial emissions are controlled mainly by setting maximum emission concentration limits.

Emissions

The six key air pollutants for which standards are set are:

- carbon monoxide (CO)
- nitrogen dioxide (NO_2)
- sulfur dioxide (SO_2)
- lead
- photochemical oxidants (ozone, O_3)
- particles – specifically PM_{10} (particles smaller than 10 micrometres (µm) in diameter) and $PM_{2.5}$ (particles smaller than 2.5 µm in diameter).

Table ES1 provides a summary of the most common pollutants targeted by the regulatory measures and concerns associated with exposure to these pollutants. Table 2 and Appendix B discuss in detail the health and environmental impacts of air pollutants.

Recommendation

Given the considerable net quantifiable public benefits and the extensive unquantifiable benefits, it is proposed that the provisions of Parts 2 and 3 of the existing Regulation be carried forward and that the proposed amendments to Parts 4, 5 and 6 of the existing Regulation be adopted.

Table ES1 Common pollutants dealt with under the Clean Air Regulation[1].

Definition of pollutant	Source of pollutant	Controls	Health impacts
Particulate matter is liquid or solid particles suspended in the air. It can be a primary pollutant (from emissions) or a secondary pollutant (resulting from atmospheric reactions on primary pollutants). PM_{10} includes all particulates that are 10 μm or less in diameter. $PM_{2.5}$ includes particulates that are 2.5 μm or less in diameter.	Particles come from both natural and human sources and are generally visible as brown haze. They include acids, organic chemicals, metals, soil or dust, and allergens. Human sources of particles include combustion and mechanical processes, such as motor vehicles, wood heaters, power stations and industrial processes.	Parts 2, 3, 4 and 5 of the existing and proposed Regulation	The health effects of particle exposure include increased mortality rates, cardiopulmonary disease and reduced lung function. Particles also impact on visual amenity and can damage buildings and crops and other vegetation.
Oxides of nitrogen (NO_x) are a group of highly reactive gases, including nitric oxide (NO) and nitrogen dioxide (NO_2), which generally are produced by combustion processes.	Electricity generation is a major source of NO_x in the NSW Greater Metropolitan Region (GMR[2]). Motor vehicles (petrol, diesel and off-road) are another major source.	Parts 4 and 5 of the existing and proposed Regulation	NO_x can irritate the eyes, nose, throat and lungs, leading to coughing, shortness of breath, tiredness and nausea. Longer-term exposure can destroy lung tissue, leading to chronic inflammatory lung disease. Asthmatics and children are particularly susceptible. Excessive levels of NO_x can reduce plant growth and result in the death of plants, as well as have harmful effects on a variety of biological systems.

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1 A number of other pollutants are also controlled by the Regulation. Scheduled industry must comply with emission limits for sulfur oxides, hydrogen sulfide, fluorine, chlorine, hydrogen chloride, cadmium, dioxins, furans and toxic metals. Sulfur dioxide is also controlled through limits on the sulfur content of fuel. Emissions of a range of air toxics are also controlled through requirements relating to wood heaters, backyard burning, industrial pollution control technology and anti-pollution devices in motor vehicles. The health benefits of these avoided emissions are not quantified to avoid double-counting, as many health impacts are similar and not necessarily cumulative. As with the pollutants described above, there are also unquantified benefits for ecosystem health.

2 Greater Metropolitan Region (GMR) is used throughout this report, in place of Greater Metropolitan Area (GMA), which appears in the Regulation, because the modelling has been undertaken from a GMR perspective. The GMR results are deemed to be representative of the GMA.

Definition of pollutant	Source of pollutant	Controls	Health impacts
Volatile organic compounds (VOCs) are a broad grouping of carbon-based compounds that vaporise at normal temperatures. VOCs as a group are significant as a precursor to the formation of ground-level ozone. Some VOCs are also known air toxics.	Exhaust and evaporative emissions of petrol from vehicles account for the largest proportion of VOCs emissions. Other sources include surface coatings (paint), aerosols and solvents.	Evaporative emissions in Parts 4 and 6 of the existing Regulation and Parts 4, 6, 7 and 8 of the proposed Regulation. Other emissions (controlling combustion) in Parts 2, 3 and 5 of the existing and proposed Regulation.	General effects of exposure to VOCs include irritation to the eyes, nose and throat; headaches; loss of coordination; nausea; and damage to the liver, kidneys and central nervous system. Some VOCs are also known or suspected to cause cancer in humans.
Ozone is a relatively insoluble gas, composed of three oxygen atoms, with a characteristic sharp odour. It is present both in the stratosphere high above the Earth's surface (where it has a beneficial effect in filtering out ultraviolet light) and at ground level (principally as a pollutant).	Ground-level ozone is created by the chemical reaction between NO_x and VOCs. Motor vehicle use is the main human source of NO_x in Sydney and a major source of VOCs. Coal-fired power stations are a major source of NO_x emissions. Global warming is projected to exacerbate ground-level ozone formation in Sydney.	Ozone is a secondary pollutant, so it is controlled by regulating its precursor pollutants: NO_x and VOCs	Ozone can be highly irritating for those who inhale it. Increases in levels of ozone are associated with a rise in hospitalisation for respiratory diseases and mortality. Repeated exposure to ozone can make people more susceptible to respiratory infection and aggravate pre-existing respiratory diseases, such as asthma.

Summary of the Regulation and proposed significant changes

Table ES2 outlines the key Parts of the Clean Air Regulation and whether significant changes are proposed to these Parts.

Table ES2 Summary of the Clean Air Regulation and significant proposed changes.

Reason for regulatory measures	Any proposed significant change	Benefits identified	Recommendation
Domestic solid fuel heaters: Part 2 of the existing and proposed Regulation (see Section 2)			
Solid fuel heaters generate particulate pollution, which can cause significant health impacts, mainly in winter. Exposure to fine particulates is associated with a range of health issues, particularly respiratory and cardiovascular illnesses. It is also associated with increased mortality and hospital admissions among people with heart and lung disease. In Sydney, more particle pollution is caused by wood smoke during winter than any other source. Wood smoke in Sydney contributes a significant proportion of PM_{10} and $PM_{2.5}$ (very fine particles) from human sources.	No change was proposed, as this Part of the Clean Air Regulation was amended in 2016 to mandate new emission and efficiency standards for wood heaters. Options considered were: • Option 1 – maintain the existing Regulation • Option 2 – repeal the existing Regulation.	Avoided $PM_{2.5}$ emissions as a result of retaining the current Regulation has a net economic benefit of approximately $413 million (in present value terms) over the analysis period. These economic gains illustrate the importance to human health of reducing $PM_{2.5}$ emissions. The benefits of lower emissions are especially important for $PM_{2.5}$, as the damage costs of $PM_{2.5}$ (on a $/tonne basis) are very high relative to the costs of other pollutants. Additional benefits include improved visibility, less offensive odours, healthier vegetation and improved condition of the built and natural environment in general.	Maintaining the status quo (Option 1) was found to deliver a material net public benefit. Under this option the substantial cumulative reductions that have already been achieved will be sustained and emissions will continue to fall as old heaters are replaced.
Control of burning: Part 3 of the existing and proposed Regulation (see Section 3)			
Before the introduction of regulatory controls on open burning regulation, the burning of waste, wood and vegetation in backyards and	No change was proposed as this Part of the Clean Air Regulation was amended in 2021 to reflect changes to council boundaries that have resulted	Maintaining the existing Regulation (Option 1), will result in a net economic benefit to the NSW GMR of about $0.36 million, due to the	Maintaining the existing Regulation (Option 1) would deliver net benefits to the NSW economy, arising from

Reason for regulatory measures	Any proposed significant change	Benefits identified	Recommendation
incinerators, referred to as 'backyard burning', was once a widespread practice in the NSW GMR. Backyard burning resulted in emissions of particulates, VOCs, metals, polycyclic aromatic hydrocarbons (PAHs) and dioxins. The introduction of controls on backyard burning has resulted in significant reductions in these emissions in the NSW GMR.	from the recent amalgamation of some councils under NSW local government reform. The options assessed for this part of the Regulation are: • Option 1 – maintain the existing Regulation • Option 2 – repeal the existing Regulation.	avoided health impacts ($2.55 million) that outweigh the total costs to residents and government ($2.19 million). The quantifiable benefits result from lower particulate matter emissions.	avoided health costs due to reduced levels of fine particulates.
Motor vehicles and motor vehicle fuels: Part 4 of the existing Regulation and Parts 4 and 8 of the proposed Regulation (see Section 4)			
Managing air emissions from motor vehicles and fuels remains a challenge in the NSW GMR. Emissions from motor vehicles are estimated to make up 53% of emissions of NO_x, 9% of emissions of PM_{10} and 10% of emissions of VOCs in Sydney. Each year, the number of kilometres travelled by passenger vehicles is increasing by approximately 1.0–1.5%, and freight travel is increasing by approximately 2–3%. Motor vehicle use is also a significant emission source of ozone precursors: NO_x and VOCs.	A proposed change to the Regulation would extend the low summer volatility limits in the NSW GMR by adjusting the dates during which those apply to correspond with the peak ozone formation period. Analysis of historic ambient air quality data shows that average ozone is increasing and exceedances are occurring prior to commencement of the current summer petrol volatility season. The options considered were: • Option 1 – maintain the existing Regulation (definition of summer is 15 November to 15 March) • Option 2 – repeal the existing Regulation • Option 3 – introduce new Regulation (amends the definition of summer to 1 November to 31 March).	Changing the definition of summer and increasing the summer volatility limits by 30 days (Option 3) would provide benefits of $20.8 million. Removing the Regulation (Option 2) will incur sizeable economic costs of $126.2 million. Total emission reductions are about 368 t/year under Option 3 (relative to Option 1), increasing to 397 t in 2040–41. The estimated value of benefits from reductions in VOC emissions under Option 3 is $26.3 million. The removal of the Regulation (Option 2) results in the loss of benefits derived from reduced emissions. In relation to the proposed exclusion of heavy vehicles over 4.5 t, the analysis found that this proposal will result in no change to the	The extension of the period defined as summer (Option 3) results in the highest net present value and benefit:cost ratio, while repealing the existing Regulation (Option 2) results in undesirable health costs. Given the closure of refineries in NSW, the portion of petrol that is domestically produced fuel is predominantly supplied by Victorian refineries. However, most petrol consumed in the NSW GMR is imported from overseas. Although the provisions excluding heavy vehicles from the requirements relating to smoky vehicles and the installation and maintenance of anti-pollution devices result in a small loss (compared with retaining the Regulation) the proposed exclusion removes regulatory duplication, as heavy vehicles are already regulated under the Heavy Vehicle (Vehicle

Reason for regulatory measures	Any proposed significant change	Benefits identified	Recommendation
	There is a proposed exclusion of heavy vehicles over 4.5 tonnes (t) from requirements relating to smoky vehicles and anti-pollution devices. This exclusion is to avoid duplication, as heavy vehicles are already regulated under the Heavy Vehicle (Vehicle Standards) National Regulation 2013, which is administered in NSW by Transport for NSW.	requirements and will be cost neutral to users and operators of heavy vehicles. However, benefits are expected due to avoided duplication of requirements and associated costs of administration.	Standards) National Regulation 2013 and by Transport for NSW.
Air impurities emitted from activities and plant: Part 5 of the existing and proposed Regulation (see Section 5)			
Emissions from activities (including industrial, agricultural or commercial activities) and plant (referred to as 'industrial emissions') are a significant source of emissions in NSW that impact local and regional air quality. These emissions are associated with significant health and environmental effects (see Appendix B). Emissions standards for industrial air pollutants have been progressively tightened over recent decades, resulting in significant improvements in air quality in NSW. The principal regulatory instrument is the POEO Act, supported by the Clean Air Regulation, which sets maximum emission standards, and the Protection of the Environment Operations (General) Regulation	The proposed Regulation will require that, from 1 July 2025, activities and plant on scheduled premises that belong to Groups 3 and 4 (those that commenced operation between 1 July 1979 and 31 July 1997) must comply with the more stringent air emission standards of Group 5 (those that commenced operation between 1 August 1997 and 31 August 2005) and, from 1 July 2030, with air emission standards of Group 6 (those that commenced operation on or after 1 September 2005). The proposal to transition Groups 3 and 4 is seen as the logical and appropriate next step that follows moving Groups 1 and 2 premises (those that commenced operation before 1 July 1979) to Group 5 by 1 January 2012.	The proposal to transition Group 3 and 4 premises to Group 5 and then to Group 6 (Option 3) would provide large net benefits of $665.6 million for NSW as a whole over the period analysed. The major benefits from the proposed changes to Part 5 of the Regulation relate to health improvements arising from reduced particulates ($PM_{2.5}$) and oxides of nitrogen (NO_x). Due to much higher population densities, the benefits and costs would be more significant in the GMR than elsewhere in NSW.	The proposed Regulation (Option 3) is strongly preferred to the other options, including continuing with the status quo (Option 1). Although there are significant costs to industry, the benefits from avoided health impacts more than offset those costs. While it is clear that benefits will accrue to society, industry may pass on the costs to consumers, in which case beneficiaries effectively will be paying for the reform costs. Where costs cannot be passed on to consumers (due to competitive pressures), industry will bear the costs.

Reason for regulatory measures	Any proposed significant change	Benefits identified	Recommendation
2021, which sets total pollutant load limits.	The three options considered were: • Option 1 – maintain the existing Regulation • Option 2 – repeal the existing Regulation • Option 3 – new Regulation (plant and activities on scheduled premises currently classified in Groups 3 and 4 of the Regulation will be moved to Group 5 of the Regulation by 1 July 2025 and to Group 6 by 1 July 2030). Current provisions for non-scheduled premises will be retained.		
Control of volatile organic liquids: Part 6 of the existing Regulation and Parts 6, 7 and 8 of the proposed Regulation (see Section 6)			
Volatile organic liquids (VOLs) evaporate in ambient conditions. Production, consumption, storage or transport of VOLs can result in vapours being released into the atmosphere as volatile organic compounds (VOCs). Vapour emissions from VOLs are a significant source of precursors for formation of ground-level ozone and secondary organic aerosols, which are associated with adverse impacts on public health and the environment.	It is proposed in the new Regulation to: • introduce more stringent VOC emission limits and control equipment requirements, reflective of available control technology and practice for VOLs in storage tanks, loading plants and tank vehicles (updated limits are proposed to apply for new tanks from 1 July 2024 and, for existing tanks, at the next maintenance period after the commencement of this Regulation) • harmonise emission limits and control equipment requirements for VOLs consistently across areas	In relation to large storage tanks, the analysis found Option 3 delivers a net economic benefit of $0.84 million. The health impact saving equates to $0.87 million, in present value terms, through reduced VOC emissions under the new Regulation (Option 3) compared with the base case (Option 1). Repealing the Regulation (Option 2) would impose no costs to industry or government but would be expected to lead to an increase in health costs due to a deterioration in air quality. Deterioration would be expected because there would be no alternative	In relation to large storage tanks, the new Regulation (Option 3) is preferred because it would improve health benefits through avoided VOC emissions. Repealing the Regulation (Option 2) would result in welfare loss due to an expected deterioration in air quality and associated impacts on public health and the environment. The analysis of petrol stations shows that retaining the existing Regulation (as opposed to repealing it) would maintain vapour recovery, ensuring there remains a net public benefit.

Reason for regulatory measures	Any proposed significant change	Benefits identified	Recommendation
	with a high risk of ozone formation due to the location of facilities, population density and meteorological conditions. The three options considered: • Option 1 – retain the existing Regulation • Option 2 – repeal the existing Regulation (thus removing current specifications) • Option 3 – new Regulation (more stringent control equipment and/or emissions limits will be required for large storage and loading plant, small loading plant and tank vehicles.	regulatory mechanisms for petrol stations. For petrol stations, benefits would arise from avoiding VOC emissions relating to ozone formation, direct impacts on the amenity (odour) of petrol stations and the health of their employees and people living and working nearby. Some VOCs, such as benzene, are individually significant as air toxics. Petrol contains up to 1% benzene, which is a human carcinogen. There is no safe level of human exposure to benzene, which has been linked to an increased incidence of leukaemia after long-term exposure. VOC emission standards are currently included in the environment protection licences of some petroleum bulk storage facilities.	

1. Introduction

1.1. Purpose of this document

This document is a Consultation Regulation Impact Statement (RIS) for the proposed Protection of the Environment Operations (Clean Air) Regulation 2022 (the proposed Regulation), prepared in accordance with the *Subordinate Legislation Act 1989*.

When a regulation is to be remade (with or without amendments), the responsible agency must prepare a RIS that examines the economic and social costs and benefits of regulatory proposals and their alternatives. In addition, the agency must provide the community with an opportunity to comment on the proposed regulation before it becomes law.

As required, this RIS also addresses the Better Regulation Principles for the proposed Regulation (as demonstrated in Appendix A). To ensure the Regulation is appropriate, effective and efficient, the NSW Government has provided the Better Regulation Principles as a framework to determine that the proposed Regulation is required, reasonable and responsive to the economic, social and environmental needs of NSW.

The proposed Regulation would replace the existing Protection of the Environment Operations (Clean Air) Regulation 2021 (the existing Regulation).

The Subordinate Legislation Act provides for regulations to have a limited life so their continued relevance and effectiveness can be assessed. The existing Regulation is due for repeal on 1 September 2022.

1.2. Purpose of the proposed Regulation

The proposed Regulation contains provisions that support the objectives and implementation of the *Protection of the Environment Operations Act 1997* (POEO Act) as it concerns air quality. Those objectives include the reduction of risks to human health and the prevention of degradation of the environment.

The proposed Regulation sets standards for the emission concentration of designated pollutants by plant, equipment, activities (industrial and commercial), households and fuels. This is achieved by specifying limits on industrial emissions; prescribing requirements for storage of volatile organic liquids and fuels; addressing the standard of equipment (such as wood-fired heaters); and prescribing controls on motor vehicles and open burning.

It is complemented in its objective of improving air quality by the Protection of the Environment Operations (General) Regulation 2021, which uses licensing (including economic incentives through such mechanisms as load-based licensing) to improve air quality.

1.3. What is changing?

A number of changes to the existing Clean Air Regulation are proposed, including changes to the structure. Substantive changes are proposed to some sections of the existing Regulation (Parts 4, 5 and 6) and are discussed in Table 1, while no changes are proposed for Parts 2 and 3 of the existing Regulation. All significant and minor amendments are set out in Table A2 in Appendix A.

Throughout this RIS, possible reforms to the existing Regulation are labelled as follows:

- Option 1 – business as usual; existing Regulation provisions would be included unchanged in a new regulation
- Option 2 – allow the existing Regulation to be repealed without making a new regulation
- Option 3 – incorporate the proposed amendments and the existing Regulation provisions in a new regulation.

Note that not all options are considered for each part of the Regulation.

Table 1 Proposed substantial changes to the Clean Air Regulation.

Regulation reference and proposed change	Reason for proposed change and significant benefits of the change
Part 4 of existing Regulation, Parts 4 and 8 of proposed Regulation: Motor vehicles and motor vehicle fuels	
Extend by one month the period during which lower summer petrol volatility limits apply in the NSW Greater Metropolitan Area (GMA) to better correspond with the peak ozone formation period in the GMR (that is, 1 November to 31 March) and to align with existing requirements in Victoria. The updated requirements are proposed to commence from 1 November 2022.	NSW and other Australian states, as well as many overseas jurisdictions, use lower petrol volatility requirements as key measures to manage ozone (photochemical smog) formation in summer months and to reduce associated impacts on community health and the environment. Petrol volatility is limited to 62 kilopascals (kPa) in any one month, with no batch allowed to exceed 64 kPa. Limits only apply in the NSW GMA. Limits apply in summer (currently 15 November to 15 March). Analysis of historic ambient air quality data shows that average ozone is increasing and exceedances are occurring prior to commencement of the existing summer petrol volatility season. Petrol volatility requirements are an important component of the Regulation. While the Commonwealth regulates national fuel quality standards, states retain responsibility for the management of petrol volatility to take account of the different regional, climatic and seasonal factors. All Australian mainland states apply petrol volatility limits. Limits overseas are often much tighter than in Australia.
Exclude heavy vehicles over 4.5 t from the requirements related to emissions of smoke and anti-pollution devices in the Regulation.	Heavy vehicles over 4.5 t are regulated by the National Heavy Vehicle Regulator (NHVR) under the Heavy Vehicle (Vehicle Standards) National Regulation 2013 that is administered in NSW by Transport for NSW. There is a duplication between the NSW Environment Protection Authority (EPA) and NHVR in regulating heavy vehicles with regards to smoke emissions and removal, disconnection or impairment of anti-pollution devices. This proposal will result in no change to the requirements and will be cost neutral to users and operators of heavy vehicles over 4.5 t. Benefits are expected due to avoiding duplication of requirements and associated costs of administration.

Regulation reference and proposed change	Reason for proposed change and significant benefits of the change
Part 5 of existing and proposed Regulation: Air impurities emitted from activities and plant	
Require that activities and plant that belong in Groups 3 and 4[a] (i.e. commenced operation between 1 July 1979 and 31 July 1997) must comply with the more stringent air emission limits[b] of Groups 5 and 6.[c] New emission limits for current Groups 3 and 4 are proposed to apply from 1 July 2025 (Group 5 limits) and then 1 July 2030 (Group 6 limits). If Group 3 and 4 activities and plants are unable to meet these updated emission limits by the due dates, different limits can be agreed via variation of the conditions of the environment protection licence.[d]	Industry sources contribute a significant proportion of the air emissions in NSW associated with significant public health impacts, including fine particles ($PM_{2.5}$) and oxides of nitrogen (NO_x)[e] in the NSW GMR.[f] Activities and plant in Groups 3 and 4 commenced operation 22–40 years ago and are currently required to meet air emission limits that are reflective of the vintage of the operating plant. Those limits are considerably less stringent than limits for activities and plant in Groups 5 and 6 and are no longer reflective of reasonably available technology and good environmental practice. Significant reductions of industrial emissions and associated health benefits can be achieved by requiring activities and plants in Groups 3 and 4 to meet more contemporary emission standards consistent with reasonably available technology.
Exclude diesel powered mobile plant and equipment from the requirement to operate the equipment with fuel of sulfur content no more than 0.5% by weight, to avoid duplication and harmonise with national fuel standard requirements.[g]	Limits for maximum sulfur content in liquid fuels are used to control emissions of sulfur dioxide during burning of fuels, which are associated with adverse impacts on public health and the environment. Operators of diesel powered mobile plant and equipment use standard diesel fuels. These are regulated by the *Fuel Quality Standards Act 2000* (Cth), which require significantly lower sulfur content than limits prescribed in the Clean Air Regulation. It is proposed that sulfur content limits in the Regulation will not apply to diesel powered mobile plant and equipment that uses standard fuel. The limits should continue to apply to stationary plant and equipment that uses non-standard fuel (e.g. waste oil). This proposal will result in no change to the status quo and will be cost neutral to users of mobile non-road diesel equipment. Benefits are expected due to avoiding costs of administration and compliance resulting from removing obsolete requirements. The sulfur in liquid fuel requirements also moved from Section 60 of the existing Regulation to Part 9 of the proposed Regulation.

Regulation reference and proposed change	Reason for proposed change and significant benefits of the change
Part 6 of existing Regulation, Parts 6 and 7 of proposed Regulation: Control of volatile organic liquids	
1. Introduce more stringent volatile organic compound (VOC) emission limits and control equipment requirements, reflective of reasonably available control technology and practice for volatile organic liquids (VOLs) in storage tanks, loading plants and tank vehicles. Updated limits are proposed to apply for new tanks and loading plant from 2024 and, for existing tanks and loading plant, at the earlier of the next prescribed upgrade or maintenance after 1 July 2024 or 1 July 2030. 2. Harmonise emission limits and control equipment requirements for VOLs consistently across areas of high risk for ozone-forming potential to reduce associated community health impacts in NSW due to the location of facilities, population density and meteorological conditions.	Vapour emissions from VOLs are a significant source of precursors for the formation of ground-level ozone and secondary organic aerosols, which are associated with adverse impacts on public health and the environment. Maximum limits and control equipment requirements for emission control from VOLs have not been updated in the Clean Air Regulation for 30 years and are not reflective of reasonably available control technology. Emission limits for vapour recovery (VR) systems on large storage tanks and loading plant, currently required in NSW, are significantly higher (less stringent) than limits in the United States and European jurisdictions. Introducing equivalent emission limits in NSW is expected to result in up to 90% reductions of VOCs from VOLs in large storage tanks and loading plant. Requiring secondary seals on all floating roof tanks is expected to reduce VOC emissions from the tanks by approximately 75–95%. Industry costs of updated control technology implementation would be offset by the savings from the recovered products. The EPA has already negotiated the implementation of such control technology with a number of operators as a condition of their environment protection licence; the average payback period for recently installed VR systems is around 2–3 years. VOL emissions and control equipment requirements currently apply to the Sydney metropolitan area only. However, some major fuel distribution facilities are located outside that area, such as in the Newcastle and Wollongong areas, which have high levels of ozone in summer months and significant populations. Expanding the coverage area for VOL control requirements will make this consistent with the VR Stage 1 (VR1) zone for service stations.

[a] Section 43 of the proposed Regulation divides activities and plant in scheduled premises into Groups 1–6, according to the date the activity/plant commenced operation.

[b] Prescribed standards of concentration for air impurities, in section 51, are provided in Schedule 2 of the proposed Regulation for activities and plant in Groups 1–6.

[c] Group 5 activities and plant commenced operation on or after 1 August 1997 and Group 6 commenced on or after 1 September 2005.

[d] Sections 47 and 48 of the proposed Regulation provides a framework for approving alternative air emissions limits.

[e] NSW EPA (2019).

[f] GMR includes the metropolitan areas of Sydney, Newcastle and Wollongong.

[g] Sulfur content limit in the national Fuel Standard (Diesel) Determination 2001 is 10 ppm (0.001%), while the Clean Air Regulation applies limits of 0.5% by weight in the Sydney, Wollongong, Newcastle and Central Coast metropolitan areas and 2.5% by weight outside the metropolitan areas.

1.4. Background: The need for government action on air quality management

Clean air is fundamental to all people's health. Poor air quality in NSW affects the health of its people, particularly children and older people. It also affects the natural environment and the liveability of communities. Air quality is consistently a key environmental issue for NSW (NSW EPA 2018b).

The public health impacts and costs of air pollution and, conversely, the benefits of reducing people's exposure to air pollution are substantial. Air pollution leads to (NSW Government 2016):

- 520 premature deaths and 6,300 cumulative years of life lost in Sydney per year (Morgan, Broome & Jalaludin 2013)
- 1,180 hospital admissions in Sydney per year (Broome et al. 2015)
- an estimated $6.4 billion (2015 $) in health costs per year in the NSW GMR (DEC 2005).

Air quality in NSW is considered relatively good by world standards. There have been significant improvements since the 1980s as a result of programs and regulatory initiatives (including the Clean Air Regulation) that have reduced air pollution from industry, businesses, homes and motor vehicles.

Concentrations of some of the most common air pollutants – including carbon monoxide (CO), lead, sulfur dioxide (SO_2), particulate matter (PM) – consistently meet national air quality standards, except during extreme events, such as bushfires, hazard reduction burning and dust storms.

The pollutants of most concern are PM_{10} airborne particles and, most significantly, the subgroup of finer $PM_{2.5}$ particles (NSW Government 2016). Gaseous pollutants of concern include ozone (O_3), NO_x and SO_2. Some exceedances of the national standards – specifically for PM_{10}, $PM_{2.5}$ and ozone – do occur.

Ground-level ozone is a secondary pollutant created by the chemical reaction between NO_x and VOCs in the presence of sunlight. High ozone can result from local emissions or precursors transported from other regions. Standards are exceeded mainly in the warmer months, when peaks coincide with high temperatures (NSW Government 2016). Sydney has exceeded ozone standards on at least one day every year since 1994 (NSW EPA 2018b).

Parts of regional NSW also face considerable challenges meeting the particle standards. Bushfires, the burning of agricultural residue, dust storms and wood heaters are the major emission sources in those regional areas.

Continuing improvement in air quality remains a challenge, particularly in the GMR, due to increases in population and numbers of motor vehicles, as well as economic growth. For example, monitoring data indicate that reductions in CO and NO_2 have tailed off, possibly due to an increase in emission sources and an increase in emission contributions from unregulated sources (NSW Government 2016). Bushfires, dust storms and hazard reduction burning also periodically affect air quality in the GMR.

Table 2 provides a summary of the most common pollutants and concerns associated with their presence. Appendix B discusses in detail the health and environmental impacts of air pollutants.[3]

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[3] CO and lead have not been included. This is because CO concentrations have continued to fall over the past 20 years due to changes in motor vehicle technology, and lead concentrations are also now low due to the ban on lead in petrol.

Table 2 Common pollutants dealt with under the Clean Air Regulation.

Definition of pollutant	Source of pollutant	Controls	Health impacts
Particulate matter is liquid or solid particles suspended in the air. It can be a primary pollutant (from emissions) or a secondary pollutant (resulting from atmospheric reactions of primary pollutants). Particles are measured using their aerodynamic diameter and range in size from 0.001 to 500 µm. Particles are categorised according to size because different sizes behave differently both in the atmosphere and in the human respiratory system. PM_{10} includes all particulates that are 10 µm or less in diameter. $PM_{2.5}$ includes particulates that are 2.5 µm or less in diameter.	Particles come from both natural and human sources and are generally visible as brown haze. They include acids, organic chemicals, metals, soil, dust and allergens. Human sources of particles include products of combustion and mechanical processes, such as emissions from motor vehicles, wood heaters, power stations and industrial processes.	Parts 2, 3, 4 and 5 of the Regulation	Fine particles are more damaging to human health, as particles larger than 10 µm do not usually enter the human respiratory system, so standards are built around PM_{10} and $PM_{2.5}$. There is no safe concentration threshold for exposure to PM_{10} or $PM_{2.5}$ at which adverse health effects have not been observed. Short-term exposures to fine particles may result in respiratory symptoms (such as irritation of the airways, coughing and difficulty breathing); aggravated asthma; irregular heartbeat; heart attacks; and premature death in people with heart or lung disease. Long-term exposures may result in decreased lung function, the development of chronic bronchitis and increased cardiovascular risk.
Oxides of nitrogen (NO_x) are a group of gases including nitric oxide (NO) and nitrogen dioxide (NO_2) that are generally produced by the combustion of fossil fuels. NO_x is significant due to its direct impacts on health but also as a precursor to ozone and secondary particle formation.	Electricity generation is a major source of NO_x in the NSW GMR. Motor vehicles (petrol, diesel and off-road) are another major source, particularly in the Sydney region.	Parts 4 and 5 of the existing and proposed Regulation	At low levels of exposure, NO_x can irritate the eyes, nose, throat and lungs, leading to coughing, shortness of breath, tiredness and nausea. Longer-term exposure can destroy lung tissue, leading to chronic inflammatory lung disease. At high levels of exposure, NO_x can cause rapid burning, spasms and swelling of tissues in the throat and upper respiratory tract, reduced oxygenation of tissues, a build-up of fluid in the lungs, and maybe even death. Asthmatics and children are particularly susceptible.

Definition of pollutant	Source of pollutant	Controls	Health impacts
Volatile organic compounds (VOCs) are a broad grouping of carbon-based compounds that vaporise at normal temperatures. VOCs as a group are significant as a precursor to the formation of ground-level ozone.	Exhaust and evaporative emissions of petrol from vehicles account for the largest proportion of VOC emissions. Other sources include combustion, surface coatings (paint), aerosols and solvents.	Evaporative emissions in Parts 4 and 6 of the existing Regulation and Parts 4, 6, 7 and 8 of the proposed Regulation. Other emissions (controlling combustion) in Parts 2, 3 and 5 of the existing and proposed Regulation.	General effects of exposure to VOCs include irritation to the eyes, nose and throat; headaches; loss of coordination; nausea; and damage to the liver, kidneys and central nervous system. Some VOCs are also known or suspected to cause cancer in humans.
Ozone is a relatively insoluble gas composed of three oxygen atoms, with a characteristic sharp odour. It is present both in the stratosphere high above the Earth's surface (where it has a beneficial effect in filtering out ultraviolet light) and at ground level (principally as a pollutant). At ground level, it is one of the components of summertime smog, which harms human health, vegetation and building materials. Ground-level ozone is created by a chemical reaction between NO_x and VOCs in the presence of sunlight. Therefore, a principal reason for controlling emissions of NO_x and VOCs is to prevent the formation of ozone.	Motor vehicle use is the main human source of NO_x in Sydney and a major source of VOCs. As noted above, coal-fired power stations are a major source of NO_x emissions. Additionally, global warming is projected to exacerbate ground-level ozone formation in Sydney (Cope et al. 2008).	Because ozone is a secondary pollutant, ozone emissions are not directly regulated through the Regulation; although, as noted above, its precursor pollutants (NO_x and VOCs) are regulated.	Ozone can be highly irritating for those who inhale it. Increases in ozone levels are associated with a rise in hospitalisations for respiratory diseases, and with mortalities. Repeated exposure to ozone can make people more susceptible to respiratory infection and aggravate pre-existing respiratory diseases, such as asthma.

1.5. Current management framework for air quality

Air quality in NSW is managed through an integrated whole-of-government approach, using a mix of regulatory and non-regulatory measures. Air quality management is increasingly linked with efforts to reduce greenhouse gas emissions.

Air quality is guided by national health-based standards for priority pollutants set under the National Environment Protection (Ambient Air Quality) Measure (the Air NEPM). Pollutants monitored under the Air NEPM standards include:

- particles less than 10 micrometres in diameter (PM_{10})
- fine particles less than 2.5 micrometres in diameter ($PM_{2.5}$)
- ozone (O_3)
- nitrogen dioxide (NO_2)
- sulfur dioxide (SO_2).

National standards for $PM_{2.5}$ and PM_{10} were strengthened in 2016 and more stringent standards for ozone, nitrogen dioxide and sulfur dioxide were adopted in May 2021. The upgrading of standards reflects new evidence of the impacts and costs of air pollution to Australian communities. Current standards are set out in Table 3, Table 4 and Table 5.

Table 3 Air NEPM standards and goals.

Pollutant	Averaging period	Maximum concentration standard
Carbon monoxide	8 hours	9.0 ppm
Nitrogen dioxide	1 hour	0.08 ppm
	1 year	0.015 ppm
Photochemical oxidants (as ozone)	8 hours	0.065 ppm
Sulfur dioxide	1 hour	0.10 ppm
	1 day	0.02 ppm
Lead	1 year	0.50 $\mu g/m^3$
Particles as PM_{10}	1 day	50 $\mu g/m^3$
	1 year	25 $\mu g/m^3$
Particles as $PM_{2.5}$	1 day	25 $\mu g/m^3$
	1 year	8 $\mu g/m^3$

Source: NEPC 1998

Additionally, there is a further goal in place for $PM_{2.5}$ particles in the NEPM (see Table 4 and Table 5).

Table 4 Goals for particles as $PM_{2.5}$ by 2025.

Pollutant	Averaging period	Maximum concentration by 2025
Particles as $PM_{2.5}$	1 day	20 $\mu g/m^3$
	1 year	7 $\mu g/m^3$

Source: NEPC 1998

Table 5 Standard for SO_2 from 2025.

Pollutant	Averaging period	Maximum concentration by 2025
Sulfur dioxide	1 hour	0.075 ppm

Source: NEPC 1998

NSW is a signatory to the national standards and goals for criteria air pollutants set by the Air NEPM. NSW has been working with other jurisdictions to update the standards by considering health impacts, leading international standards and World Health Organization guidance.

As discussed in Section 1.2, the POEO Act is the key piece of environment protection legislation setting the statutory frameworks for managing air quality in NSW. It is supported by the Clean Air Regulation and the Protection of the Environment Operations (General) Regulation 2021. The POEO Act and the two supporting Regulations are administered by the NSW EPA.

There is also capacity to control air emissions through land-use planning, by one of the following means:

- approvals made under the integrated development process whereby an environment protection licence may be required for the development
- by local councils within the parameters of a local approvals policy, local environmental plan or development control plan.

The Clean Air Regulation provides regulatory measures for a number of air quality issues:

- domestic solid fuel heaters
- control of burning
- motor vehicles and motor vehicle fuels
- air impurities emitted from activities and plant[4]
- control of volatile organic liquids.

1.6. Consultation

The proposed Regulation and this RIS are available for public comment. The EPA welcomes written submissions from all stakeholders and the public and will carefully consider any matters raised before the Regulation is finalised.

Please email written submissions to air.policy@environment.nsw.gov.au

This RIS, and details about the dates for the consultation period, are available on the EPA Have Your Say website at https://yoursay.epa.nsw.gov.au/.

4 Industrial air emissions are also the focus of the General Regulation, which (together with the POEO Act) provides the system to license emissions from industrial plant and activities, including load-based licensing.

1.7. Structure of the Regulation and this document

The remainder of this document follows the structure of the existing Regulation. Chapters 2–6 discuss any proposed changes to the existing Regulation and refer to the relevant parts of the proposed Regulation. The discussion for each part of the Regulation covers:

- the need for government action
- the management framework for the relevant emissions
- for each option (including no Regulation), a detailed description and analysis of the costs and benefits
- a recommendation on the preferred option.

In addition, the following appendixes are provided:

- Appendix A demonstrates compliance with the Better Regulation Principles
- Appendix B provides detail on the health and environmental impacts of the air pollutants covered by the Regulation
- Appendix C sets out details of the cost–benefit calculations.

2. Domestic solid fuel heaters

Regulation reference

Part 2 of the existing and proposed Regulation.

Air pollution source

In NSW, solid fuel heaters are mainly wood heaters and so are referred to as 'wood heaters' throughout this document. They generate particulate pollution that can cause significant health impacts, especially during winter. Exposure to fine particulates is associated with a range of health issues, particularly respiratory and cardiovascular illnesses.

Options considered

The two options considered were:

- Option 1 (business as usual) – retain the existing Regulation, with no change to the current control measures for wood smoke in NSW. This Regulation sets out efficiency and emission limits on wood heaters sold in NSW.
- Option 2 (no regulation) – remove the regulatory controls for sales of new wood heaters in NSW. Controls could be maintained through planning instruments available to local councils and voluntary industry compliance with the Australian Standards on energy efficiency and emission limits on wood heaters.

Analysis

The cost–benefit analysis finds that retaining the existing Regulation (Option 1) is preferred, as it would result in a net public benefit of $413.2 million in present value terms from reduced $PM_{2.5}$ emissions, compared to Option 2.

There are also other, unquantifiable, benefits, such as improved visibility, less offensive odours and an improved condition of the built and natural environment in general.

Recommendation

It is recommended that the existing Regulation be retained (Option 1), as this delivers a net public benefit from reduced particulate emissions.

2.1. Background

2.1.1. Need for government action

Solid fuel heaters are the most significant sources of particulate pollution in the Sydney region and many regional centres in NSW during the winter months.

Wood heating is a popular primary or secondary heating source because it can be relatively cheap and has the potential for high heat output. It may also be perceived by some members of the public as being more sustainable. In addition, many rural areas do not have access to the reticulated gas supply network that would be an alternative option for heating.

In 2014, in NSW 10.2% of homes used wood combustion heating as their main heat source. Of those, 4.4% of homes in Sydney and 19.2% of homes outside Sydney used wood heaters (ABS 2014).

It has been estimated that sales of wood heaters in Australia dropped from a peak of 120,000 units per year in 1988 to around 25,000 units per year in 2012 (NEPC 2013). Emissions from wood heaters in the Sydney region appear to have peaked in 2008, after which a reduction of 8% in associated emissions occurred between 2008 and 2013 (NSW Government 2017). This drop in wood heater emissions is likely a result of an uptake of wood heaters with better emission controls.

The efficiency levels of the heater models listed on the Australian Home Heating Association (AHHA) website indicate that over 70% of the existing models are certified as compliant with the requirements for 60% heating efficiency and 1.5 g/kg emission ('Tier 2').

On an annual basis, wood smoke in Sydney contributes 25% of PM_{10} and 36% of $PM_{2.5}$ total particulate pollution from both natural and human sources (NSW EPA 2019). On a winter day, the contribution of PM_{10} and $PM_{2.5}$ particle pollution from wood smoke in Sydney can be as high as 67% and 81%, respectively (NSW EPA 2019). In colder climates, for example in Armidale, wood heaters can contribute over 85% of winter particle pollution (AECOM 2014).

In addition to fine particles, wood smoke contains a number of VOCs, including known air toxics. Table 6 shows the annual contribution of wood smoke to total annual emissions of significant air pollutants in the NSW GMR and Sydney region. This indicates that wood smoke accounts for a significant proportion of many of the air pollutants listed.

Table 6 Contribution of domestic solid fuel heaters to annual pollutant emissions.

Air pollutant	NSW GMR (%)	Sydney region (%)
Carbon monoxide (CO)	4	15
Particulate matter		
Particulate matter ≤10 µm (PM_{10})	3	25
Particulate matter ≤2.5 µm ($PM_{2.5}$)	6	36
VOCs (air toxics)		
1,3-butadiene	7	23
Benzene	17	19
Formaldehyde	35	42
Isomers of xylene	1	1
Polycyclic aromatic hydrocarbons (PAHs)	23	36
Toluene	1	2

Source: NSW EPA (2019)

A range of environmental and health impacts are associated with the use of wood heaters. They include reduced habitat and biodiversity impacts from firewood harvesting and collection, and health and environmental impacts associated with the emission of particulates and air toxics from wood heaters (NEPC 2013).

The most significant impact of wood heaters is the health impact of particulate pollution. Exposure to particulate matter has been associated with a range of health impacts, particularly respiratory and cardiovascular illnesses. It is associated with increased mortality and hospital admissions among people with heart and lung disease. In addition, there is evidence that exposure to VOCs (which are also emitted by wood heaters) is linked to cancer, birth defects, genetic damage, immune deficiency, and respiratory and nervous system disorders. See Appendix B for further information on the health and environmental impacts of particulate matter and VOCs.

2.1.2. Management of wood smoke emissions

Figure 1 shows the overall approach of the NSW Government to controlling wood smoke pollution.

In NSW, control of wood smoke emissions is largely managed at the local government level, supported by NSW Government regulatory controls, funding and education initiatives. The main controls are:

- Appliances sold for wood heating must meet minimum emission standards as set out in Part 2 of the Clean Air Regulation.
- The correct use of wood heaters is promoted by providing information to the community, including targeted education for households.
- Periodically, local governments and the NSW Government run wood heater replacement programs (for example, the recent program in the Upper Hunter region over three winters from 2016–18).
- Local government planning instruments, such as development control plans and approval policies that may restrict installation of wood heaters or open fireplaces, are used in some areas.[5] Further, under section 68(1) of the *Local Government Act 1993*, 'solid fuel heating appliances' (including wood heaters) other than portable appliances cannot be installed without the approval of the local council.
- The POEO Act provides local councils with powers to issue smoke abatement notices to mitigate emissions of excessive smoke.

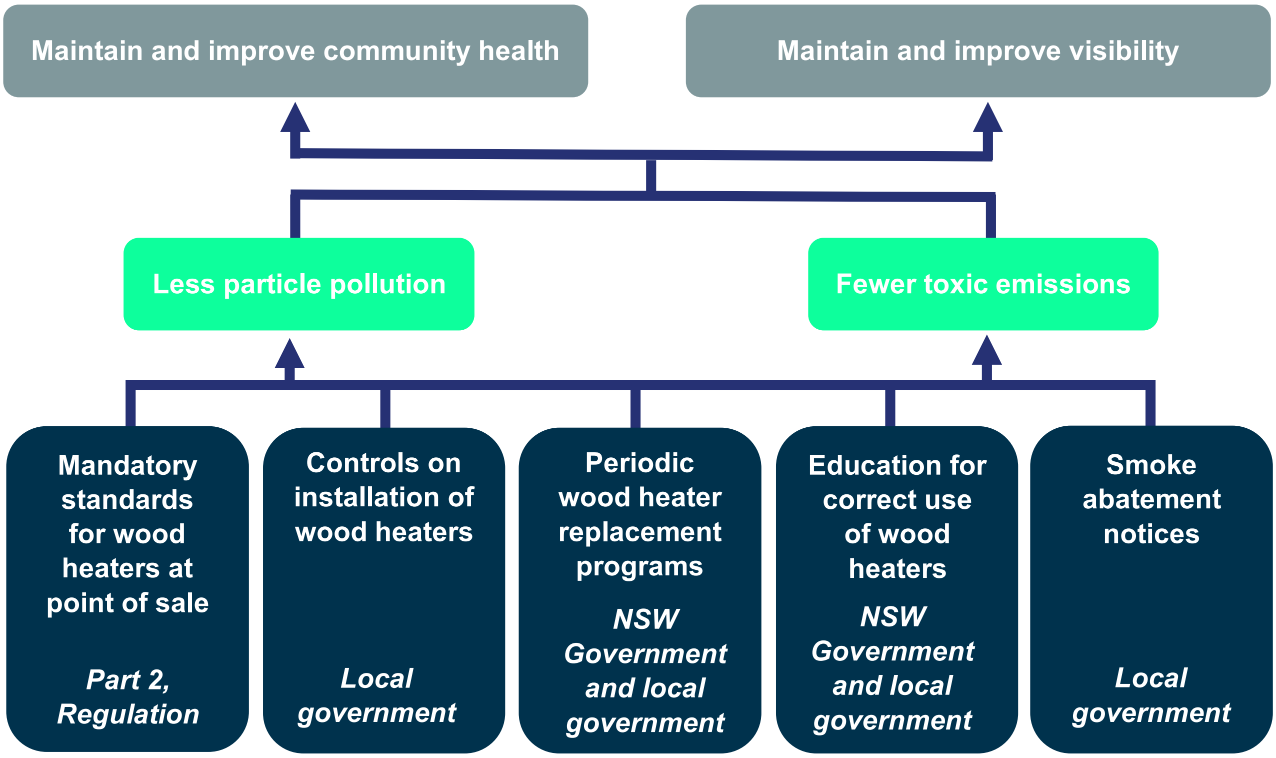

Figure 1 Management of emissions from wood heaters in NSW.

Source: DECCW (2010)

[5] Councils that have adopted planning controls on the installation of wood heaters in several new release areas in their local government areas include Camden, Blacktown and The Hills Shire.

2.2. Options considered

In reviewing the Regulation, two options for government action are considered in detail below:

- Option 1 – business as usual; existing Regulation provisions would be included unchanged in a new regulation
- Option 2 – allow existing Regulation to be repealed without making a new regulation.

2.2.1. Option 1: Base case (business as usual)

Option 1 assumes there is no change to the current wood smoke control measures in NSW. This means the existing Regulation is retained.

Under the existing Regulation, all heaters offered for sale in NSW must have a certificate issued by a body approved by the EPA and certifying that all heaters of that model:

- comply with Standard 4012 and Standard 4013, and
- have an overall average efficiency of not less than 60%, as tested and calculated in accordance with Standard 4012, and
- have an appliance particulate emission factor, as tested and calculated in accordance with Standard 4013, not greater than:
  - 1.5 g/kg for heaters without catalytic combustors, or
  - 0.8 g/kg for heaters with catalytic combustors.

2.2.2. Option 2: No Regulation

Under Option 2, NSW would remove the regulatory controls for sales of new wood heaters. Councils would be able to use their planning instruments to control the installation of new wood heaters and open fireplaces in designated areas. Control of wood smoke would rely on voluntary industry compliance with the Australian Standards. Reliance on voluntary compliance was assumed to be reasonably effective, given that various members of the industry (including the AHHA) indicated their agreement to comply with the new standards. Further, many existing models of wood heaters supplied by Australian manufacturers have already met or are expected to meet these standards. It is likely, however, that voluntary compliance would not result in full compliance by the entire industry. In general, commercial incentives for voluntary compliance do not exist for all suppliers and manufacturers (for example, producers and importers of low-cost or export models).

A proportion of heater models for sale in Australia already comply with the 60% efficiency standard. The efficiency levels of the heater models listed on the AHHA website indicate that over 70% of the existing models are certified as compliant with the requirements for 60% heating efficiency and 1.5 g/kg emission (‘Tier 2’).

Based on the EPA’s experience and consultation with AHHA, it was assumed that levels of voluntary compliance with the standards would be around 70%.

2.3. Benefits and costs

2.3.1. Summary results

For Part 2 of the Regulation, a comparison of the costs and benefits of Option 2, incrementally to the base case (Option 1), is set out in Table 7. As the timing of the costs and benefits varies over time, they are compared as present values over a 20-year period at a 7% discount rate.

If the existing Regulation is repealed (Option 2), there will be significant net economic costs to NSW that are estimated to be in the order of $413.2 million, mainly due to the costs associated with additional health impacts.

Table 7 **Part 2: Comparison of present value costs and benefits for Option 2.**

Cost and benefit elements	Option 2 (present values, $m)
Costs to industry	0.00
Health impact ($PM_{2.5}$) – GMR	413.37
Present value (PV) total costs	**413.37**
Saving to government	0.19
PV total benefits	**0.19**
Net present value (NPV)	**–413.18**
Benefit:cost ratio (BCR)	**0.0005**

2.3.2. Benefits

An inventory of existing wood heaters established for the purpose of the analysis illustrates that, over time, there is expected to be a decline in the number of wood heaters in the NSW GMR, based on the historical trend (Appendix C contains the details of this and other assumptions used in the analysis).

Appendix B outlines the health and environmental benefits of reducing emissions of particulate matter.

The benefits of lower emissions are especially important for $PM_{2.5}$, since exposure to and the health impacts of $PM_{2.5}$ tend to be closely correlated to proximity to the source. Also, the damage costs of $PM_{2.5}$ (on a $/t basis) are very high relative to other pollutants.

The quantifiable benefits of maintaining the existing Regulation relative to Option 2 (no regulation) is that it will result in lower emissions of $PM_{2.5}$, which result in human health benefits.

Figure 2 and Figure 3 show the decline in emissions that is expected to occur under Option 1 and Option 2, respectively.

The avoided $PM_{2.5}$ emissions are estimated to range from 126–142 t/year over the 20-year analysis period (based on a 35-year life for a wood heater). From Figure 2 and Figure 3, it can be seen that the avoided $PM_{2.5}$ emissions per year are relatively small due to the long life of wood heaters and a relatively slow replacement rate.

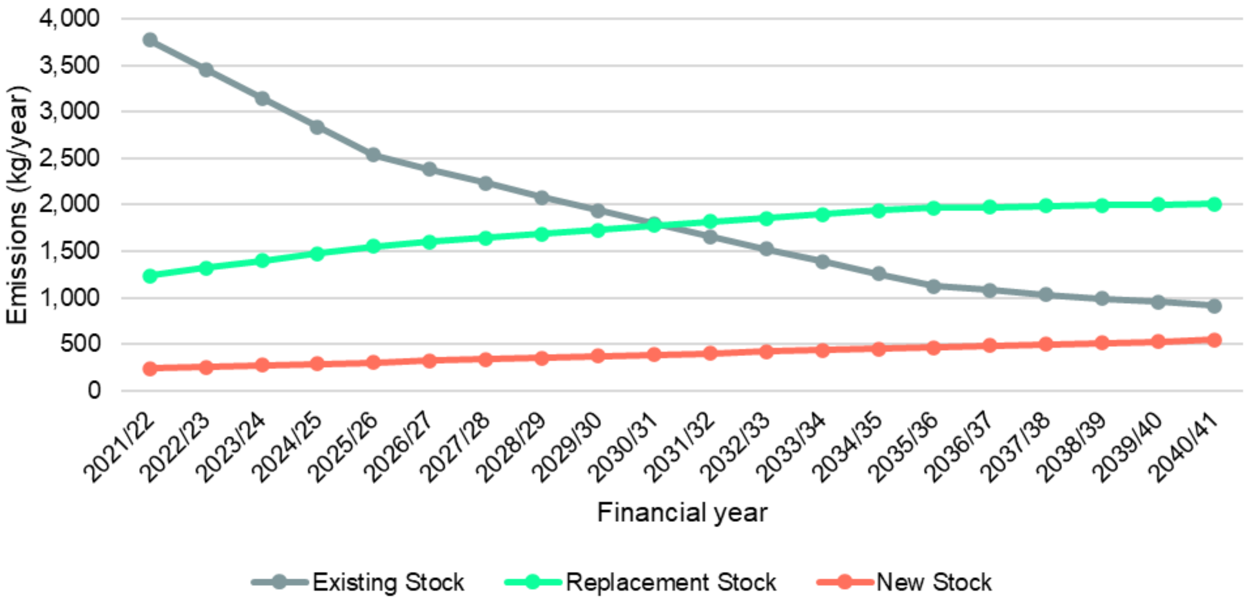

Figure 2 **Fine particulate ($PM_{2.5}$) emissions from wood heaters under Option 1.**

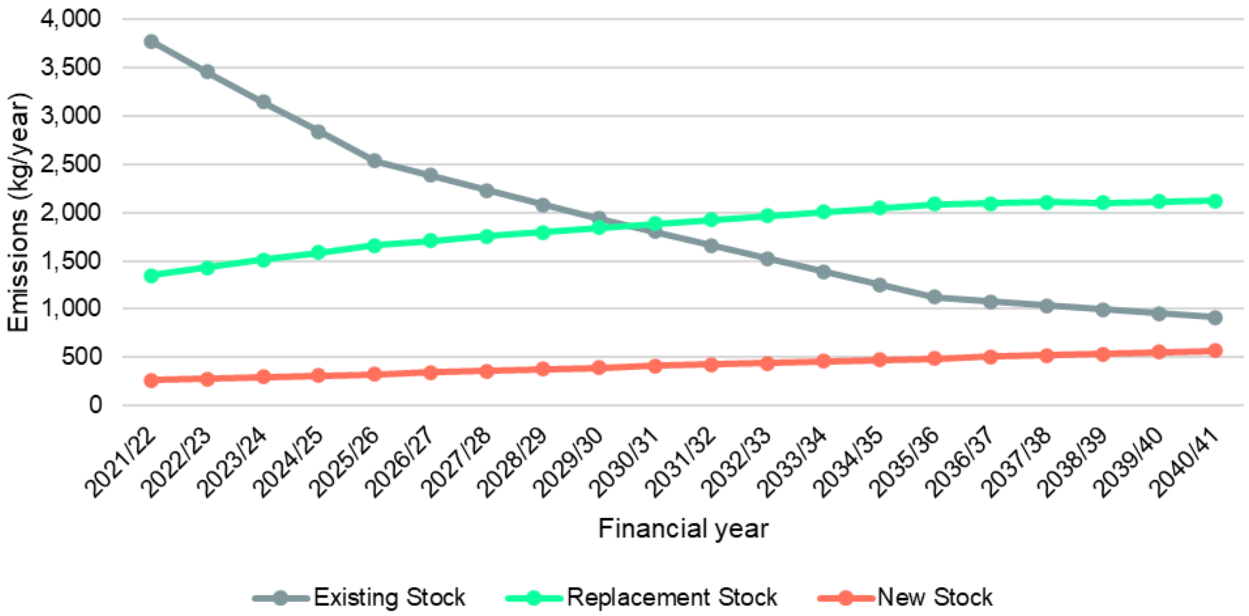

Figure 3 **Fine particulate ($PM_{2.5}$) emissions from wood heaters under Option 2.**

Figure 4 and Figure 5 show that the difference in emissions between Options 1 and 2 is quite small; however, due to the significant health impacts associated with $PM_{2.5}$ emissions, the benefits of small reductions are substantial, as illustrated in Figure 6.

The avoided $PM_{2.5}$ emissions as a result of retaining the existing Regulation (Option 1) have an estimated health benefit of $33 million in the first year, increasing to approximately $413.2 million (in present value terms) over the analysis period (2021–40). These economic gains illustrate the importance for human health of reducing $PM_{2.5}$ emissions.

In addition, there would be other benefits, which have not been quantified, as a result of the avoidance of other emissions (even if in small quantities), such as VOCs. They include improved visibility, less offensive odours and a generally improved condition of the built and natural environment.

A benefit of removing the Regulation would be that the costs of administration are no longer borne by government; however, this is only a small cost compared with the health benefits gained. It has been estimated that administration and enforcement costs are approximately $15,000 per year (AECOM 2014).

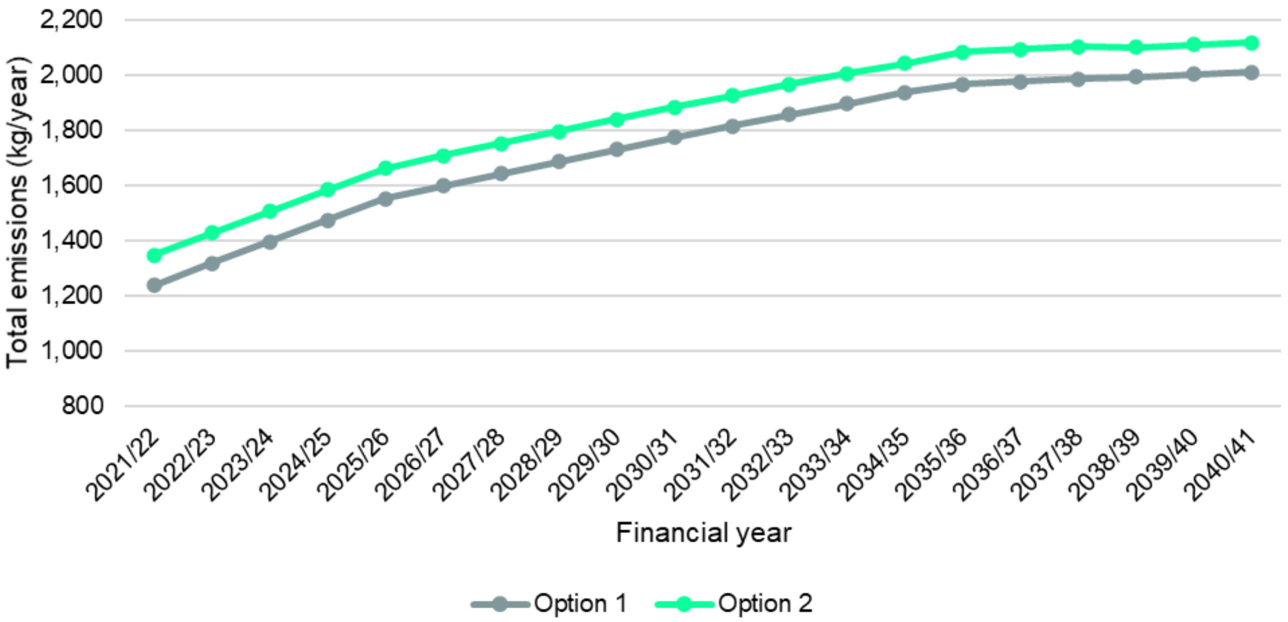

Figure 4 **Fine particulate ($PM_{2.5}$) emissions from replacement wood heater stock.**

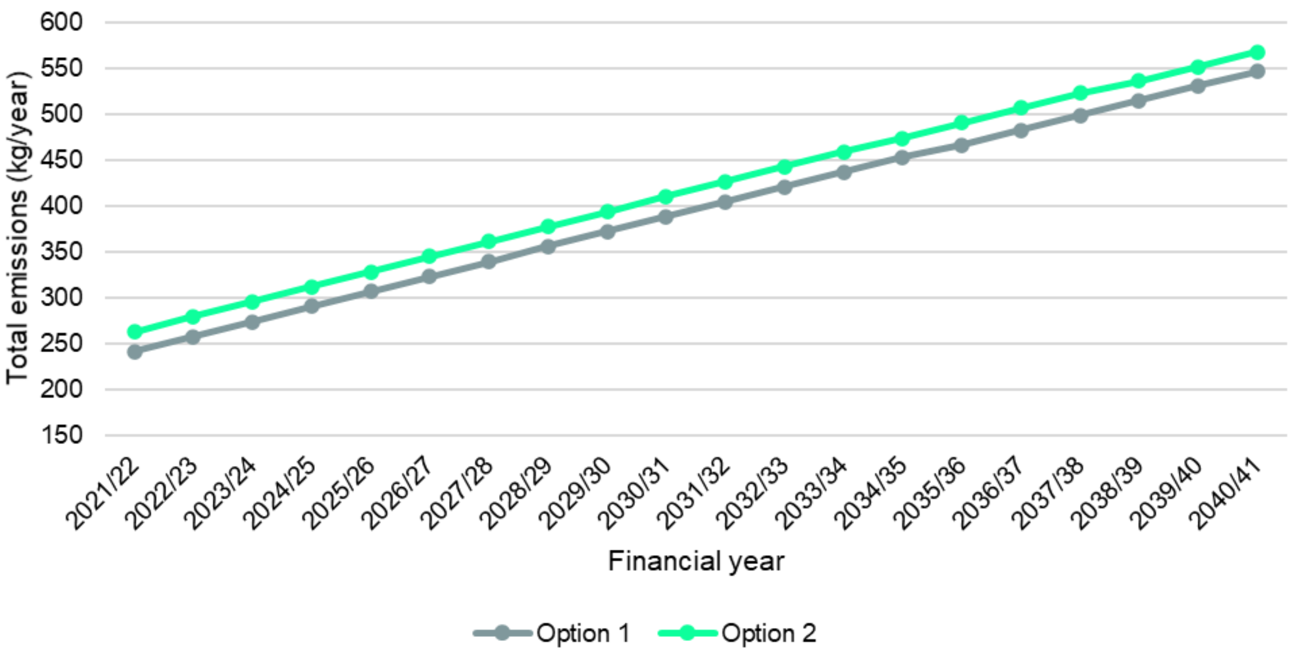

Figure 5 **Fine particulate ($PM_{2.5}$) emissions from new wood heater stock.**

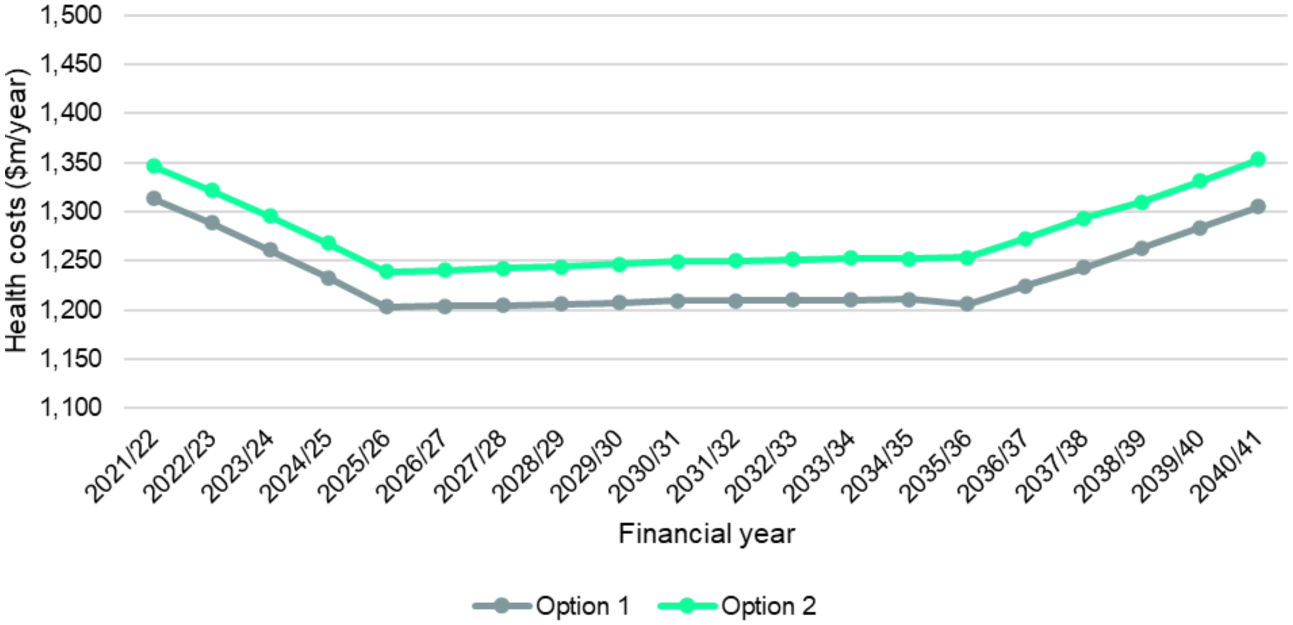

Figure 6 **Health impacts of fine particulate ($PM_{2.5}$) emissions from wood heaters.**

2.3.3. Costs

Quantifiable costs to government in maintaining the minimum standards for wood heaters are the costs of government administration (both state and local). This modelling is based on estimated costs of $15,000 per year for administration and enforcement (AECOM 2014).

If minimum standards are removed, a return of wood heaters with poorer emission control could be seen over the longer term. Repealing the Regulation might not lead to an increase in wood heater numbers, but could lead to an increase in emissions and, therefore, increased health costs (the reverse of the health benefits discussed above).

The repeal of minimum standards would still result in costs to government, including for alternative regulatory measures to reduce emissions. It is difficult to know what those costs would be because the types of measures that would be needed are not known.

There may also be costs to the environment, including poorer visibility, increases in offensive odour and damage to buildings and crops and other vegetation; however, those costs are currently unquantified.

2.4. Conclusion

Particulate pollution in Sydney and many regional centres has a more significant impact on air quality in winter than in summer. Reducing emissions from wood heaters significantly improves air quality in winter. Even with the existing Regulation in place, wood smoke contributes a significant proportion to pollutant emissions, so removing the Regulation may increase emissions and health impacts associated with them.

Maintaining business as usual (Option 1) is found to deliver a material net public benefit because it means the substantial cumulative reductions that have already been achieved will be sustained and emissions will remain below the levels that would be expected if the existing Regulation was repealed.

3. Control of burning

Regulation reference

Part 3 of the existing and proposed Regulation.

Air pollution source

Part 3 of the Protection of the Environment Operations (Clean Air) Regulation 2021 sets specific conditions for the control of burning in the open in NSW and for ensuring any burning is done in a way that prevents or minimises air pollution. The burning of waste, wood and vegetation in backyards and incinerators, referred to as 'backyard burning', was once widespread in NSW. Backyard burning resulted in emissions of particulates, VOCs, metals, PAHs and dioxins. Introduction of regulatory controls on backyard burning has resulted in significant reductions in these emissions, particularly in the NSW GMR.

Options considered

The two options considered were:

- Option 1 (business as usual) – retain the existing Regulation and maintain the three approaches to the control of burning available to local government
- Option 2 (no regulation) – remove the controls on open burning or the incineration of household waste or vegetation.

Analysis

The cost–benefit analysis finds that, if the existing Regulation is repealed (Option 2), there would be net economic costs to the NSW GMR in the order of $0.36 million, due to the costs associated with additional health impacts ($2.56 million) outweighing the total savings to residents and government ($2.19 million).

A non-quantifiable benefit of maintaining the existing Regulation is increased sustainability in waste management practices.

Recommendation

It is recommended that the existing Regulation be retained (Option 1), as this delivers a net public benefit from reduced fine particulate emissions.

3.1. Background

3.1.1. Need for government action

Burning wood, rubbish and vegetation in backyards and incinerators can produce smoke and cause air pollution. Burning in the open or in inadequately controlled incinerators results in incomplete combustion, generating fine particles that are suspended in the atmosphere and may be transported over large areas.

Backyard burning of household waste and vegetation was once a widespread weekend practice in NSW. It has been estimated that in 1984, before the introduction of relevant regulatory controls or education programs, backyard burning contributed 5,000 t/year (including a high proportion of fine particulates) to brown haze in the Sydney region (Dean & Ferrari 1990). Regulatory controls on backyard burning have reduced emissions of particles in Sydney by 99% over the past three decades (NSW Government 2011).

Depending on the composition of the waste burned, emissions from backyard burning may also include VOCs, metals and other toxic air pollutants, such as PAHs. Appendix B provides further details on the health and environmental effects of particulate matter, VOCs and metals.

3.1.2. Management of emissions from burning

Backyard burning is mostly a waste management issue. To encourage changes in the behaviour of residents in managing their domestic waste (including plastics and other packaging, newspapers, food waste and garden refuse), local councils provide domestic waste collection services, recycling facilities and associated community information services.

Most NSW councils provide such services and facilities. In the period from 2012–13 to 2014–15 it was estimated that 55% of councils provided a kerbside collection service for garden waste or food and garden waste, while 86% of councils provided a kerbside dry recycling collection service (NSW EPA 2018b).

Kerbside collection services are provided to 99% of households in the Sydney metropolitan area, 96% in the 'extended area', 88% in the 'regional area' and 86% in the 'rest of state' (NSW EPA 2016b); see Table 8.

Table 8 Organics collection services.

Region/ waste service[6]	Councils in region	Councils in region with an organics service	Proportion of councils with an organics service	Total population	Population with an organics service	Proportion of population with an organics service
Hunter councils	11	6	55%	958,276	780,477	81%
MACROC	3	3	100%	270,740	270,740	100%
MIDWASTE	8	7	88%	302,697	297,633	98%
NE Waste	7	5	71%	293,119	251,469	86%
NetWaste	26	3	12%	322,889	67,254	21%
NIRW	13	8	62%	186,320	141,090	76%
NSROC	7	7	100%	598,877	598,877	100%
RAMROC Murray	11	2	18%	105,170	62,537	59%
RAMROC Riverina	5	0	0%	48,690	0	0%
REROC	12	3	25%	126,390	74,856	59%

[6] Macarthur Regional Organisation of Councils (MACROC); MidWaste Regional Waste Forum (MIDWASTE); North East Waste (NE Waste); NetWaste voluntary regional waste group (NetWaste); Northern Inland Regional Waste (NIRW); Northern Sydney Regional Organisation of Councils (NSROC); Riverina and Murray Regional Organisation of Councils (RAMROC Murray); Riverina Eastern Regional Organisation of Councils (RAMROC Riverina); Riverina Eastern Regional Organisation of Councils (REROC); South Eastern Resource Recovery Network (SERRN); Shore Regional Organisation of Councils (SHOROC); Southern Sydney Regional Organisation of Councils (SSROC); Western Sydney Regional Organisation of Councils (WSROC).

Region/ waste service[6]	Councils in region	Councils in region with an organics service	Proportion of councils with an organics service	Total population	Population with an organics service	Proportion of population with an organics service
SERRN	13	8	62%	220,750	183,463	83%
SHOROC	4	4	100%	293,689	293,689	100%
Southern councils	5	4	80%	443,470	344,454	78%
SSROC	16	16	100%	1,657,801	1,657,801	100%
WSROC	11	10	91%	1,688,472	1,608,784	95%
Total	**152**	**86**	**57%**	**7,517,350**	**6,633,124**	**88%**

Source: MJA (2017)

Those councils that did not provide access covered only 12% of NSW households. Furthermore, it was estimated that 1.56 million tonnes of organic material were recycled and reused each year (MJA 2017).

The intention of Part 3 of the existing Regulation is to reduce or prevent emissions from backyard burning. It does this by:

- imposing a general obligation to prevent or minimise air pollution when burning in the open or in an incinerator
- prohibiting the burning of certain articles, such as tyres and wood treated with copper chromium arsenate or pentachlorophenol, with certain limited exceptions
- specifying a framework for councils to control open burning in their local areas.

Figure 7 sets out the management framework for emissions from domestic burning.

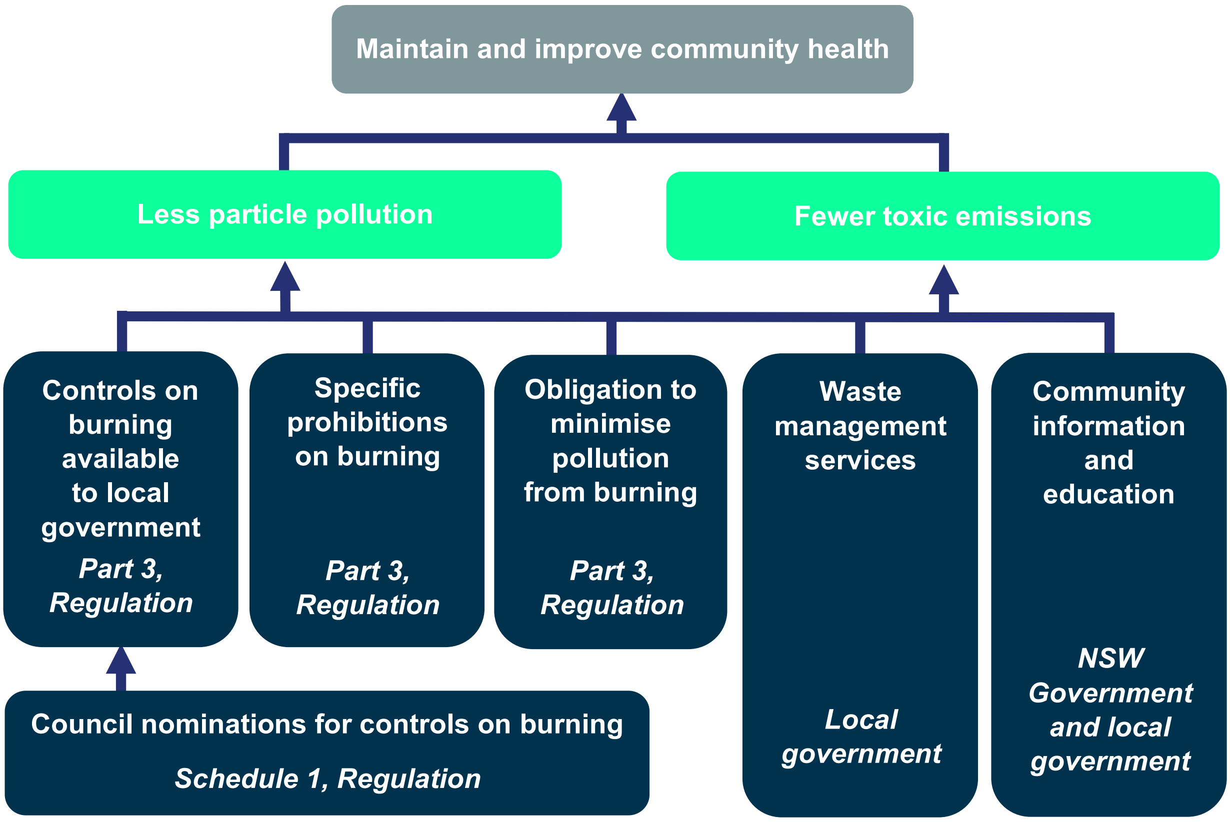

Figure 7 **Management of emissions from domestic burning in NSW.**

3.2. Options considered

No changes are proposed for Part 3 of the Regulation. This Part was amended in 2021 to reflect changes to council boundaries that have resulted from the recent amalgamation of some councils under NSW local government reform. The options assessed for this part of the Regulation are:

- Option 1 – business as usual; existing Regulation provisions would be included unchanged in a new regulation
- Option 2 – allow the existing Regulation to be repealed without making a new regulation.

3.2.1. Option 1: Base case (business as usual)

This option assumes there is no change to the current controls on open burning in NSW. This means the existing Regulation is retained.

Schedule 1 of the existing Regulation provides for three approaches to the control of burning by local governments:

- Part 1 (highest level of control) – local government areas in which all burning (including burning of vegetation and domestic waste) is prohibited except with approval
- Part 2 (may permit burning of vegetation on rural lots that are not serviced by green waste collection) – local government areas in which burning of vegetation is prohibited except with approval

- Part 3 (may permit burning of domestic waste where there is no domestic waste collection service) – local government areas in which all burning (other than burning of vegetation) is prohibited except with approval.

3.2.2. Option 2: No Regulation

Repealing the existing Regulation would result in the absence of controls on open burning or the incineration of household waste or vegetation.

3.3. Benefits and costs

3.3.1. Summary results

For Part 3 of the Clean Air Regulation, a comparison of the costs and benefits of Option 2 incrementally to the base case (Option 1) is set out in Table 9. As the timing of the costs and benefits varies over time, they are compared as present values over a 20-year period using a 7% discount rate.

If the existing Regulation is repealed (Option 2), there will be net economic costs to the NSW GMR in the order of $0.36 million, due to the costs associated with additional health impacts ($2.56 million) outweighing the total savings to residents and government ($2.19 million).

Table 9 Part 3: Comparison of PV costs and benefits for Option 2.

Cost and benefit elements	Option 2 (present values, $m)
Health impact ($PM_{2.5}$)	2.56
PV total costs	**2.56**
Saving to government	1.98
Saving to residents	0.21
PV total benefits	**2.19**
NPV	**–0.36**
BCR	**0.86**

3.3.2. Benefits

The quantifiable benefits of the controls on burning (relative to the no Regulation option) result from lower particulate matter emissions, leading to improved human health. The avoided particulate matter emissions in the Sydney region due to the existing Regulation being in place are about 5 t/year of PM_{10}, of which approximately 4.75 t/year is $PM_{2.5}$.

The health benefit of the avoided $PM_{2.5}$ is estimated at around $248,000 per year. The figures are conservative because it is assumed that current waste management practices would act as a control on increased burning, at least for a significant period. Appendix C contains the detailed calculation of these benefits.

A non-quantified benefit of maintaining the status quo is increased sustainability in waste management practices. The existing Regulation has supported the development of a range of sophisticated waste management and recycling services, with flow-on economic development gains.

Other benefits of maintaining the Regulation include:

- reductions in odours, smoke and ash
- reduction in air toxics
- reduction in accidental fires
- reduction in greenhouse gas emissions
- improved amenity in natural and built environments.

3.3.3. Costs

There are costs to government and residents in maintaining the status quo.

The EPA and local councils are responsible for issuing approvals and notices related to burning. This is carried out in consultation with the Rural Fire Service, local councils and other fire management agencies. An open burn will be approved by the EPA only in exceptional circumstances, such as for ecological burns to stimulate or assist the regeneration of native vegetation or to implement an appropriate fire regime to maintain or improve biodiversity, and to produce special effects for filming or large-scale events that require open burning or the production of smoke. However, the costs of such approvals are quite small and have not been estimated.

The quantifiable costs of controls on burning are the costs of government administration and waste collection costs to residents (see Appendixes B and C).

The total costs to councils of administering the existing Regulation are estimated at $187,000 per year.[7] Costs vary among councils depending on local policies (for example, some councils require residents to submit an application for each proposed open burn, while others have a standing approval for burning on rural lots but prohibit this type of burning in residential-zoned areas).

Community expectations have changed in recent years, and councils' management of waste continues to improve. This has been accompanied by a change in community perceptions about the importance of air quality since controls on backyard burning were first introduced.

Allowing the existing Regulation to be repealed would result in the absence of controls on the open burning of household waste or vegetation or its burning in incinerators.

The previous RIS (DECCW 2010) found that controls on burning had reduced emissions from backyard burning in Sydney from 5,000 t/year to 5 t/year (a reduction of 99.9%).

Because of the convenience of domestic waste collection and recycling services, and changes in community behaviour, it is unlikely there would be an immediate and widespread return to the levels of backyard burning prevalent before controls were introduced. However, failure to continue the controls on burning could result in environmental deterioration as a proportion of the community becomes aware that restrictions no longer apply.

Efforts by some councils to encourage more recycling by reducing waste collection services for general household waste may also lead to an increase in burning in the absence of the Regulation.

Any increase in burning would result in more particle pollution and impacts on health, visibility, odour and accidental fires. This may lead to an increased reliance on alternative regulatory mechanisms that are already in place. As for wood heaters, other regulatory mechanisms that have the potential to control burning to some extent are the Local Government Act and the POEO Act;[8] however, most of those controls cannot be used proactively to prevent backyard burning (particularly by limiting the locations and types of substances being burned) and may increase the costs to local councils in dealing with domestic burning. The extent to which they may be used successfully is speculative and cannot be assessed quantitatively.

3.4. Conclusion

Option 1 (maintaining the existing Regulation) would deliver net benefits to the NSW economy over Option 2 (repealing the Regulation). The benefits would arise from avoided health costs as a result of reduced levels of fine particulates.

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7 Total estimated local government costs are the equivalent of two full-time employees across all councils listed on the schedules, including on-costs (see Table C8 in Appendix C).

8 Through the use of prevention notices, orders prohibiting burning in certain weather conditions, orders to extinguish a fire (sections 96, 133 and 134 of the POEO Act).

4. Motor vehicles and motor vehicle fuels

Regulation reference

Motor vehicles and motor vehicle fuels were in Part 4 of the existing Regulation. In the proposed Regulation these have been split to Part 4 motor vehicles and Part 8 petrol.

Air pollution source

Managing air emissions from motor vehicles and fuels remains a challenge in the NSW GMR. In Sydney, emissions from motor vehicles are estimated to make up 53% of emissions of NO_x, 9% of emissions of PM_{10}, and 10% of emissions of VOCs. In Sydney, the number of kilometres travelled by passenger vehicles is increasing by approximately 1.0–1.5% per year, and freight travel is increasing by approximately 2–3% per year. Legislation at both state and federal levels has resulted in cleaner vehicles and fuels, which has made a significant difference to the levels of air pollution emitted from individual vehicles.

Options considered

The three options considered were:

- Option 1 (base case) – retain the existing Regulation, including the definition of summer as the period from 15 November to 15 March
- Option 2 (no Regulation) – repeal the existing Regulation
- Option 3 (new Regulation) – amend the definition of summer to be the period from 1 November to 31 March and exclude heavy vehicles over 4.5 t from the requirements relating to excessively smoky vehicles and installation and maintenance of anti-pollution devices.

Analysis

The cost–benefit analysis finds that extending by 30 days the period when summer volatility limits apply (Option 3) would provide a significant net benefit of approximately $20.8 million. Removing the Regulation (Option 2) will incur a sizeable net cost of approximately $126.1 million.

Option 3 also has a non-quantifiable benefit in aligning the definition of summer with that used in Victoria, given closure of NSW refineries means mostly Victorian refineries are supplying domestically produced fuel to NSW.

In relation to the provisions excluding heavy vehicles from the requirements relating to smoky vehicles and the installation and maintenance of anti-pollution devices, retaining the existing Regulation results in a small net welfare gain.

Recommendation

It is recommended that the new Regulation be implemented (Option 3), as this delivers a large net public benefit from avoided health costs.

4.1. Background

4.1.1. Need for government action

Cleaner vehicles and fuels have made a significant difference to the levels of air pollution emitted from individual vehicles, and ambient concentrations of CO and NO_2 are generally well below the Air NEPM standards. However, motor vehicles remain a major contributor to some air emissions in the GMR and regional centres of NSW. For example, in Sydney and the Illawarra, between 2015 and 2017, ozone concentrations exceeded the standards on up to nine days a year (NSW EPA 2018b).

It has been estimated that vehicle kilometres travelled are increasing: passenger transport is increasing in line with population growth of around 1.0–1.5% annually and freight travel is increasing at approximately 2–3% per year (NSW EPA 2019). This means that meeting the ground-level ozone and particle NEPM standards remains a challenge.

Sydney and the urban GMR remain a particular challenge in relation to emissions from motor vehicles. Motor vehicles are estimated to contribute 53% of NO_x, 10% of VOCs, 9% of PM_{10} and 9% of $PM_{2.5}$ to total annual emissions in Sydney (NSW EPA 2019) and 45% of NO_x, 10% of VOCs, 7% of PM_{10} and 8% of $PM_{2.5}$ to total annual emissions in the urban GMR (Sydney, Newcastle and Wollongong) (NSW EPA 2019).

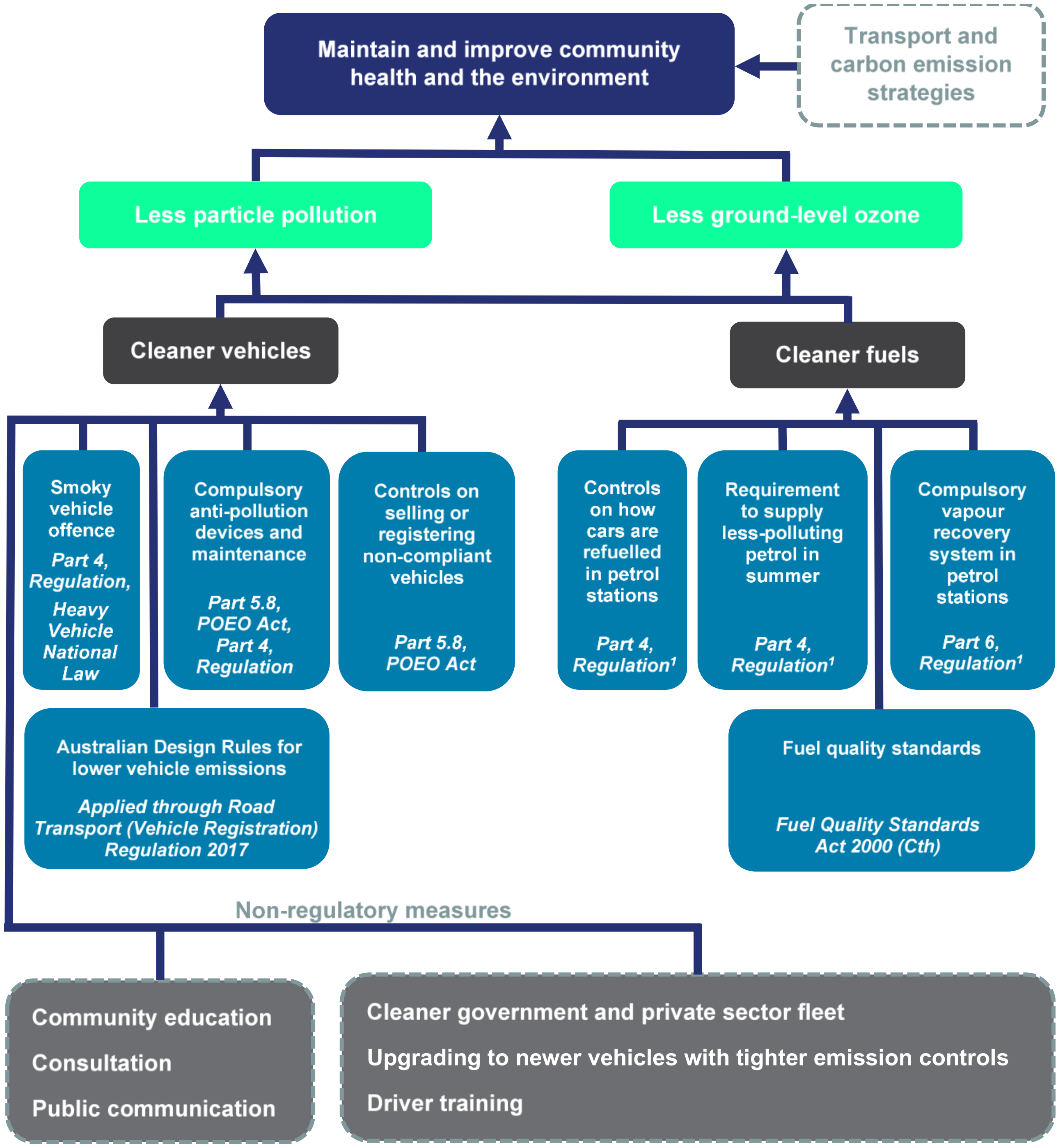
For the health and environmental impacts of particulate matter, ozone, VOCs and NO_x, see Appendix B.

4.1.2. Management of emissions from motor vehicles and motor vehicle fuels

Figure 8 outlines the management of emissions associated with motor vehicles in NSW. The current management strategy uses a mix of regulatory and non-regulatory measures. The regulatory measures are shared between the NSW and Australian governments.

National legislation covers both fuel quality standards and emission standards for new motor vehicles. Health issues that are of concern across Australia are also addressed at the national level, such as by limiting the benzene content of fuel to 1%.

Regulation at the state level takes into account regional characteristics, such as the role that the geography and meteorology of the Sydney Basin plays in forming higher concentrations of ozone. In practice, some provisions are better regulated at the state level, such as those covering smoky vehicles, tampering with pollution equipment or management of petrol volatility.



[1] Moved to Part 8 of the proposed Regulation.

Figure 8 **Management of emissions associated with motor vehicles in NSW.**

4.1.3. Regulatory measures

Vehicle emission standards are set in the Australian Design Rules and have been significantly tightened over the last 40 years. The current minimum standard for new light vehicles is Vehicle Standard (Australian Design Rule 79/04 – Emission Control for Light Vehicles) 2011, while the minimum standard for heavy vehicles is the Vehicle Standard (Australian Design Rule 80/03 – Emission Control for Heavy Vehicles) 2006. These are applied in NSW through the Road Transport (Vehicle Registration) Regulation 2017.

The *Fuel Quality Standards Act 2000* (Cth) provides the legislative framework for setting national fuel quality and fuel quality information standards. Those standards have progressively required cleaner fuels and enabled the use of improved emission control technology.

Part 4 of the existing Regulation aims to reduce emissions from motor vehicles and motor vehicle fuels. The measures in Part 4 address smoky vehicles, anti-pollution devices, petrol overfill protection, and the supply of less-polluting petrol. They aim to complement other non-regulatory and regulatory measures designed to control emissions from motor vehicles, including the Australian Design Rules and fuel quality standards.

Proposed changes to Part 4 of the existing Regulation relate to heavy vehicle anti-pollution devices and petrol volatility. They include:

- exclusion of heavy vehicles over 4.5 t from the requirements relating to excessively smoky vehicles and installation and maintenance of anti-pollution devices on motor vehicles (Part 4, section 20 and Divisions 2, 3 and 4 of the proposed Regulation).
- extension of the period for low summer volatility limits in the NSW GMR to correspond with the peak ozone formation period (Part 8 of the proposed Regulation).

The existing Part 4, Division 5 has been moved to Part 8, Division 3 of the proposed Regulation but remains the same in substance.

As the exclusion of heavy vehicles over 4.5 t is largely administrative,[9] analysis of the new Regulation option for Part 4 is confined to the proposed change to requirements regarding petrol volatility in Part 8 of the proposed Regulation, which is Part 4, Division 6 of the existing Regulation.

Decreasing petrol volatility means less evaporation of petrol. This reduces emissions of VOCs, which are precursors to the formation of smog. Reducing summer petrol volatility is a key measure to reduce ozone formation in summer when ozone exceedances occur.

4.2. Options considered

Three regulatory options were considered:

- Option 1 – business as usual; existing Regulation provisions would be included unchanged in a new regulation
- Option 2 – allow the existing Regulation to be repealed without making a new regulation

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9 There is currently a duplication between the NSW EPA and NHVR in regulating heavy vehicles over 4.5 t with regards to emissions of smoke and the removal, disconnection or impairment of anti-pollution devices. This proposal will result in no change to the requirements and will be cost neutral to users and operators of heavy vehicles over 4.5 t. Benefits are expected from avoided duplication of requirements and the associated costs of administration.

- Option 3 – incorporate the proposed amendments and the existing Regulation provisions in a new regulation.

4.2.1. Option 1: Base case (business as usual)

Option 1 assumes that Division 6 of the existing Regulation ('Petrol Volatility') remains unchanged. This means that summer, as set out in section 27, is defined as 'the period commencing on 15 November in that year and ending on 15 March, inclusive, in the following year'. In addition, the requirements for smoky vehicles and anti-pollution devices for light vehicles are retained.

4.2.2. Option 2: No Regulation

This option presumes that the Regulation relating to the supply of low volatile fuel, as set out in Division 6 of the existing Regulation, is repealed and that the benefits from the regulatory controls over smoky vehicles and anti-pollution devices for light vehicles also lapse.

4.2.3. Option 3: New Regulation

Option 3 proposes to amend the definition of summer to the period from 1 November to 31 March (inclusive) each year and maintain the current smoky vehicle and anti-pollution device requirements for light vehicles. This means that the period during which the petroleum industry must supply lower volatility fuel is extended by 30 days compared to Option 1, beginning slightly earlier and ending later in the season. Analysis of historic ambient air quality data shows that average ozone is increasing, and exceedances are occurring prior to commencement of the current summer petrol volatility season. This change aligns with the Victorian definition of summer and could have some benefits in aligning requirements with those of another state. Retaining the smoky vehicle and anti-pollution device provisions and extending the summer petrol volatility period will deliver health benefits from reduced exposure to pollution.

4.3. Benefits and costs

4.3.1. Summary results

For Part 4 of the existing Regulation, a comparison of the costs and benefits of Options 2 and 3 incrementally to the base case (Option 1) is set out in Table 10 and Table 11. As the timing of the costs and benefits varies over time, they are compared as present values over a 20-year period using a 7% discount rate.

The cost–benefit analysis finds that increasing the summer volatility limits by 30 days (Option 3) would provide significant net benefits of $20.8 million. Removing the Regulation (Option 2) would incur a sizeable net cost of $126.1 million.

In relation to the provisions for smoky vehicles and anti-pollution devices, the analysis finds that retaining the existing Regulation would result in a small net welfare gain of $3.7 million.

Table 10 **Part 4: Comparison of PV costs and benefits of Options 2 and 3 with those of Option 1 – summer petrol volatility limits.**

Cost and benefit elements	Option 2 (present values, $m)	Option 3 (present values, $m)
Cost to industry	–21.50	5.54
Cost to government	–0.62	0.00
PV total cost	**–22.12**	**5.54**
Value of health impact	–142.32	25.06
Motorist savings	–3.70	0.70
Distributor savings	–2.30	0.58
PV total benefits	**–148.30**	**26.34**
NPV	**–126.18**	**20.80**
BCR	**n.a.**[a]	**4.76**

a In this and subsequent similar tables a BCR marked “n.a.” is one that could not be calculated because benefits and/or costs are negative.

Table 11 **Part 4: Comparison of PV costs and benefits of Options 2 and 3 with those of Option 1 – smoky vehicles.**

Cost and benefit elements	Option 2 (present values, $m)	Option 3 (present values, $m)
Cost to motorist	–0.41	0
Cost to government	–0.85	0
PV total cost	**–1.26**	**0**
Value of health impact	–4.96	0
PV total benefits	**–4.96**	**0**
NPV	**–3.70**	**0**
BCR	**n.a.**	**n.a.**

4.3.2. Benefits

Summer petrol volatility limits

Lower petrol volatility over summer reduces the amount of petrol vapour lost during petrol distribution and the transfer of petrol to a motor vehicle at a service station. It also reduces the amount of petrol vapour that evaporates from a car’s petrol tank and the amount emitted in the car’s engine exhaust.

Figure 9 sets out the projected reductions in VOC emissions over a 20-year period, relative to Option 1. Under Option 3 (extending the summer volatility limit timeframe by 30 days and ending it later in the season), emission reductions are about 370 t/year relative to Option 1, increasing to 397 t in 2040–41. The estimated value of benefits from reductions in VOC emissions under Option 3 is $26.3 million (see Table 10 and Table 11). Those benefits include:

- lower emissions of VOCs, resulting in less ozone at ground level and less damage to human health, which is shown in the avoided health costs
- less fuel lost to the atmosphere, which benefits motorists and petrol distributors (savings to motorists and distributors).

As stated in Appendix B, controls on VOC emissions are in place for two reasons:

- Some VOCs, such as benzene and PAHs, are individually significant for health and the environment as air toxics.
- VOCs as a group are significant as a precursor to the formation of ground-level ozone.

The health impacts of direct exposure to VOCs depend on the composition of the VOCs, their concentration and the length of exposure. General effects of exposure to VOCs include irritation to the eyes, nose and throat; headaches; loss of coordination; nausea; and damage to the liver, kidneys and central nervous system. Some VOCs are also known or suspected to cause cancer in humans.

Based on those impacts, the damage cost of VOC emissions has been estimated at $5,288/t in 2021–22, increasing to $6,698/t in 2040–41 (see Appendix B).

The removal of the Regulation (Option 2) would result in the loss of benefits derived from reduced emissions.

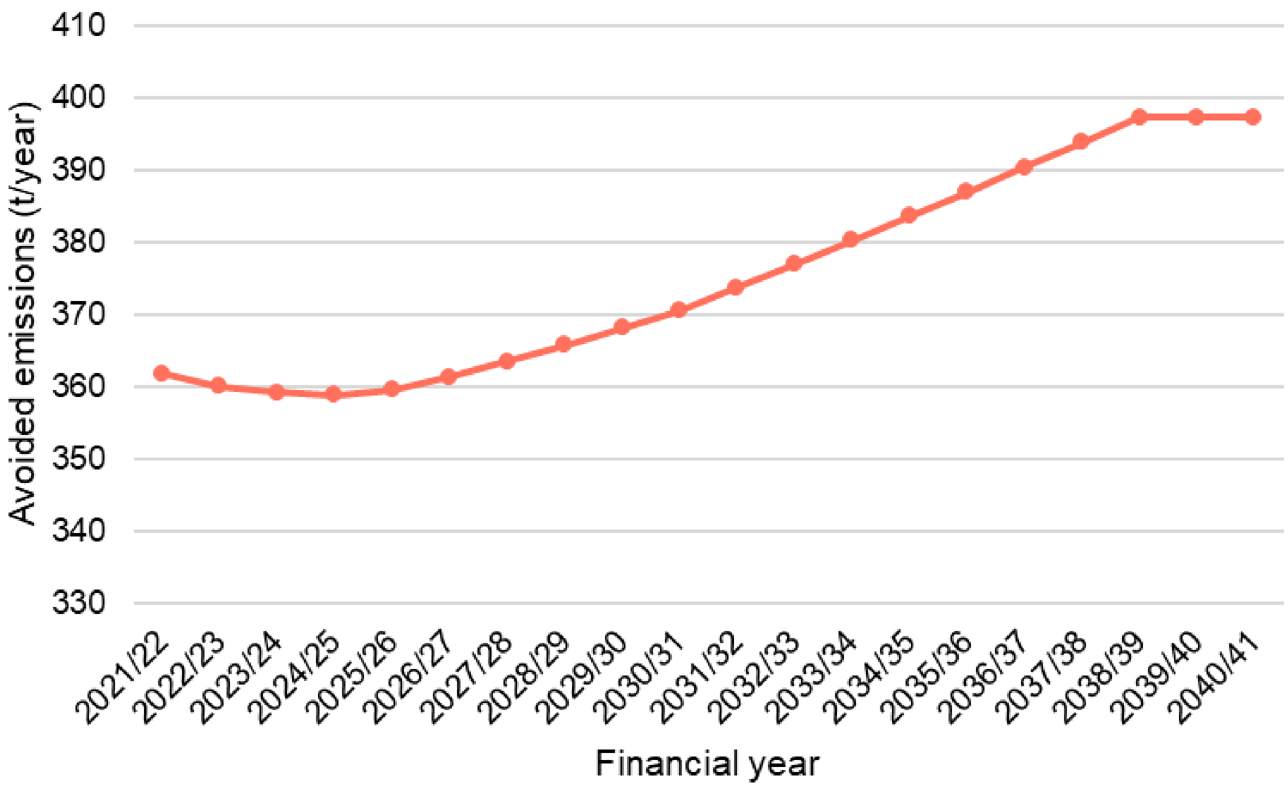

Figure 9 Avoided VOC emissions, Option 3 relative to Option 1.

Smoky vehicles and anti-pollution devices

A smoky vehicle emits higher concentrations of pollutants than an average vehicle. If the regulation is repealed (Option 2) the benefits from current provisions that relate to smoky vehicles would lapse. Removing this provision is estimated to result in an increase of 0.23 t of NO_x emissions, 0.17 t of VOCs emissions and 1.73 t of PM_{10} emissions, compared to current emissions under the Regulation.

The quantifiable benefit of the smoky vehicles provisions are lower health costs due to the decrease in emissions of pollutants from vehicles repaired in response to infringement notices or notices to repair a smoky vehicle. Removing the Regulation would result in increased emissions and, consequently, a loss of avoided health costs of approximately $5 million (PV) over 20 years.

The regulations covering anti-pollution devices include anti-tampering provisions that aim to discourage interference with the anti-pollution mechanisms required by law or installed by the manufacturer.

The control of emissions from vehicles relies on the efficient operation of either discrete devices or key components of a variety of integrated systems. A number of those devices and components are defined as ‘prescribed anti-pollution devices’, and it is an offence for an owner to use (or allow to be used) a vehicle that should have such a device fitted but does not.

The benefit of the anti-tampering provisions for anti-pollution devices is lower health costs due to the decrease in emissions of pollutants from vehicles.

4.3.3. Costs

Summer petrol volatility limits

If a longer definition of ‘summer’ were introduced, there would be potential operating costs to the petroleum industry (domestic refineries and importers) for supplying lower volatility petrol (Table 10 and Table 11). On average (for all petrol consumed in the GMR), those costs are estimated to be about initially 0.09 cents/litre, increasing to about 0.14 cents/litre in 2040–41, based on a small cost impact on domestically produced petrol and a zero impact on imported petrol.

Domestically produced petrol

Due to the scope of the analysis, only cost impacts on domestic refineries that are passed through to NSW motorists are relevant.[10] Since the closure of refineries in NSW, it is estimated that, at most, only 20% of the petrol consumed in the GMR, and therefore subject to the summer volatility limit, is produced by domestic refineries, principally in Victoria (Fueltrac 2018). The cost impact on those refineries will result from forgone revenue due to the extraction of butane from the petrol in order to meet the summer volatility limit, from its highest value end-product (petrol) and doing one or both of the following:

- using it to increase butane blend ratios in automotive liquefied petroleum gas (LPG) up to the specification limit and/or using incremental refining (such as alkylation) to combine light olefins to form an alkylate (a blended paraffin, high-octane, low-vapor-pressure gasoline component)
- selling it into the petrochemical or export market.

The cost implications are dependent on prevailing oil prices and exchange rates. Nevertheless, available information suggests it is likely that only a very small proportion of the butane (<1%) will

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[10] Impacts occurring outside of NSW are outside the scope of this analysis.

be redirected to a low-value use, such as petrochemicals, or to exports. Most will go either to alkylation/blending (with no loss in value) or to LPG production (with only a small loss in value).

Overall, at present the cost to domestic refineries of meeting the summer volatility limit is estimated to be about 0.45 cents/litre (Fueltrac 2018). With the increase in international oil prices projected over the assessment period, this impact is estimated to increase to about 0.67 cents/litre by 2040–41.[11]

Imported petrol

The premium on imported petrol that meets the summer volatility limit is estimated to be zero, since the volatility of gasoline imported from efficient, large-scale export refineries in Asia is typically limited to 60 kPa throughout the year (Fueltrac 2018).

Government costs

The annual costs to government associated with monitoring compliance and enforcement activities are estimated to be $58,505 per year. There would be no discernible increase in those costs under Option 3. As would be expected, if the Regulation were repealed these costs in Option 2 would be removed.

Smoky vehicles and anti-pollution devices

The quantifiable costs of the provisions for smoky vehicles and tampering with anti-pollution devices are the costs of government administration and the costs of repairing vehicles.

Removing the provisions would remove the cost to the motorist of having to undertake repairs. Typical repairs to a smoky diesel vehicle include tuning, filter replacements, new injectors and possibly engine reconditioning. Typical repairs to a smoky petrol vehicle include retuning, head gasket replacement and possibly engine reconditioning or rebuilding.

Defective vehicle notices require the vehicle owner to undertake the necessary mechanical repairs or risk having the vehicle registration cancelled. Penalty infringement notices may also be issued for smoky vehicles. To comply with the anti-tampering provisions, vehicle owners are required to repair vehicles found to have their emission systems altered.

The cost to government of enforcing the smoky vehicle and anti-tampering provisions of the Regulation can include staff salaries and on-costs and provision of vehicles for use in enforcement activities, stationery and postage, the administration of the website reporting system, the training of authorised officers and prosecutions. These costs would clearly not be incurred should the provisions be removed.

4.4. Conclusion

Extending the period defined as summer (Option 3) would result in the highest NPV and BCR, while repealing the existing Regulation (Option 2) would result in undesirable health costs. With NSW refineries closed, domestically produced fuel would mainly be supplied by Victoria.

[11] This is a conservative estimate. It is possible that domestic refineries are not losing any revenue to meet the summer volatility limit, since imported crude oil that has higher levels of butane was probably obtained at low cost.

5. Air impurities emitted from activities and plant

Regulation reference

Part 5 of the existing and proposed Regulation.

Air pollution source

Emissions from activities (including industrial, agricultural or commercial activities) and plant (referred to as ‘industrial emissions’) are a major source of air pollution in NSW, significantly affecting ambient and local air quality.

Options considered

The three options considered were:

- Option 1 (base case) – retain the existing Regulation
- Option 2 (no Regulation) – repeal the existing Regulation
- Option 3 (new Regulation) – plant and activities on scheduled premises currently classified in Group 3 and Group 4 of the Regulation will be moved to Group 5 of the Regulation by 1 July 2025 and to Group 6 by 1 July 2030.

Analysis

The cost–benefit analysis finds that amending the existing Regulation to ensure an earlier transition for scheduled premises to Group 5 and then to Group 6 (Option 3) would provide very large net benefits ($665 million over the 20-year period) for NSW. Due to the GMR’s high population densities, the benefits (and costs) would be more significant in the GMR than elsewhere. The major quantified benefits would be from health improvements arising from reduced particulates ($PM_{2.5}$) and NO_x.

Repealing the Regulation (Option 2) would incur a large economic cost on NSW through the impact on health of increased emissions. Emissions are expected to increase relative to Option 1 because most industry stack emissions (for scheduled and non-scheduled premises) are controlled through the existing Clean Air Regulation.

Recommendation

The new Regulation (Option 3) is strongly preferred to other options, including continuing with the status quo (Option 1). Although there would be considerable costs to industry, the benefits from avoided health impacts would more than offset those costs.

5.1. Background

5.1.1. Need for government action

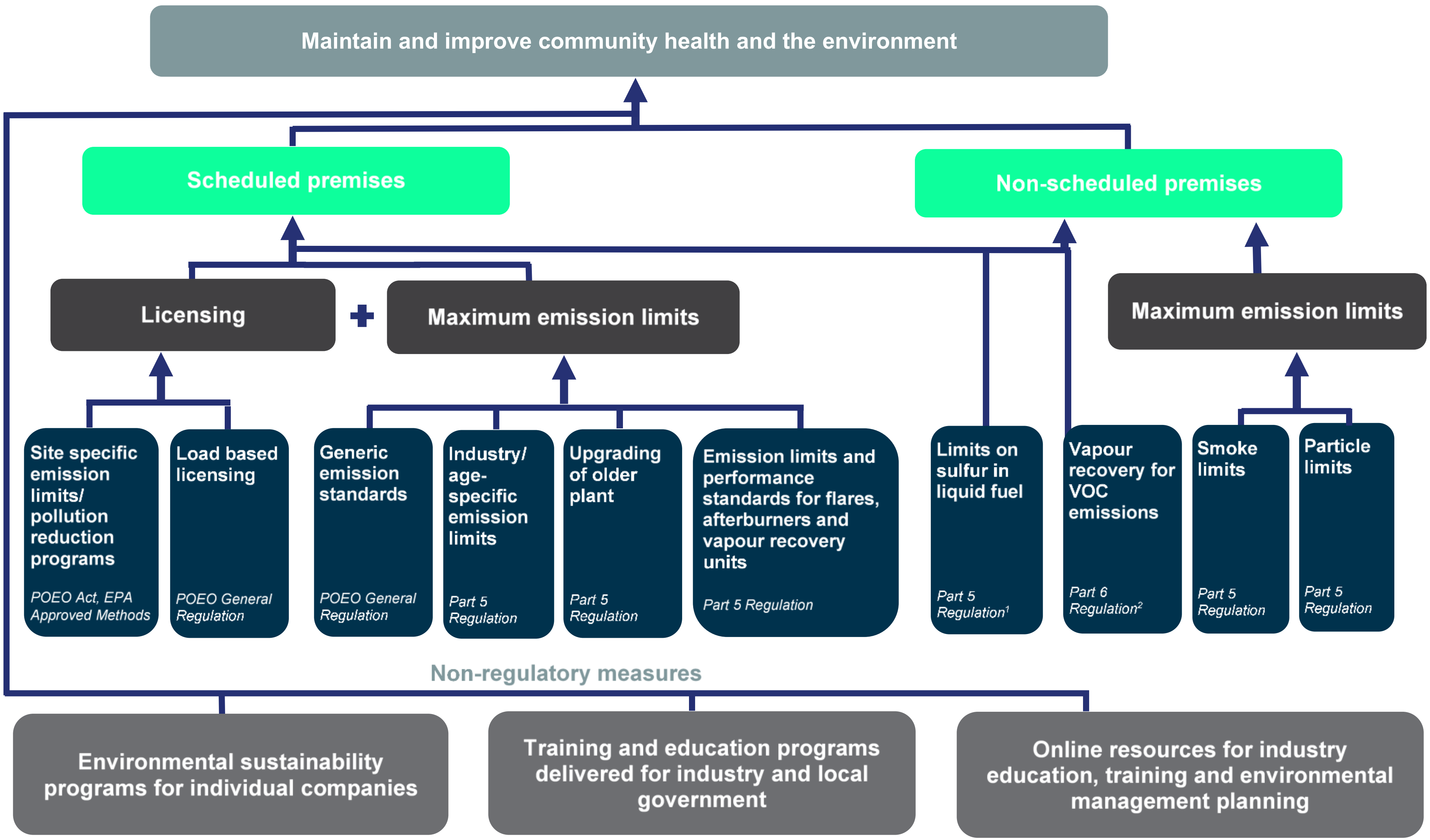
Industrial emissions make a major contribution to total air pollution emissions in NSW, significantly affecting ambient and local air quality. Even with existing controls, industry is responsible for approximately 85% of all anthropogenic emissions of particulate matter (PM_{10}), 57% of $PM_{2.5}$ and 60% of the anthropogenic emissions of NO_x in the NSW GMR (NSW EPA 2019). Industry is also a principal source of air toxics in the region (NSW EPA 2019). These substances are associated with significant health and environmental effects (see Appendix B).

Older activities and plant account for a disproportionate amount of emissions compared to newer sources. Emission controls on older sources that have not already upgraded are now 20–40 years old and approaching the end of their serviceable life. The emission standards for industrial air pollutants have meanwhile been progressively tightened over the past few decades. Previously, the oldest scheduled premises classified in Groups 1 and 2 were moved to Group 5 or have site-specific emission concentration standards. These revised emission standards are responsible for much of the improvement in air quality in NSW.

Requiring older activities and plant to progressively upgrade their emissions controls with reasonably available control technologies ensures a level playing field for industry, removing barriers to entry for new facilities to contribute to economic development in NSW. A phased transition of older activities and plant to the more stringent emission standards applicable to newer industry participants provides a structured path to upgrade and greater certainty for new investment with sufficient lead times and a transparent process for setting alternative emission limits where upgrades are not economically feasible.

5.1.2. Management of industrial emissions

The current management strategy for industrial emissions in NSW consists of maximum emission standards and regulatory and non-regulatory incentives, together with a range of programs providing both targeted and generalised assistance to encourage industry to integrate sustainability into its operations (see Figure 10).



[1] Moved to Part 8 of the proposed Regulation, [2] moved to Parts 6, 7 and 8 of the proposed Regulation.

Figure 10 Management of industrial emissions in NSW.

5.1.3. Regulatory measures

In NSW, industrial air emissions are regulated through the setting of maximum emission concentration standards, together with a risk-based licensing system for individual industrial premises (discussed below). The principal regulatory instrument is the POEO Act, supported by the:

- Clean Air Regulation, which sets maximum emission concentration standards
- Protection of the Environment Operations (General) Regulation 2021 (the POEO General Regulation), which makes provisions for load-based licensing.

Risk-based licensing can inform the level of regulatory and compliance oversight for activities that hold an environment protection licence under the POEO Act (NSW EPA 2016a). Risk-based licensing involves an assessment of all of the following:

- the risk of different licensed activities
- the allocation of more attention to more risky activities or licensees with a poor compliance history
- the reduction of licence fees if risk is minimised by the licensee.

Where an activity is seen to pose a higher risk to the environment, the EPA can attach specific conditions to an environment protection licence. If a licence has already been issued, the EPA can vary the licence, attaching new conditions.

The POEO Act contributes towards reducing air emissions from industry by:

- requiring industrial premises to comply with emission standards set in the Clean Air Regulation or, where no standards are applicable, requiring air pollution to be minimised
- requiring environment protection licences for specific premises and activities, which may include emission standards additional to or more stringent than those specified in the Clean Air Regulation and contain conditions requiring the holder to undertake pollution studies or comply with a pollution reduction program determined by the EPA
- creating offences for air pollution because of failures in maintenance or in proper and efficient operation or handling
- creating offences for odours emitted from licensed premises except in accordance with the conditions of the licence.

Part 5 of the Clean Air Regulation controls air emissions from plant and activities operating on scheduled and non-scheduled industrial and commercial premises. It contributes to minimising emissions by applying:

- general standards of emission concentration for all industry
- specific standards of emission concentration based on the type of industrial activity and the age of the plant and/or emission units
- a process for reviewing emission concentration standards that apply to older scheduled plant
- performance standards for afterburners, flares and vapour recovery units (VRUs).

The Clean Air Regulation also works to minimise industrial emissions by regulating the storage and distribution of VOLs (see Section 6 of this RIS).

The POEO General Regulation also contributes to minimising emissions from NSW industry by:

- providing an ongoing economic incentive for specified licensed activities to reduce emissions through fees based on industries' emission loads (load-based licensing)
- providing incentives for reducing emissions through load reduction agreements, which allow fee rebates in return for measures taken to reduce pollution in the future

- setting administrative fees for environment protection licences in accordance with an environmental management category as part of the risk-based licensing approach
- giving effect to the *National Environment Protection (National Pollutant Inventory) Measure* by requiring the submission and publication of relevant industrial emissions data.

Part 5 of the Clean Air Regulation operates in conjunction with the POEO Act and the POEO General Regulation to set limits on emissions from plant, including emissions of particulates, NO_x, sulfuric acid mist, dioxins, furans, hydrogen sulphide, fluorine, hydrogen chloride and chlorine.

Comparing emission standards under the Clean Air Regulation with those under licensing

The Clean Air Regulation sets standards for maximum emission concentrations. Under the POEO Act, many (but not all) industries require environment protection licences for their activities. An environment protection licence may contain conditions that require specific emission standards more stringent than those that would apply under the Clean Air Regulation.

Under the POEO General Regulation, a subset of environment protection licence holders are also subject to the load-based licensing scheme, which links licence fees to the level of emissions as an incentive to reduce emissions and limit annual pollutant loads.

Whereas load-based licensing focuses purely on the annual mass of pollutants, the Clean Air Regulation also targets localised and acute impacts of emissions. It applies short-term emission concentration standards to individual stacks at the point of discharge to the atmosphere and reflects the proper and efficient operation of the technology installed. This sets a minimum standard of performance to reduce the risk of localised and acute pollution episodes in addition to longer-term impacts.

Table 12 summarises the role of the Clean Air Regulation, the licensing provisions of the POEO Act and the POEO General Regulation in reducing emissions at licensed activities.

Table 12 Emission standards for industry under the Clean Air Regulation and POEO General Regulation.

Point of discharge standards		POEO General Regulation: load-based licensing
Clean Air Regulation	POEO risk-based licences	
Applies to all activities	Applies to licensed activities	Applies to a subset of licensed activities
Sets emission concentration standards as minimum performance standards	Sets emission concentration standards at the same or more stringent levels than general standards Sets fees based on the assessed risk of the premises	Sets fees by reference to annual emission loads to create an incentive to reduce loads emitted
Applies to individual emission points		Applies to entire premises or sites
Emissions averaged for specified periods		Emission load over 12 months
Protects against localised and acute impacts of emissions, protects local air quality, and protects ambient air quality against cumulative increases in emissions		Protects ambient air quality against cumulative increases in emissions
No aggregation		Option for aggregation of load-based licensing emissions for more than two licences (with approval of EPA)

Source: DECCW (2010)

For scheduled premises, emission standards are differentiated according to the date an activity or plant commenced operation. Table 13 sets out the current applicable ‘Groupings’ of emission standards based on the date of commencement (note that Group 1 or 2 premises have been upgraded to Group 5 or have site-specific emission concentration standards). Approximately 18% of current sources are classified as either Group 3 or Group 4, based on the date they were commissioned or significantly modified, upgraded or replaced. Schedules 2, 3, 4 and 6 of the existing Regulation set out the emission standards applicable to each group of activities and plant. The groups reflect the development of emissions control technology over time and emission standards become more stringent in line with the technology’s emissions reduction capability.

For non-scheduled premises – where the occupier is not required to hold an environment protection licence under the POEO Act – the existing regulation sets emission standards for smoke and solid particles.

Table 13 Current emission standards according to date of commencement.

Time period	Scheduled premises				Non-scheduled premises	
	Default	Transition	Replacement (GMR only)/ alteration	Lower standard for licence variation[a]	Default	Replacement (GMR only)
Before 1 Jan 1972	Group 1	Group 5 from 1 Jan. 2012	Group 6	Group 1[b]	Group A	Group C
1 Jan 1972 – 30 June 1979	Group 2	Group 5 from 1 Jan. 2012	Group 6	Group 2		
1 July 1979 – 30 June 1986	Group 3	n.a.	Group 6	Group 3		
1 July 1986 – 31 July 1997	Group 4	n.a.	Group 6	Group 4		
1 Aug 1997 – 31 Aug 2005	Group 5	n.a.	Group 6	Group 5	Group B	Group C
On or after 1 Sept 2005	Group 6	n.a.	Group 6	n.a.	Group C	Group C

[a] Licence variations may apply to standards in relation to the alteration or replacement of emission units (Group 6) or the transition of standards from Groups 1 and 2 to Group 5.

[b] Under the Clean Air Regulation, former Group 1 plant became subject to Group 2 standards on 1 January 2008 and Group 5 on 1 January 2012. Licence variations allow alternative standards for some plant.

Source: DECCW (2010)

There are currently around 100 licensed premises with around 260 individual air emission sources that emit air impurities from activity or plant that are classified as belonging to Group 3 or 4. Table C22 in Appendix C provides more detail on the number of sources requiring emission reductions to meet Group 5 and 6 standards for PM, NO_x and VOCs.

For non-scheduled premises, in the absence of the Regulation, there are a number of pollution offences that could be used to regulate them, as for scheduled premises. However, relying on enforcement as the primary regulatory option would become more challenging and resource intensive in the absence of a licensing regime.

5.2. Options considered

Proposed changes to Part 5 of the Clean Air Regulation relate to the introduction of more stringent emission requirements for plant and activities. Three regulatory options were considered:

- Option 1 – business as usual; existing Regulation provisions would be included unchanged in a new regulation
- Option 2 – allow the existing Regulation to be repealed without making a new regulation
- Option 3 – incorporate the proposed amendments and the existing Regulation provisions in a new regulation.

5.2.1. Option 1: Base case (business as usual)

Option 1 assumes that Part 5 of the Clean Air Regulation remains unchanged. This means that maximum emission concentration standards currently in place by industry category and age of plant would remain unchanged and would complement the role of licence conditions under the POEO General Regulation. Existing provisions for non-scheduled premises would also be maintained.

It is important to note that the status quo under this option refers to the regulatory framework, not emissions or (in some cases) compliance costs linked to that framework. Under Option 1, emissions are expected to fall over time, reflecting that:

- certain older plant in some premises (currently classified under Groups 3, 4 and 5) is expected to undergo a major upgrade and will be required under the existing Regulation (section 34) to improve emission control efficiency to meet Group 6 emission concentration standards in the analysis timeframe
- some activities, including power stations, are expected to cease their operation in the timeframe of the analysis.

Unlike the regulatory regime for scheduled premises, there is no requirement for existing non-scheduled premises to upgrade to more stringent emission standards, although upon replacement, an emission unit in the GMR belonging to Group A or Group B is then regarded as belonging to Group C.

Despite an expected fall in emissions over time from existing premises, exposure to air pollution is increasing along with health impacts and costs, due to population growth and urbanisation. This will especially be an issue for growth areas in Western Sydney, which experience higher levels of ozone and fine particles. Not requiring emission reductions from existing premises also disadvantages new industry players.

5.2.2. Option 2: No Regulation

Option 2 assumes that the regulated emission concentration standards as set out in Part 5 of the Regulation would no longer be in place. Emissions are expected to marginally increase but would be mitigated using other regulatory measures such as licensing and offences under the POEO Act. Regulatory costs to government would approximately double and potentially increase for industry relative to Option 3.

5.2.3. Option 3: New Regulation

Under the amended Part 5 of the Clean Air Regulation, it is proposed that plant and activities on scheduled premises[12] currently classified in Groups 3 and 4 of the Regulation[13] will be moved to Group 5 of the Regulation by 2025 and to Group 6 by 2030.

Thus, premises with scheduled plant and activities, currently classified in Groups 3 and 4, would be subject to more stringent emission concentration standards. It is expected that this would result in emission reductions relative to Option 1 but also impose greater capital and operating costs on the relevant premises.

Existing regulatory provisions for non-scheduled premises would be retained.

5.3. Benefits and costs

5.3.1. Summary results

For Part 5 of the Regulation, a comparison of the costs and benefits of Options 2 and 3 incrementally to the base case (Option 1) is set out in Table 14. As the timing of the costs and benefits varies over time, they are compared as present values over a 20-year period using a 7% discount rate.

Table 14 Distributional analysis and comparison of PV costs and benefits for Options 2 and 3 with the base case.

Cost and benefit elements	Option 2			Option 3		
	GMR	Non-GMR	NSW	GMR	Non-GMR	NSW
Cost to industry						
• $PM_{2.5}$	0.0	0.0	0.0	7.3	1.7	9.0
• NO_x[a]	0.0	0.0	0.0	208.9	3.9	212.8
Cost to government	8.7	7.2	15.9	6.5	1.5	7.9
PV total cost	**8.7**	**7.2**	**15.9**	**222.7**	**7.1**	**229.7**
Industry savings	0.0	0.0	0.0	0.0	0.0	0.0
Value of health impact						
• $PM_{2.5}$	–483.9	–71.6	–555.5	258.2	9.4	267.6
• NO_x[a]	–119.5	–1.5	–121.0	626.0	1.7	627.7
PV total benefits	**–603.4**	**–73.1**	**–676.5**	**884.2**	**11.1**	**895.3**
NPV	**–612.1**	**–80.3**	**–692.4**	**661.5**	**4.0**	**665.6**
BCR	**n.a.**	**n.a.**	**n.a.**	**4.0**	**1.6**	**3.9**

[a] Includes both scheduled and non-scheduled premises.

[12] Non-scheduled premises would not be affected by the proposed change in regulation.

[13] Group 3 includes plant or activities that commenced operation between 1 July 1979 and 30 June 1986. Group 4 includes plant or activities that commenced operation between 1 July 1986 and 31 July 1997.

Amending the existing Regulation to ensure an earlier transition of scheduled premises to Group 5 and then to Group 6 (Option 3) would provide very large net benefits of $661.5 million for the NSW GMR, $4 million for the non-GMR regions of NSW, and $665.6 million for NSW as a whole over the 20-year period analysed. Removing the Regulation (Option 2) would incur a sizeable net economic cost of $612.1 million for the NSW GMR, $80.3 million for the non-GMR regions of NSW, and $692.4 million for NSW as a whole over the 20-year period. Due to the GMR's much higher population densities, the benefits and costs would be more significant in the GMR than in other regions.

5.3.2. Benefits

The major quantified benefits that arise from the proposed reforms to Part 5 of the Regulation relate to health improvements arising from reduced $PM_{2.5}$ and NO_x for scheduled premises. The Regulation would also result in reduced emissions of other pollutants, with associated health benefits.

Under Option 2 (no Regulation), emissions are expected to marginally increase relative to Option 1 (the status quo) because many industry stack emissions (from scheduled premises) are controlled through the existing Clean Air Regulation. Importantly, this does not mean emissions would increase in direct proportion to the number of premises currently covered by the Regulation. Rather, considering likely real-world outcomes, the implementation of Option 2 is expected to result in the following:

- for scheduled premises, other mechanisms will be found to achieve the desired emission outcomes, most likely by incorporating the emission concentration standards in the environment protection licences of those premises. However, this is expected to entail substantially greater regulatory costs for both government and potentially for industry than is involved in the existing Regulation
- for some premises, emissions could also be controlled to an extent by the general provisions of Part 5.2 of the POEO Act, which create offences for polluting. Section 128(2) of the POEO Act requires, in the absence of specific emission standards, the use of such 'practicable means' as may be necessary to prevent or minimise air pollution. It is anticipated that over time there would be a gradual deterioration in emission levels for pollutants and that the parameters of the term 'practicable' would be tested using cost as a factor.

Other key considerations for this analysis are that:

- under the base case (Option 1), emissions increase by 1% per year
- some power stations are assumed to progressively close during the analysis period as renewable electricity sources increasingly meet NSW's energy needs. Timing of this transition cannot be predicted due to uncertainty in economic conditions and supply and demand issues. The analysis takes a conservative approach to estimating closure timeframes and power stations' contributions to emissions reductions under the options assessed in this RIS.

Figure 11 shows the projected path of NO_x emissions over the 20-year analysis period. Noticeable downward steps in emissions coincide with the indicative and conservatively estimated closures of power stations. Under Option 3, significant reductions in NO_x emissions are evident following the requirement that all sources achieve Group 5 emission standards by 2025.

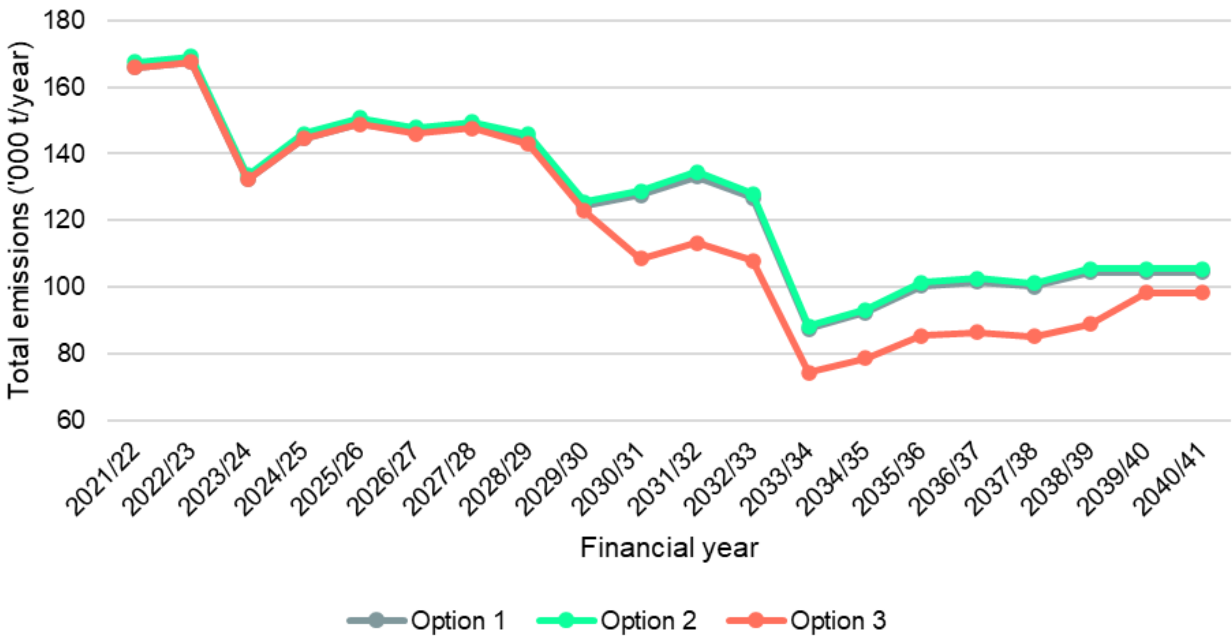


Figure 11 **Total NO_x emissions from industrial sources in the Greater Metropolitan Region.**

5.3.3. Costs

Under Option 3, there would be additional capital and operating costs to industry associated with meeting the more stringent standards. Amending existing regulations to ensure an earlier transition to Group 5 and then to Group 6 (Option 3) is estimated to result in additional costs (in PV terms) of $208.9 million for the NSW GMR, $3.9 million for those outside the GMR and $212.8 million for NSW as a whole over the 20-year period analysed. The cost estimation methodology is explained in Appendix C.

Other industry reforms occurring concurrently under NSW Government energy policies and the decarbonisation of the economy may influence industry's investment decisions, including to upgrade plant, and the speed with which some industries are phased out. It may be that industry can pass costs associated with changes to the Regulation on to consumers. Where costs cannot be passed onto consumers industry would bear the cost. The impacts of the Regulation changes and broader economic factors on industry and consumers cannot be readily determined and are not addressed in this RIS.

PM abatement

The current regulatory emission concentration standards for PM are, depending on the industry, 200–250 milligrams per cubic metre (mg/m^3) for Groups 3 and 4; 100 mg/m^3 for Group 5; and 50 mg/m^3 for Group 6. Theoretically, moving Group 3 and 4 sources to the Group 5 standard would require a reduction of 60% in the emissions concentration standard and a reduction of 80% in the emissions concentration standard to meet Group 6 standards. To achieve this level of control it is assumed that fabric filters (baghouses) would offer the least cost option applicable to most sources (US EPA 2012). This analysis assumes that sources with existing controls (baghouse or electrostatic precipitator) or sources that burn natural gas are already achieving Group 6 emission standards, so no 'real' emission reduction potential exists.

Baghouse control was identified for 28% of potential PM emissions sources, with a total emission reduction potential of 107 t/year in the GMR (assuming 99% control of the reported existing emissions) and 132 t/year in the whole of NSW.

NO_x abatement

The current regulatory emission standards of concentration for NO_x are, depending on the industry, 2500 mg/m^3 for Groups 3 and 4, 70–2000 mg/m^3 for Group 5, and 70–700 mg/m^3 for Group 6. Moving Group 3 and 4 sources from their current standards of concentration to the Group 5 standard would generally require a reduction of 20% for most sources.

The reported control efficiencies that can be achieved with low NO_x burners (LNBs) range from 25% (cement manufacturing) to 84% (natural gas turbines); however, control efficiencies greater than 50% are generally not achieved (US EPA n.d., accessed 30 August 2018). This analysis assumes that LNBs are required to achieve Group 5 standards, although it is noted that other combustion controls (that is, those that adjust air:fuel ratios) may be sufficient for those sources with a lower emission reduction requirement. The assumption of LNBs for all sources would be likely to result in a higher cost to industry and is therefore a more conservative assumption for the cost–benefit analysis.

Moving Group 3 and 4 sources from their current standards of concentration to Group 6 standards would generally require a reduction greater than 70%.

The reported control efficiencies that can be achieved with selective non-catalytic reduction (SNCR) range from 35% (utility boilers) to 75% (fluidised bed combustion); however, control efficiencies greater than 60% are generally not reported (US EPA n.d., accessed 30 August 2018). The reported control efficiencies that can be achieved with selective catalytic reduction (SCR) range from 75% to greater than 90%.

This analysis therefore assumes that SCR is needed to achieve Group 6 standards for most sources. While LNB might provide lower cost options for some sources such as power stations, consistent with the analysis for Group 5, an assumption of SNCR would result in a higher cost to industry overall and is therefore a more conservative assumption for the cost–benefit analysis.

It is acknowledged that SCR is a high-cost technology option, and this technology is not stipulated within the Regulation. However, if industry were able to implement lower cost alternatives to achieve the requirements of the Regulation, that would improve the net welfare gain, as estimated in the cost–benefit analysis.

The monitoring and enforcement cost for government would also be higher under Option 2 by approximately $15.9 million for NSW over the 20-year period analysed.

5.4. Conclusion

Option 3 is strongly preferred to other options, including Option 1 (business as usual). Although there would be considerable costs to industry, the benefits from avoided health impacts would more than offset those costs. The BCR of Option 3 relative to Option 1 is 4.0 for the NSW GMR, 1.6 for regions outside the GMR and 3.9 for NSW as a whole.

From the analysis it is clear that the benefits would accrue to society, but it is unclear to whom the costs will accrue. It may be that industry can pass the costs on to consumers, in which case the beneficiaries could effectively be paying for the reform costs. Where costs cannot be passed on to consumers (due to competitive pressures), industry would bear the cost. The proposed changes in the draft Regulation are just one of a number of factors influencing industry’s investment decisions, along with actions being considered by the NSW Government under its energy policies and decarbonisation of the economy. The full impact of these combined factors cannot be readily determined.

6. Control of volatile organic liquids

Regulation reference

Part 6 of the existing Regulation. In the proposed Regulation the parts have been split to Part 6 Volatile organic liquids – tanks and loading plant, Part 7 Volatile organic liquids – large tanker trucks and Part 8 Petrol including vapour recovery at petrol service stations.

Air pollution source

Volatile organic liquids (VOLs) have the potential to evaporate in ambient conditions. The production, consumption, storage or transport of VOLs can result in these vapours being released into the atmosphere as volatile organic compounds (VOCs), contributing to local, regional and global air pollution.

Options considered

The three options considered were:

- Option 1 (base case) – retain the existing Regulation so there is no change to the specifications required for storage and loading facilities
- Option 2 (no Regulation) – remove the existing specifications
- Option 3 (new Regulation) – implement more stringent control equipment and/or emissions limits for large storage and loading plant and small loading plant.

Analysis

The cost–benefit analysis finds that, in relation to large storage tanks, the proposed Regulation (Option 3) would result in a net economic benefit of $0.84 million, with a health impact benefit of $0.87 million (in PV terms) through reduced VOCs emissions, compared to Option 1.

In the case of petrol stations, repealing the existing Regulation (Option 2) would result in significantly higher health costs, so Option 1 is preferred. Option 3 does not affect emissions from petrol stations and so is not considered.

Recommendation

In relation to large storage tanks, Option 3 (the new Regulation) is preferred, as it results in improved health benefits through avoiding VOCs emissions. Option 2 (repealing the Regulation) would result in welfare loss due to an expected deterioration in air quality and the associated impacts on public health and the environment.

The analysis of petrol stations shows that retaining the existing Regulation requiring VR (as opposed to repealing the Regulation) provides a net public benefit.

6.1. Background

6.1.1. Need for government action

VOLs are any organic compounds that exist as liquids at normal temperatures of use or storage. They have a high vapour pressure,[14] resulting from a low boiling point, making them highly volatile. VOLs, such as petrol,[15] can be released into the atmosphere as VOCs, which contribute to local, regional and global air pollution.

A range of industries (such as the petroleum, petrochemical, chemical and bulk storage industries) consume, distribute, produce, store or transport VOLs. Those industries have the potential to release VOCs into the atmosphere from:

- storage tanks
- loading plant
- road tankers being filled at terminals
- underground storage tanks at service stations
- fuel tanks when vehicles are filled with petrol at service stations.

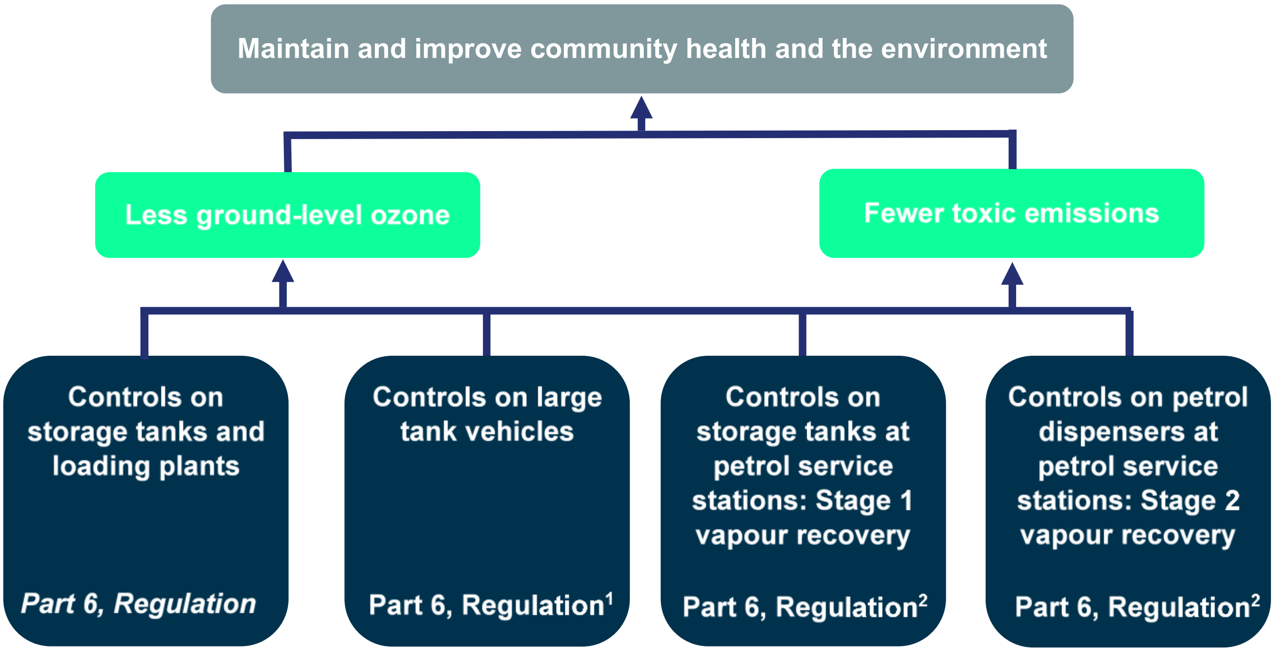
6.1.2. Management of volatile organic liquids

The Clean Air Regulation aids in the control of VOLs (see Figure 12) by specifying control equipment, such as:

- vapour disposal units (VDUs) or vapour recovery units (VRUs), covers and seals for large storage tanks
- vapour collection systems for large loading plant, tank vehicles and underground storage tanks at service stations
- fuel bowsers at service stations.

[14] The Clean Air Regulation defines VOLs as liquids with vapour pressure of more than 3.44 kPa.

[15] Organic liquids in the petroleum industry, such as petrol and crude oil, are mixtures of hydrocarbons having dissimilar true vapour pressures. Organic liquids in the chemical industry, such as benzene or mixtures of isopropyl and butyl alcohols, are composed of pure chemicals or mixtures of chemicals with similar true vapour pressures.



[1] Moved to Part 7 of the proposed Regulation, [2] moved to Part 8 of the proposed Regulation.

Figure 12 Management of volatile organic liquids in NSW.

Storage tanks

VOCs are released when VOLs are stored in or transferred to stationary storage tanks. There are two types of VOC losses:

- Standing losses occur when vapour is expelled from a tank through vapour expansion and contraction, as a result of changes in temperature, atmospheric pressure and fuel Reid vapour pressure.
- Working losses result from the filling and emptying of storage tanks. During filling, vapours in the empty storage tank are displaced by the added VOL. During emptying, evaporative loss occurs as air is drawn into the tank and becomes saturated with organic vapour and expands, exceeding the capacity of the vapour space.

Table 15 Types of tank.

Tank	Design
Fixed roof tanks	Cylindrical steel shell with a permanently fixed roof
External floating roof tanks	Open-topped cylindrical steel shell with a roof that floats on the surface of the storage liquid and a seal system attached to the roof perimeter that forms a seal between the roof and the tank wall
Internal floating roof tanks	Cylindrical steel shell with a permanently fixed roof and an internal roof that floats on the surface of the storage liquid

There are three types of tank design (see Table 15).

In fixed roof tanks, most VOL emissions result from the displacement of vapours during filling and the evaporation of product left in the tank during tank emptying. To minimise vapour loss, fixed roof tanks require a pressure/vacuum vent so the tank operates at a slight internal pressure or vacuum to prevent the release of vapours during very small changes in temperature, pressure or liquid level.

In floating roof tanks, most VOL emissions are due to standing losses in which vapour leaks past seals and roof fittings. Working losses are not as significant, as the roof floats on top of the liquid, leaving no space for the liquid to evaporate into. Therefore, the losses that occur are due to the evaporation of product left on the tank shell as product is removed from the tank and the roof level drops. To minimise vapour loss, floating roof tanks require some form of device (referred to as a 'rim seal') to seal the gap between the tank wall and the deck perimeter. Current practice involves the use of a primary and secondary rim seal.[16]

In NSW, storage tanks that have a capacity of 150 kilolitres (kL) or more and store VOLs with a vapour pressure at or below 75 kPa are currently required to have, as a minimum, a floating metal roof, a floating impervious cover or a vapour disposal or recovery system. The floating roof or cover must have skirt plates and a minimum of one closure seal, which is shielded from the weather. Storage tanks that have a capacity of 150 kL or more and store VOLs with a vapour pressure above 75 kPa must have a vapour disposal or recovery system.

There are currently 120 large storage tanks located in the Sydney, Newcastle and Wollongong areas, 57 of which have external floating roofs and 63 of which have internal floating roofs. Eighty-one of the tanks are used to store VOLs that have a higher vapour pressure, such as liquid fuels. Of those, approximately 37% (30) are external floating roof tanks and 63% (51) are internal floating roof tanks and are made up of both welded and bolted construction. All the tanks have primary seals, while about 50% (40) have secondary seals. Of the 50% that have secondary seals, 69% (28) are external roof tanks and 31% (12) are internal roof tanks.

Loading plant and tank vehicles

During the loading of VOLs from loading plant to tank vehicles and from tank vehicles to small storage tanks, VOCs are released as a result of vapour losses. To enable the management of those emissions, the Clean Air Regulation specifies controls for large loading plant and large tank vehicles within the Sydney metropolitan area.

The specified controls for large loading plant require the use of vapour collection systems so any vapour displaced during loading is collected and conveyed to a vapour recovery or disposal system. An interlock system that prevents the loading of a delivery tank unless a vapour collection system is connected to the tank is also required.

The specified controls for tank vehicles require the use of a vapour collection system, an overfill protection device to prevent the flow of VOL into the tank if overfilling occurs, liquid-tight couplings, vapour-tight hatch covers, and pressure vacuum valves (PV valves) on all atmospheric vents.

Petrol service stations

Petrol vapour from vehicles and service stations adversely affects air quality in NSW. As well as contributing to ozone formation, VOCs in petrol vapour can have direct impacts on the health of service station employees and people living and working nearby, and on the amenity (odour) of service stations and surrounding areas. Each year Sydney exceeds national health-based ozone standards. Petrol also contains up to 1% benzene, which is a human carcinogen. There is no safe

[16] There are three general forms of rim seal: mechanical (metallic) shoe shields, liquid-filled seals, and vapour or liquid mounted foam-filled seals.

level of human exposure to benzene, long-term exposure to which has been linked to an increased incidence of leukaemia.

To reduce petrol vapours and mitigate the impact of ozone in NSW, the EPA has implemented VR requirements at petrol service stations across the metropolitan areas of NSW.

VR control equipment aims to capture petrol vapours before they enter the atmosphere. VR requirements were designed and implemented in two stages: VR1 and VR2. VR1 introduced controls that cover the storage and distribution of VOLs in underground storage tanks and road tankers, while VR2 introduced controls that cover the refuelling of vehicles at service stations.

Large storage tanks have been covered by VR1 controls in the Sydney, Newcastle and Wollongong metropolitan areas since 1986. In 2009, amendments to the Clean Air Regulation required service stations in the Sydney, Central Coast, Illawarra, Shoalhaven and Lower Hunter regions to introduce more stringent VR1 controls. The prescribed equipment is designed to achieve a capture efficiency of 97% of petrol vapour (NSW EPA 2017). VR1 systems must return displaced vapour to the delivery tanker via a vapour return line or to a vapour processing unit.

VR2 controls have been required progressively since July 2010 for petrol service stations in the Sydney, Newcastle, Wollongong and Central Coast metropolitan areas (NSW EPA 2017). The following requirements have been implemented:

- From 1 July 2010, new and newly modified petrol service stations supplying more than 0.5 million litres of petrol per year were required to have the VR2 prescribed control equipment fitted and operating.
- From 1 January 2014, the remaining petrol service stations supplying more than 12 million litres of petrol per year were required to have VR2 controls fitted and operating.
- From 1 January 2017, the remaining petrol service stations supplying more than 3.5 million litres of petrol per year in the Sydney Metropolitan Area – B (as defined in the Regulation) were required to have VR2 controls fitted and operating.

The VR2 prescribed control equipment is required to capture 85% or more of the vapour displaced when vehicles refuel. VR2 has now been fully implemented by facilities across Sydney, Newcastle, Wollongong and the Central Coast.

On 31 January 2017, in NSW regulatory responsibility for VR was moved away from the NSW EPA and handed to local councils. Local councils are the ‘appropriate regulatory authority’ for service stations in NSW under the POEO Act and therefore are already responsible for compliance and planning issues relating to petrol service stations.

6.2. Options considered

Three regulatory options were considered:

- Option 1 – business as usual; existing Regulation provisions would be included unchanged in a new regulation
- Option 2 – allow the existing Regulation to be repealed without making a new regulation
- Option 3 – incorporate the proposed amendments and the existing Regulation provisions in a new regulation.

6.2.1. Option 1: Base case (business as usual)

Option 1 assumes there is no change to the existing Part 6 (Control of volatile organic liquids) measures in NSW. This means the existing Regulation would be retained.

In the Clean Air Regulation, VOLs are managed through a number of measures that are detailed in the following:

Measure	**Existing Regulation**	**Proposed Regulation**
Requirements to fit control equipment	Part 6, Division 2	Part 6, Division 1
Storage tanks and loading plants (details control equipment and threshold sizes for large and small tanks and loading plant)	Part 6, Division 3	Part 6, Divisions 2, 3 and 4
Tank vehicles (requirements for both control equipment and loading and unloading)	Part 6, Division 4	Part 7
Petrol stations (VR1 controls, which cover storage and distribution of VOLs in underground storage tanks and road tankers, and VR2 controls, which apply to the refuelling of vehicles at service stations).	Part 6, Division 5	Part 8, Division 2

6.2.2. Option 2: No Regulation

Under this option, the existing Regulation would be repealed.

6.2.3. Option 3: New Regulation

Under Option 3, a new Regulation will require more stringent control equipment standards and/or emissions limits to be applied, particularly large storage tanks and loading plant.

The proposed changes are outlined in Table 16.

Table 16 Proposed amended requirements for management of VOLs in storage tanks and loading plant.

Type of equipment	Requirements for control equipment and/or emission limits
Large tanks: VOLs with vapour pressure of, or below, 75 kPa	
Existing	
External floating roof tanks commissioned before 1 July 2024 that store VOLs	Secondary seals must be installed by 1 Jul 2030 or at the nearest scheduled tank maintenance, whichever comes sooner. A weather shield is not required once installed.
New	
All tanks commissioned on or after 1 July 2024 that store VOLs	Mechanical shoe primary seal (or seal with similar efficiency)
All tanks commissioned on or after 1 July 2024 that store VOLs	Internal floating roof or external domed floating roofs
	Rim mounted secondary seals

Type of equipment	Requirements for control equipment and/or emission limits
Large tanks and large loading plant	
New	
VDUs commissioned on or after 1 July 2024	By 1 July 2027, the total concentration of unburnt vapour emitted to the atmosphere must not exceed 20 mg/m^3 if the VOL contains a principal toxic air pollutant (PTAP) or 40 mg/m^3 if the VOL does not contain a PTAP
VRUs commissioned on or after 1 July 2024	By 1 July 2027, the total concentration of unrecovered vapour emitted to the atmosphere from a VRU must not exceed emission concentrations of 10 milligrams per litre (mg/L) over a 4-hour period
Existing	
VDUs commissioned before 1 July 2024	By 1 July 2027, the total concentration of unburnt vapour emitted to the atmosphere must not exceed 20 mg/m^3 if the VOL contains a PTAP or 40 mg/m^3 if the VOL does not contain a PTAP
VRUs commissioned before 1 July 2024	By 1 July 2027, the total concentration of unrecovered vapour emitted to the atmosphere from a VRU must not exceed 10 mg/L over a 4-hour period
As specified below	
All new storage tanks (large and small) commissioned on or after 1 July 2024	Required to have bottom or submerged loading
Large storage tanks, large loading plant, small storage tanks and loading and unloading large tank vehicles	From 1 July 2024 requirements apply in the geographical area where the Stage 1 VR zone (petrol service stations) applies

6.3. Benefits and costs

6.3.1. Summary of results

For Part 6 of the existing Regulation, a comparison of the costs and benefits of Options 2 and 3 incrementally to the base case (Option 1) is set out in Table 17 and Table 18. As the costs and benefits vary over time, they are compared as present values over a 20-year period using a 7% discount rate.

The key conclusions from this are that the proposed reform to the Regulation of large storage tanks delivers a material net public benefit, and the existing Regulation for VR at petrol stations should be retained.

Table 17 Part 6 results compared to Option 1, for large storage tanks.

Cost and benefit elements	Option 2 (present values, $m)	Option 3 (present values, $m)
Cost to industry	0.00	0.19
Cost to government	0.00	0.00
PV total cost	**0.00**	**0.19**

Cost and benefit elements	Option 2 (present values, $m)	Option 3 (present values, $m)
Industry savings (recovered product)	–0.02	0.17
Value of health impact	–0.11	0.87
PV total benefits	**–0.14**	**1.03**
NPV	**–0.14**	**0.84**
BCR	**n.a.**	**5.41**

Table 18 Part 6 results compared to Option 1, for petrol stations.

Cost and benefit elements	Option 2 (present values, $m)
Cost to industry	–11.0
Cost to government	0.0
Total cost	**–11.0**
Industry savings (recovered product)	–65.5
Value of health impact	–337.7
Total benefits	**–403.2**
NPV	**–392.2**
BCR	**n.a.**

6.3.2. Benefits

The main benefits of avoiding VOC emissions relate to ozone formation, direct impacts on the health of service station employees and people living and working nearby, and on amenity (odour) in the surrounding area. Some VOCs, such as benzene and PAHs, are individually significant air toxics that impact people's health and the environment. Petrol contains up to 1% benzene, which is a human carcinogen. There is no safe level of human exposure to benzene, long-term exposure to which has been linked to an increased incidence of leukaemia. Other effects of exposure to VOCs include irritation to the eyes, nose and throat; headaches; loss of coordination; nausea; and damage to the liver, kidneys and central nervous system. For the purposes of this assessment only the health impacts of VOCs have been calculated.

Regarding storage tanks, Option 3 would result in a health impact saving of $0.87 million over the 20-year analysis period compared to Option 1. Conversely, Option 2 would result in additional negative health impacts costing approximately $0.11 million over 20 years.

Regarding petrol stations, Option 2 would result in significantly higher health costs.

6.3.3. Costs

The cost–benefit analysis of the three options finds that Option 3 would impose a small cost ($0.19 million) on industry due to the requirement to install second seals on some large storage tanks. Table C34 in Appendix C provides more detail on the number of large storage tanks in NSW and costs to upgrade. The majority of storage tanks, loading plant and tank vehicles are expected to already comply or be ready to comply with the control requirements and will not incur any costs. Where costs are incurred they would be offset somewhat by the $0.16 million savings to industry (see Table 17). Option 2 would impose no cost to industry or government, but repealing the Regulation would result in an increase in health costs as a result of air quality deterioration.

6.4. Conclusion

Regarding large storage tanks, Option 3 is strongly preferred to Option 1, due to Option 3's BCR of 5.41, even though the NPV of $0.84 million is small. Option 2 is not preferred, as it would result in a net welfare loss. In the analysis of petrol stations, maintenance of business as usual (Option 1) is preferred.

This analysis of petrol stations concludes that repealing the existing Regulation leads to deterioration in air quality, with consequent impacts on public health and the environment, because there would be no alternative regulatory mechanisms for petrol service stations, whereas VOC emission standards are currently included in the environment protection licences of some petroleum bulk storage facilities. In particular, the analysis assumes the following:

- Stage 1 VR would not significantly change at petrol stations if the Regulation were repealed, as VR systems are often relied on to satisfy other requirements, such as workplace health and safety and fuel recovery requirements, and the emissions reduction requirements in load reduction agreements. However, for industries other than petrol stations, the VR1 could be removed or maintenance could decline over time, reducing effectiveness.
- Stage 2 VR would probably be disabled at petrol stations. The aim of VR2 is to reduce the emission of VOCs during vehicle refuelling. This would result in a cost saving to the petrol station but would have material health cost implications.

Appendix A: Compliance with the Better Regulation Principles

Under *TC19-02: Guide To Better Regulation* (NSW Treasury 2019), where new regulations are significant, associated regulatory impact statements are required to address the Better Regulation Principles set out in the *NSW Government Guide to Better Regulation* (NSW Government 2019), in addition to meeting the requirements of the *Subordinate Legislation Act 1989*. These principles have been applied throughout this report. Compliance with the specific principles is as set out in Table A1.

A complete list of the proposed amendments to the Clean Air Regulation is given in Table A2.

Table A1 Compliance with Better Regulation Principles.

Better Regulation Principle	Air quality issue	Compliance
Principle 1: The need for government action should only occur where it is in the public interest, that is where the benefits outweigh the costs	General	1.1
	Domestic solid fuel heaters	2.1.1
	Control of burning	3.1.1
	Motor vehicles and motor vehicle fuels	4.1.1
	Industrial emissions from plant and activities	5.1.1
	Control of volatile organic liquids	6.1.1
Principle 2: The objective of government action should be clear	General	1.2
	Domestic solid fuel heaters	2.1.1
	Control of burning	3.1.1
	Motor vehicles and motor vehicle fuels	4.1.1
	Industrial emissions from plant and activities	5.1.1
	Control of volatile organic liquids	6.1.1
Principle 3: The impact of government action should be properly understood by considering the costs and benefits of a range of options, including non-regulatory options	Domestic solid fuel heaters	2.2–2.4
	Control of burning	3.2–3.4
	Motor vehicles and motor vehicle fuels	4.2–4.4
	Industrial emissions from plant and activities	5.2–5.4
	Control of volatile organic liquids	6.2–6.4

Better Regulation Principle	Air quality issue	Compliance
Principle 4: Government action should be effective and proportional	Domestic solid fuel heaters	2.4
	Control of burning	3.4
	Motor vehicles and motor vehicle fuels	4.4
	Industrial emissions from plant and activities	5.4
	Control of volatile organic liquids	6.4
	Consultation	1.6
Principle 5: Consultation with business, and the community, should inform regulatory development	Consultation	1.6
Principle 6: The simplification, repeal, reform, modernisation or consolidation of existing regulation should be considered	Motor vehicles and motor vehicle fuels	4.1–4.4
	Industrial emissions from plant and activities	5.1–5.4
	Control of volatile organic liquids	6.1–6.4
Principle 7: Regulation should be periodically reviewed, and if necessary reformed, to ensure its continued efficiency and effectiveness	This is the purpose of this RIS	

Table A2 Complete list of proposed regulatory changes.

Regulation reference and proposed change	Reason for proposed change
Preliminary – Part 1 existing and proposed Regulation	
No amendments proposed	
Domestic solid fuel heaters – Part 2 existing and proposed Regulation	
No amendments proposed	
Control of burning – Part 3 existing and proposed Regulation	
No amendments proposed	
Motor vehicles and motor vehicle fuels – Part 4 of existing regulation and Parts 4 and 8 of proposed Regulation	
Significant changes	
Part 4, section 20 and Divisions 2, 3 and 4 of the proposed Regulation Exclude heavy vehicles over 4.5 t from the requirements related to emissions of smoke and anti-pollution devices in the Regulation to avoid duplication with the Heavy Vehicle (Vehicle Standards) National Regulation (NSW).	Heavy vehicles over 4.5 t are regulated by the National Heavy Vehicle Regulator (NHVR) under the Heavy Vehicle (Vehicle Standards) National Regulation that is administered in NSW by Roads and Maritime Services (RMS). There is a duplication between the NSW EPA and NHVR in regulating heavy vehicles over 4.5 t regarding emissions of smoke and the removal, disconnection or impairment of anti-pollution devices.

Regulation reference and proposed change	Reason for proposed change
Part 8, subdivision 2 and the definition of summer in the Dictionary of the proposed Regulation Extend the period when lower summer petrol volatility limits apply in the NSW Greater Metropolitan Area (GMA) by one month, and adjust dates to better correspond with the peak ozone formation period in the GMA (from 1 November to 31 March) and to better align with existing requirements in Victoria. The updated requirements are proposed to commence from 2022.	NSW, other Australian states and many overseas jurisdictions use lower petrol volatility requirements as key measures to manage ozone (photochemical smog) formation in summer, and reduce associated impacts on community health and the environment. Lower petrol volatility limits of 62 kPa apply in the NSW GMA from 15 November until 15 March. The ozone monitoring data in the GMA, for 2002 to 2016[a] suggests the average ozone concentrations start to increase, and exceedances occur, outside the currently required lower petrol volatility period.
Air impurities emitted from activities and plant – Part 5 existing and proposed Regulation	
Significant changes	
Part 5, subdivision 2 and Schedule 2 of the proposed Regulation Require that activities and plant that belong in Groups 3 and 4[b] (i.e. commenced operation between 1 July 1979 and 1 August 1997) must comply with more stringent air emission concentration limits[c] of Groups 5 and 6.[d] New emission concentration limits for current Groups 3 and 4 are proposed to apply from 2025 (Group 5) and 2030 (Group 6). If Group 3 and 4 activities and plant are unable to meet updated emission limits of Groups 5 and 6 by the due date, different limits can be agreed via variation of the conditions of the licence.[e] Activities and plant in Groups 1 and 2 that commenced operation before 1 July 1979 have been taken to Group 5 since 2012[f] and must meet more stringent emission limits. The proposal to transition Groups 3 and 4 is the logical and appropriate next step under the existing regulatory framework.	In NSW, industry sources contribute a significant proportion of air emissions associated with significant public health impacts.[g] Activities and plant in Groups 3 and 4 commenced operation 20–40 years ago and are currently required to meet air emission concentration limits that are reflective of the vintage of the operating plant. Those limits are considerably less stringent than limits for activities and plant in Groups 5 and 6 and are no longer reflective of reasonably available technology and good environmental practice. As a result, Group 3 and 4 activities and plant are emitting air pollutants at considerably higher concentrations than Groups 5 and 6 and contribute significantly, relative to the size of their operation, to total industrial air emissions, including particles, NO_x and toxic pollutants.
Minor changes	
Section 60 of the proposed Regulation Update definition of dioxin and furans to reflect the latest World Health Organization (WHO) toxic equivalency factors.	The definition of dioxins and furans in the Regulation is based on WHO's toxic equivalency factors from 1998. WHO updated the toxic equivalency factors in 2005. It is likely that PCB-like dioxins and furans may currently not be included in the Regulation.
Part 9 of proposed Regulation Exclude diesel powered mobile plant and equipment from the requirement to operate the equipment with fuel of sulfur content no more than 0.5% by weight, to avoid duplication and harmonise with national fuel standard requirements.[h]	Moved from Section 60 of the existing Regulation to Part 9 of the proposed Regulation. Limits for maximum sulfur content in liquid fuels are used to control emissions of sulfur dioxide during burning of fuels, which are associated with adverse impacts on public health and the environment. Operators of diesel-powered mobile plant and equipment use standard diesel fuels that are regulated by the national fuel standards, which require

Regulation reference and proposed change	Reason for proposed change
	significantly lower sulfur content than limits prescribed in the Clean Air Regulation. It is proposed that sulfur content limits in the Regulation do not apply to diesel powered mobile plant and equipment that uses standard fuel. The limits should continue to apply to stationary plant and equipment that use non-standard fuel, such as waste oil. This proposal will result in no actual change to the status quo and will be cost-neutral to users of diesel-powered mobile plant and equipment. Benefits are expected from avoided costs of administration and compliance resulting from removing obsolete requirements.
Control of volatile organic liquids – Part 6 of existing regulation and Parts 6 and 7 of proposed Regulation	
Significant changes	
Parts 6 and 7 of the proposed Regulation 1. Introduce more stringent volatile organic compound (VOC) emission limits and control equipment requirements, reflective of reasonably available control technology and practice for volatile organic liquids (VOLs) in storage tanks, loading plants and tank vehicles. Updated limits are proposed to apply for new tanks and, for existing tanks, at the next maintenance period after the commencement of this Regulation. 2. Harmonise emission concentration limits and control equipment requirements for VOLs consistently across areas of high risk for ozone-forming potential and associated community health impacts in NSW, due to location of facilities, population density and meteorological conditions. The proposed changes include: • Introduce more stringent limits, equal or less than 10 mg/L as n-propane equivalent, for VOCs emitted from vapour recovery units or systems. • Introduce more stringent limits for VOCs emitted from vapour destruction units, equal or less than 20 mg/m^3 for processes treating VOLs containing principal toxic air pollutants (PTAPs), or 40 mg/m^3 for processes treating VOLs not containing PTAPs. • Introduce more stringent requirements for floating roof tanks, including requirements for secondary seals. • Require all tanks to have bottom or submerged loading.	Vapour emissions from VOLs are a significant source of precursors for formation of ground-level ozone and secondary organic aerosols, which are associated with adverse impacts on public health and the environment. Maximum limits and control equipment requirements for emissions control from VOLs have not been recently updated in the Clean Air Regulation and are not reflective of reasonably available control technology. Emission limits for VR systems on large storage tanks and loading plant, currently required in NSW, are significantly higher (less stringent) than limits in the United States and European jurisdictions. VOL emissions and control equipment requirements currently apply to the Sydney metropolitan area only. However, some major fuel distribution facilities are in the Newcastle and Wollongong areas (outside the Sydney metropolitan area), which have high levels of ozone in summer and significant populations. Expanding VOL control requirements will also make it consistent with VR1 requirements for service stations. The Clean Air Regulation currently exempts small storage tanks, below 600 kL per year, from the requirement for VOC control equipment.

Regulation reference and proposed change	Reason for proposed change
• Extend requirements for control equipment for small and large storage tanks to areas consistent with Stage 1 VR (VR1) zone.[i] • Extend requirements for VOCs control equipment for large loading plant to areas consistent with VR1 zone. • Add operational requirements, such as disallowing hatches and manhole covers on tank vehicles to be opened to discharge vapour to the atmosphere. • Include provisions for exemption from requirement for control equipment in emergency situations.	
Minor changes	
Dictionary of the proposed Regulation Update definition of VOL to make units for vapour pressure consistent throughout the Regulation.	Definition of VOL in the Regulation expresses vapour pressure in millimetres of mercury and pounds per square inch absolute. This is inconsistent with other sections and parts of the Regulation, which use kilopascals.
Miscellaneous – Part 7 of existing Regulation and Part 10 of proposed Regulation	
No amendments proposed	
All Parts as required	
Editorial changes	Changes to grouping of Parts and Sections for clarity and to modernise into plain English.
Update the Regulation to reflect changes to the 'Approved Methods for Sampling'.	The 'Approved Methods for Sampling and Analysis of Air Pollutants' provide statutory requirements for the measurement of air emissions in NSW. The approved methods are referred to in the Regulation. They have been the subject of a separate review because they were last updated in 2006. Any changes made to the list of approved methods need to be reflected in the Regulation remake.

[a] NSW Department of Environment and Conservation historical ambient air data.

[b] Section 35 of the Regulation divides activities and plant in scheduled premises into Groups 1–6, according to the date the activity/plant commenced its operation.

[c] Prescribed standards of concentration for air impurities, as referred to in section 43, are provided in Schedules 2, 3 and 4 for activities and plant in Groups 1–6.

[d] Group 5 activities and plant commenced operation on or after 1 August 1997 and Group 6 commenced on or after 1 September 2005.

[e] Sections 41 and 42 of the Regulation provide a framework for approving alternative air emissions limits.

[f] Refer to sections 37 and 38 of the Regulation.

[g] GMR includes the metropolitan areas of Sydney, Newcastle and Wollongong.

[h] Sulfur content limit in the national Fuel Standard (Diesel) Determination 2001 is 10 ppm (0.001%), while the Clean Air Regulation applies limits of 0.5% by weight in Sydney, Wollongong, Newcastle and Central Coast metropolitan areas and 2.5% by weight outside the metropolitan areas.

[i] VR1 zone: geographical zone for Stage 1 VR from petrol stations that includes the Central Coast metropolitan area, the Illawarra region, the Lower Hunter region and the Sydney metropolitan area.

Appendix B: Health and environmental impacts of air pollutants

Introduction

This section examines the major impacts of air pollutants in NSW that are controlled by the Clean Air Regulation and the approach used to estimate avoided damage costs resulting from the proposed regulatory changes. The discussion and analysis focus on the health impacts and associated costs of air pollutants, since the environmental impacts of air pollutants (including on vegetation, ecosystems and buildings) are difficult to quantify and likely to be minor relative to the health impacts.

Over the past 15–20 years, scientific studies have greatly expanded our understanding of the nature and extent of the health effects of major air pollutants. This research is generally done by means of epidemiological studies, which examine relationships between exposure levels in communities and human health, studying the acute or chronic effects associated with real-time air pollution exposures while measuring health end-points. Studies on acute health effects examine daily changes in illness (‘morbidity’) and death (‘mortality’) and their correlation with exposure to air pollution. Data on acute health effects are drawn from episodes of respiratory symptoms, asthma and other impacts on lung function, days of restricted activity, hospitalisation and death. Studies of chronic health effects examine the statistical correlation of a range of illnesses and premature death in a target population, compared with broader population statistics. These illnesses include lung and heart (‘cardiopulmonary’) conditions and cancer.

Everyone has the potential to be affected by air pollution when concentrations of pollutants are high. However, some groups of the population are more susceptible to certain air pollutants than others and can be affected even when concentrations are relatively low. Those groups include children, elderly people (especially those with pre-existing cardiorespiratory conditions), other people with cardiorespiratory conditions, asthmatics and people who are engaging in strenuous exercise.

Sources and health impacts of major pollutants

Particulate matter

Particulate matter (or particles) is a term used to describe liquid or solid particles suspended in the air. It can be a primary pollutant (from emissions) or a secondary pollutant (resulting from atmospheric reactions on primary pollutants). Parts 2, 3, 4 and 5 of the existing Clean Air Regulation are relevant to the control of particulate matter. Only the impacts associated with primary particulate matter are assessed in the analysis, however, since it is difficult to quantify secondary particulate formation and associated damage costs.

Particles come from natural and human sources. Their size, shape and chemical composition vary greatly, depending on their source and other factors, such as time, location and weather. They include acids, organic chemicals, metals, soil, dust and allergens. Particles are visible as brown haze. Human (anthropogenic) sources of particles come from products of combustion and mechanical processes and include emissions from motor vehicles, wood heaters, power stations, industrial processes, and industrial and domestic incinerators.

Particles are measured using their aerodynamic diameter and range in size from 0.001–500 micrometres (μm) in diameter, but particles larger than 10 μm do not usually enter the human respiratory system. Particles are categorised according to size because different sizes behave differently in both the atmosphere and the human respiratory system; for example, smaller particles are more easily inhaled, with a potentially stronger impact on human health. Table B1 sets out the categories of particulate matter by size, principal human sources and differences in mobility.

PM_{10} is one of the six key pollutants for which health-based Air NEPM goals have been set.[17] In 2015, the standards and goals of the Air NEPM were updated specifically to take into account recent evidence on the health impacts of fine particles, especially very fine particles ($PM_{2.5}$).

Table B1 Categorisation of particulate matter.

Particle category	Particle size	Principal human sources	Deposition
PM_{10} 0–10.0 μm Fine particles	Particles with a diameter of 2.5–10 μm	Mechanical activity, such as roads, farming and mining	Settles relatively quickly (within minutes to hours)
$PM_{2.5}$ 0–2.5 μm Very fine particles	Particles with a diameter of 0.1–2.5 μm	Combustion processes, used in industry, power generation, and vehicles; transformations of primary pollutants (SO_x, NO_x and VOCs)	Can normally remain airborne for several hours to several weeks and may be transported thousands of kilometres from the original source
$PM_{0.1}$ <0.1 μm Ultra-fine particles	Particles with a diameter less than 0.1 μm	Vehicle emissions and atmospheric photochemical reactions	Can accumulate into $PM_{2.5}$; removed through rain

Health impacts of particulate matter

Epidemiological studies worldwide have shown that increases in particle pollution are associated with a range of health outcomes, including increases in daily mortality, hospital admissions and attendances at emergency rooms. Problems from short-term exposures include respiratory symptoms, such as irritation of the airways, coughing and difficulty breathing; aggravated asthma; irregular heartbeat; heart attacks; and premature death in people with heart or lung disease. Long-term exposures may result in decreased lung function, the development of chronic bronchitis and increased cardiovascular risk.

Significantly, there is no safe concentration threshold for exposure to $PM_{2.5}$ at which adverse health effects have not been observed. This means that even low levels may have an adverse impact on human health. Health studies frequently focus on the impacts of a particular size: PM_{10}, $PM_{2.5}$ or $PM_{0.1}$. Older studies focused on PM_{10}, while more recent studies have concentrated on $PM_{2.5}$ because of their potentially greater health risks (see, for example, Pope & Dockery 2006).

Oxides of nitrogen

Oxides of nitrogen (NO_x) are a group of highly reactive gases that include nitric oxide (NO) and nitrogen dioxide (NO_2). These gases are produced mainly by combustion processes. Combustion

[17] Variation to the National Environment Protection (Ambient Air Quality) Measure 2015, www.legislation.gov.au/Details/F2016L00084.

of fossil fuels converts atmospheric nitrogen and any nitrogen in the fuel into its oxides, mainly to nitric oxide, which slowly oxidises to NO_2 in the atmosphere. This reaction occurs more rapidly in the presence of ozone. NO_2 is a pungent acidic gas that is corrosive and strongly oxidising. NO_2 is one of the six key pollutants for which Air NEPM goals have been set.

Emissions of NO_x are principally controlled through Parts 4 and 5 of the existing Clean Air Regulation. Controls on NO_x emissions are in place for three reasons. NO_x is significant as a pollutant:

- as a precursor to ground-level ozone formation
- as a precursor gas to the formation of secondary fine particle pollution, including nitric acid
- with impacts on health and the environment.

In 2013, electricity generation was the major source of NO_x in the NSW GMR, accounting for around 45%. Motor vehicles, including petrol, diesel and off-road vehicles, were responsible for about 30%. Iron and steel production accounted for around 2% of total NO_x emissions in 2013 (NSW EPA 2019).

Health impacts of NO_x

The health impacts of NO_x fall into two categories.

The first category includes those effects caused by direct exposure to NO_x. At low levels of exposure, NO_x can irritate the eyes, nose, throat and lungs, leading to coughing, shortness of breath, tiredness and nausea. Exposure can cause a build-up of fluid in the lungs for 1–2 days after exposure. Longer-term exposure can destroy lung tissue, leading to chronic inflammatory lung disease. At high levels of exposure, NO_x can cause rapid burning, spasms and swelling of tissues in the throat and upper respiratory tract, reduced oxygenation of tissues, a build-up of fluid in the lungs, and maybe even death. Asthmatics and children are particularly susceptible.

The effects of direct exposure to NO_x are similar to some of the effects observed for exposure to ozone and particulate matter. As those other pollutants are generally also present at the same time, earlier studies found it difficult to attribute particular impacts to NO_x. More recent studies have concluded that there is a causal link between NO_2 and respiratory illness (see COMEAP 2018, WHO 2013 and US EPA 2016 for reviews of the studies). The studies have established, with very high likelihood, that there is a causal link between short-term, high-level NO_2 exposure and cardiorespiratory mortality. The studies further conclude that there is likely to be a causal link between long-term, low-level exposure and cardiorespiratory mortality, although there are greater uncertainties about that link. The studies also conclude that there is an overlap between NO_2 and $PM_{2.5}$ in health risk association.

The second category of health impacts results from ozone formation at ground level. They are discussed below in the section on ozone.

Volatile organic compounds

Volatile organic compounds (VOCs) are a broad grouping of carbon-based compounds that vaporise at normal temperatures.[18] The existing Clean Air Regulation controls evaporative emissions of VOCs through Parts 4 and 6. Other emissions of VOCs are controlled by ensuring combustion efficiency or controlling combustion through Parts 2, 3 and 5.

In 2013 in the NSW GMR, surface coating (paint), aerosols and solvents accounted for the largest proportion of anthropogenic VOC emissions, around 27.9%. Petrol vehicle exhaust, evaporative emissions and fuel retailing accounted for another 16%, with the rest from a number of diverse sources (NSW EPA 2019).

Health impacts of VOCs

Controls on VOCs emissions are in place for two reasons:

- Some VOCs, such as benzene and PAHs, are individually significant for health and the environment as air toxics.
- VOCs as a group are significant as a precursor to the formation of ground-level ozone.

The health impacts of direct exposure to VOCs depend on the composition of the VOCs present, their concentration and the length of exposure. General effects of exposure to VOCs include irritation to the eyes, nose and throat; headaches; loss of coordination; nausea; and damage to the liver, kidneys and central nervous system. Some VOCs are also known or suspected to cause cancer in humans.

Health impacts resulting from ozone formation at ground level are discussed in the following section.

Ozone

Ozone is a relatively insoluble gas composed of three oxygen atoms, with a characteristic sharp odour. It is present in the stratosphere high above the Earth's surface (where it has a beneficial effect in filtering out ultraviolet light) and at ground level (principally as a pollutant). At ground level, it is one of the components of summertime smog, which harms human health, vegetation and building materials. Ozone is one of the six key pollutants for which Air NEPM goals have been set (NEPC 1998).

Because ozone is a secondary pollutant, ozone emissions are not directly regulated through the Clean Air Regulation, but its precursor pollutants, NO_x and VOCs, are regulated. Ground-level ozone is created by a chemical reaction between NO_x and VOCs in the presence of sunlight. A principal reason, therefore, for controlling emissions of NO_x and VOCs is to prevent the formation of ozone. International and Australian studies indicate that ozone formation may be more sensitive to reduction of VOCs than NO_x (AQEG 2009; Azzi et al. 2007; DECC 2007).

Motor vehicle use is the main anthropogenic emission source of NO_x in Sydney and a major source of VOCs. As previously noted, around half of NO_x emissions in the NSW GMR were attributable to coal-fired power stations in 2013. With the population of the GMR forecast to grow up to 8 million

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[18] For the purposes of controlling industrial emissions, the existing Regulation defines 'volatile organic compound' as 'any chemical compound that: (a) is based on carbon chains or rings, and (b) contains hydrogen, and (c) has a vapour pressure greater than 2 mm of mercury (0.27 kPa) at 25°C and 101.3 kPa, and includes any such compound containing oxygen, nitrogen or other elements, but does not include methane, carbon monoxide, carbon dioxide, carbonic acid, metallic carbides and carbonate salts'.

by 2040, emissions of VOCs and NO_x from motor vehicles are projected to remain high in the future, meaning that ozone goals may be difficult to achieve without further controls on emissions of NO_x and VOCs. Further, global warming is projected to exacerbate ground-level ozone formation in Sydney (Cope et al. 2008).

Health impacts of ground-level ozone

Ozone can be highly irritating for those who inhale it. Exposure to concentrations above the Air NEPM limits can be harmful to people's health. Increases in levels of ozone are associated with a rise in hospitalisation for respiratory diseases and mortality. Repeated exposure to ozone can make people more susceptible to respiratory infection and aggravate pre-existing respiratory diseases, such as asthma (US EPA 2006; WHO 2006). Long-term exposure to ozone causes an increase in mortality (Jerrett et al. 2009; Smith et al. 2009).

Valuing health impacts

Approaches to assessing and valuing health impacts

Two possible approaches can be used to value the health impacts of air pollutants under the status quo (base case) and options:

- an impact pathway approach
- a damage cost approach.

Impact pathway approach

The impact pathway (or dose–response) approach allows a quantitative link to be assessed between changes in emissions, ambient air quality and health outcomes (Figure B1). This enables the quantification of public health benefits across a population. It entails modelling the effects of changing emissions associated with various fuel quality parameters, then modelling the atmospheric fate and transport of those emissions in key urban airsheds to yield estimates of ground-level concentrations that can be used to assess population exposure and health risks.

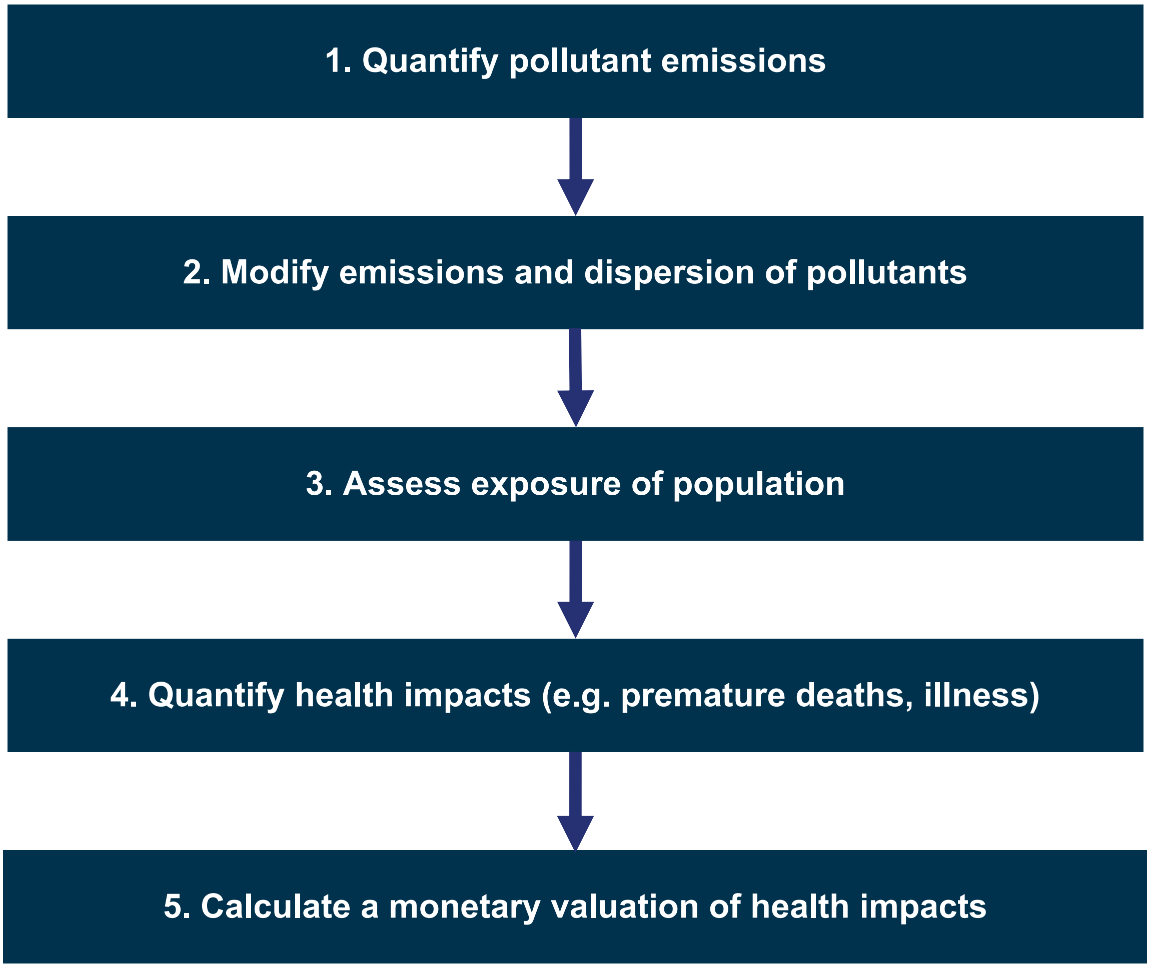

Figure B1 Impact pathway approach to valuing health impacts of air pollution.

Damage cost approach

The damage cost approach entails:

- projecting emissions for the status quo and identified options
- applying damage costs estimates (expressed as $/t of pollutant) to emissions to estimate health costs under the status quo and identified options
- estimating avoided health costs of each option relative to the status quo.

The damage cost approach is not as robust as the impact pathway approach. It is typically used when time and/or resources do not permit the application of the impact pathway approach.

Damage cost estimates applied in this study

A damage cost approach has been applied in this study. The decision to apply this approach reflects the fact that the impact pathway approach is very time and resource intensive (especially steps 2 to 4, as set out in Figure B1) and therefore not feasible given the time and resources available for this analysis. Nevertheless, considerable attention has been given to ensuring that damage cost estimates applied in the analysis are as rigorous as possible and reflect localised conditions, such as exposure in areas surrounding major emission sources. This is especially important for $PM_{2.5}$, since exposure and health impacts of $PM_{2.5}$ tend to be closely correlated to proximity to source. Also, the damage costs of $PM_{2.5}$ (on a $/t basis) are very high relative to those of other pollutants.

A range of literature and studies were sourced to derive the damage estimates, notably AEA Technology Environment (2005), Defra (2011, 2015a, 2015b), MJA (2017) and PAE Holmes (2013). Tables B2, B3 and B4 provide summaries of health damage cost estimates applied in the analysis for $PM_{2.5}$, NO_x and VOCs, respectively.

Table B2 Damage cost estimates, $PM_{2.5}$ ($/t avoided).

	2021	2026	2031	2036	2041
Major industrial: GMR					
Central	**261,521**	**279,605**	**297,677**	**316,119**	**335,203**
High	392,066	419,177	446,269	473,918	502,527
Low	167,274	178,841	190,400	202,196	214,402
Power stations					
Central	**42,733**	**43,929**	**44,963**	**45,773**	**46,591**
High	64,065	65,857	67,407	68,621	69,847
Low	27,333	28,098	28,759	29,277	29,800
Wood heaters: GMR					
Central	**245,813**	**262,811**	**279,797**	**297,132**	**315,069**
High	368,517	393,999	419,465	445,452	472,343
Low	157,227	168,099	178,964	190,051	201,524
Non-GMR (including industrial and open-air burning)					
Central	**44,949**	**46,207**	**47,294**	**48,146**	**49,007**
High	67,387	69,272	70,902	72,179	73,469
Low	28,750	29,555	30,250	30,795	31,346

Table B3 Damage cost estimates, NO_x ($/t avoided).

	2021	2026	2031	2036	2041
GMR					
Central	**7,006**	**7,552**	**8,223**	**8,975**	**9,787**
High	11,859	12,755	13,858	15,088	16,413
Low	2,950	3,388	3,927	4,560	5,290
Non-GMR					
Central	**958**	**1,032**	**1,124**	**1,227**	**1,338**
High	1,621	1,744	1,894	2,063	2,244
Low	403	463	537	623	723

Table B4 Damage cost estimates, VOCs ($/t avoided).

	2021	2026	2031	2036	2041
GMR					

	2021	2026	2031	2036	2041
Central	**5,288**	**5,653**	**6,019**	**6,392**	**6,777**
High	7,050	7,538	8,025	8,522	9,037
Low	3,525	3,769	4,012	4,261	4,518
Non-GMR					
Central	**719**	**739**	**756**	**770**	**784**
High	958	985	1,008	1,026	1,045
Low	479	493	504	513	522

Particulate emissions, $PM_{2.5}$

The literature points to a strong correlation between levels of exposure to particulate emissions ($PM_{2.5}$ and PM_{10}) and the density of populations in proximity to major sources of those emissions (DEC 2005; Defra 2011; PAE Holmes 2013), although other factors, notably local meteorological conditions, are very important in influencing the exposure of populations. Given the importance of population density, considerable attention in the analysis has been given to assessing likely population density in proximity to emission sources and adjusting damage costs to reflect population density.

PAE Holmes (2013) provides the most comprehensive Australian assessment to date of $PM_{2.5}$ damage cost estimates. That assessment was reviewed for this study and, for the most part, was found to be robust. Damage cost estimates derived through the PAE Holmes assessment were therefore used as the starting point for the $PM_{2.5}$ damage costs used in this analysis, although important adjustments (explained below) have been made.

After an extensive literature review, PAE Holmes (2013) concluded that the best approach to assessing $PM_{2.5}$ damage costs was to transfer damage cost values from the UK Department for Environment, Food and Rural Affairs (Defra 2011). As noted in PAE Holmes (2013):

The UK values were selected primarily because of their greater sensitivity (relative to other studies). Rather than just taking geographically aggregated UK values in pounds sterling and converting to them to Australian dollars (2011 prices), a more sophisticated approach was used. Firstly, the UK damage costs were adjusted to take into account the difference between the Value of a Life Year (VOLY) in the UK and Australia, as well as differences in currency and inflation. A linear regression function was then fitted to the adjusted damage cost and population density data. This permitted a greater spatial discrimination of damage costs.

Unit damage costs were then developed for specific geographical areas of Australia using a simplified and standardised method which will allow users to relate the location of emissions to an approximate population-weighted exposure.

Using this approach, damage cost estimates (on a population-weighted exposure) were estimated in the PAE Holmes analysis to be about $282/t/person/km^2 ($2011) in the GMR. Adjusted to $2017, this is approximately $307/t/person/km^2. All the damage cost estimates for $PM_{2.5}$ presented in Table B2 reflect this estimate, with differences in damage cost estimates between major industrial sources, power stations, wood heaters and the non-GMR reflecting estimated average population densities at source. In all cases, damage cost estimates were adjusted upwards over time to take account of projected increases in population densities.

However, there are three important points to note about the PAE Holmes estimates:

- First, the PAE Holmes estimates (and, hence, estimates applied in this analysis) are only for primary $PM_{2.5}$ formation. PAE Holmes concludes, and we concur, that it is not feasible to derive secondary $PM_{2.5}$ damage costs from UK, European and US estimates.
- Second, PAE Holmes estimates are based on a VOLY estimate produced in the report *The health of nations: The value of a statistical life* (Access Economics 2008). The estimate in that study is significantly higher than the VOLY estimate recommended in the *Best practice regulation guidance note: Value of statistical life* (OPBR 2014). In our view, the former study is more comprehensive and, although it is an earlier study, appears to be based on more recent evidence. Arguably, therefore, the higher VOLY estimate recommended in the Access Economics study is as valid, or more valid, than the OPBR estimate.
- Third, the unit damage costs 'developed for specific geographical areas of Australia' are appropriate for emissions from motor vehicles or possibly from multiple sources. For this analysis, however, it was necessary to adjust for the population-weighted exposure considering the location of major sources of the emissions being considered, that is power stations, other major industrial sources, solid fuel (wood) heaters and open-air burning. The damage cost estimates presented in Table B2 reflect estimates of the population density in the vicinity of these sources. Major industrial sources, for example, tend to be located in outer urban and urban fringe areas of the GMR. Similarly, power stations are located, for the most part, outside the urban boundaries of the GMR.

Population density estimates were calculated using a number of sources, notably the ABS (2016). It is important to note that the way in which population density is calculated in urban areas differs between sources depending on whether spaces with very low or zero population density are included in the estimates. Most estimates now exclude areas with zero population density (such as national parks) but some also exclude areas with very low density (such as parklands and surrounds and major industrial areas). For this analysis we have used estimates of population density that exclude national parks but not the very low density areas. This means that the density weighted $PM_{2.5}$ damage cost estimates applied in this analysis are, if anything, conservative.

Oxides of nitrogen

In contrast to $PM_{2.5}$, there has not been a recent analysis of NO_x damage costs suitable for application in the Australian context. The central NO_x damage cost estimate applied in this analysis was therefore derived from a recent estimate of the health impacts of NO_x emissions for the Sydney region. That, in turn, was achieved via an impact pathway study of emissions, air quality and health impacts of motor vehicle emissions in the GMR (MJA 2017; Pacific Environment 2016a, 2016b).[19]

The 2018 GMR damage costs estimate (in $/t) presented in Table B3 was derived by dividing health costs due to transport NO_x emissions,[20] estimated through the study described above, by the estimated quantity of transport NO_x emissions. This estimate was adjusted downwards by 20% to remove the potential for double-counting of the health impacts of $PM_{2.5}$. Damage costs estimates

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[19] Deriving damage costs estimates for multiple sources of emissions based on estimated health impacts of motor vehicle emissions is considered a reasonable approach in this instance, since, unlike $PM_{2.5}$ emissions, emissions and impacts (within the same air shed) do not differentiate greatly between location. Local population density therefore has less impact in determining the damage costs of NO_x emissions (PAE Holmes 2013; Watkiss 2002).

[20] Health outcomes assessed include years of life lost (YoLL) due to acute and long-term exposure, reduced quality of life and costs associated with hospitalisations and emergency department visits. Consistent with an OPBR (2014) recommendation, a willingness to pay (WTP) value of ~$192,000 for each YoLL was applied in the analysis.

for subsequent time periods were adjusted upwards to take account of projected increases in population density in the GMR.

As with $PM_{2.5}$, damage costs estimates for the non-GMR were derived by applying an adjustment factor of 0.14, which reflects the estimated population density of regional towns and cities relative to the GMR.

Further details of the rationale for and approach to estimating NO_x damage costs are provided in MJA (2018).

Volatile organic compounds

Similar to NO_x, there has not been a recent analysis of VOC damage costs suitable for application in the Australian context. Unlike NO_x, it was difficult to derive a robust damage costs estimate for VOC emissions for the Sydney region based on results of recent impact pathway analyses, since most of the damage costs of VOCs are linked to their role as a precursor of ozone.

Therefore, for this study we have used VOC damage costs estimates for the European Union (AEA Technology Environment 2005), converting to Australian dollars and adjusting for inflation.[21] Damage costs estimates for subsequent time periods were adjusted upwards to take account of projected increases in population density in the GMR.

Similarly to NO_x, damage costs estimates for the non-GMR were derived by estimating a non-GMR damage cost factor for $PM_{2.5}$ damage costs, and applying it to the VOC GMR damage costs estimate.

Uplift factor

Both Defra (2011) and PAE Holmes (2013) apply an 'uplift factor' to damage costs for each subsequent year to reflect an assumption that willingness to pay (WTP) for avoided health impacts (reflected in the value of statistical life (VOSL) and VOLY) will rise in line with growth in incomes. The evidence on the application of an uplift factor is unclear; for example, the OPBR (2014) is mute on the subject.

We suggest that if an uplift factor is applied it should be on the basis of real per capita economic growth or real per capita income growth. This will remove distortionary impacts of inflation and population growth on WTP estimates. On that basis, for this analysis we have applied an uplift factor of 0.9% per year to central damage costs estimates. This value reflects real annual per capita gross domestic product (GDP) growth that has been achieved in Australia over the past 10 years and is assumed to continue over the period of the analysis.

Lag effect

The literature points to the potential for a lag between a reduction in exposure to air pollutants and any associated reduction in health impacts. This is especially true of health effects associated with chronic exposure to $PM_{2.5}$. There is limited empirical evidence of the precise structure of this lag; some studies suggest a lag of up to 40 years is appropriate, while others suggest the lag should be close to zero years. Many assessments now use a lag structure recommended by the US EPA

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21 We recognise that deriving a damage costs estimate in this way from European sources means that the estimate is subject to considerable uncertainty.

(2009), which assumes that 30% of the effect occurs in the first year of reduced exposure, an additional 12.5% in years 2–5 and the remaining 20% in years 6–20.

The damage costs estimates developed by Defra (2011) incorporate a lag. While the exact nature of the lag is unclear, it is seemingly consistent with the approach applied by the US EPA, which introduces a lag that is closer to zero years than to 40. This lag effect is, effectively, captured in the damage cost estimates developed by PAE Holmes (2013) and therefore applied in this analysis.

Appendix C: Cost–benefit calculations

General assumptions

Several general assumptions have global application in this RIS and are applied to all parts. They include the analysis base year; the base year for valuation (of costs and benefits); the discount rate applied to costs and benefits over time and sensitivity discount rates; the evaluation period; and the health damage costs associated with the pollutants considered.

The general assumptions for the cost–benefit analysis (CBA) are outlined in Table C1. The methodology for deriving the health damage costs in Table C1 is explained in Appendix B.

Table C1 General assumptions.

Variable	Assumption
Base year	FY 2020
Prices	FY 2018
Evaluation period	FY 2021 – FY 2041
Discount rate	7% (real)
Discount rate sensitivity	3% and 10% (real)
Health damage cost $PM_{2.5}$: GMR	330,721 (FY 2021) – 423,899 (FY 2041) (excluding uplift factor)
Health damage cost $PM_{2.5}$: non-GMR	44,949 (FY 2021) – 49,007 (FY 2041) (excluding uplift factor)
Health damage cost NO_x: GMR	7,006 (FY 2021) – 9,787 (FY 2041) (excluding uplift factor)
Health damage cost NO_x: non-GMR	958 (FY 2021) – 1,338 (FY 2041) (excluding uplift factor)
Health damage cost VOCs: GMR	5,288 (FY 2021) – 6,777 (FY 2041) (excluding uplift factor)
Health damage cost VOCs: non-GMR	719 (FY 2021) – 784 (FY2041) (excluding uplift factor)
Health damage cost: annual uplift factor	0.9%

Part 2: Domestic solid fuel heaters

Benefits

The quantifiable benefits of the minimum emission standards for domestic solid fuel heaters are lower emissions of particulate matter, leading to improved human health.

To determine the $PM_{2.5}$ emissions from domestic solid fuel heaters, an inventory of existing wood heaters was developed by the NSW EPA, which indicated a total stock of nearly 240,000 wood heaters in the GMR in 2013, comprising approximately 34% slow combustion heaters, 33% open fireplaces, around 19% being combustion heaters without a compliance plate and the balance being potbelly stoves (NSW EPA 2019).

The decline in wood heaters over time is based on a set of assumptions regarding the replacement cycle and decommissioning of different wood heater types (Table C2).

Costs

The quantifiable costs of the minimum standards for domestic solid fuel heaters are the costs of government administration. AECOM (2014) estimated administration and enforcement costs of $15,000 per year.

Table C2 Wood heater replacement and decommissioning assumptions.

Variable	Assumption
Existing slow combustion heaters *without compliance plate* replaced by	2025
Existing slow combustion heaters *with compliance plate* replaced by	2035
Percentage of existing slow combustion heaters permanently retired each year (instead of being replaced)	1.2%
Percentage of new (installed after 2018) slow combustion heaters permanently retired	1.2%
New slow combustion heaters permanently retired n years after installation	15 years
Percentage of existing open fireplaces replaced with slow combustion heaters each year	2.8%
Percentage of existing open fireplaces permanently retired each year	1.2%
Percentage of existing potbelly stoves replaced with slow combustion heaters each year	2.8%
Percentage of existing potbelly stoves permanently retired each year	1.2%

Source: AECOM 2014, NEPC 2013, NSW EPA 2019

Sensitivity tests

Because there is a degree of uncertainty in some of the assumptions, a number of sensitivity tests were undertaken. The tests found that the results are robustly positive.

Central case

Table C3 shows the central case, as described in Section 2.

Table C3 CBA result, 20-year analysis period, 7% discount rate (central case).

Cost and benefit elements	Option 2 (present values, $m)
Cost to industry	0.00
Health impact ($PM_{2.5}$): Greater Metropolitan Area	413.37
PV total cost	**413.37**
Saving to government	0.19
PV total benefits	**0.19**
NPV	**–413.18**
BCR	**0.0005**

Discount rates

In accordance with the NSW Government Guidelines for Economic Appraisal (TPP07-5), the stream of costs and benefits (in real terms) has been discounted using a real discount rate of 7%; sensitivity testing used real discount rates of 3% and 10%.

Table C4 shows that different discount rates change the NPV, but do not materially change the BCR and overall result. In each scenario, Option 1 (retaining the existing Regulation) is strongly preferred to Option 2 (repealing the existing Regulation).

Table C4 CBA result, 20-year analysis period, 3–10% discount rates.

Cost and benefit elements	Option 2 Discount rate = 3% (present values, $m)	Option 2 Discount rate = 7% (present values, $m)	Option 2 Discount rate = 10% (present values, $m)
Cost to industry	0.0000	0.0000	0.0000
Health impact ($PM_{2.5}$): Greater Metropolitan Area	596.67	413.37	326.05
PV total cost	**596.67**	**413.37**	**326.05**
Saving to government	0.27	0.19	0.15
PV total benefits	**0.27**	**0.19**	**0.15**
NPV	**–596.41**	**–413.18**	**–325.90**
BCR	**0.0005**	**0.0005**	**0.0005**

Administrative and enforcement cost and health impact

Both benefits and costs resulting from a policy change are uncertain. Although the assumptions for the base analysis are already conservative, the following sensitivity analyses assume even less favourable conditions:

- a 20% increase in administrative and enforcement costs
- health impacts of pollutants being approximately one-third lower, in accordance with the lower bound identified from the prevailing literature.

Table C5, Table C6 and Table C7 show that high costs and lower benefits change the NPV but do not materially change the BCR and overall result. The key driver is the large magnitude of health impacts, relative to all other benefits and cost. In each scenario, Option 1 (retaining the existing Regulation) is strongly preferred to Option 2 (repealing the existing Regulation).

Table C5 CBA result, 20-year analysis period, high administrative and enforcement cost.

Cost and benefit elements	Option 2 (present values, $m)
Cost to industry	0.00
Health impact ($PM_{2.5}$): Greater Metropolitan Area	413.37
PV total cost	**413.37**
Saving to government	0.23
PV total benefits	**0.23**
NPV	**–413.14**
BCR	**0.0006**

Table C6 CBA result, 20-year analysis period, low health impact.

Cost and benefit elements	Option 2 (present values, $m)
Cost to industry	0.00
Health impact ($PM_{2.5}$): Greater Metropolitan Area	264.40
PV total cost	**264.40**
Saving to government	0.19
PV total benefits	**0.19**
NPV	**–264.21**
BCR	**0.0007**

Table C7 CBA result, 20-year analysis period, high administrative and enforcement cost and low health impact.

Cost and benefit elements	Option 2 (present values, $m)
Cost to industry	0.00
Health impact ($PM_{2.5}$): Greater Metropolitan Area	264.40
PV total cost	**264.40**
Saving to government	0.23
PV total benefits	**0.23**
NPV	**–264.17**
BCR	**0.0009**

Part 3: Control of burning

Benefits

The quantifiable benefits of controls on burning are lower emissions of particulate matter, leading to improved human health.

Current particulate matter emissions from the burning that remains in the Sydney region are less than 5 t/year of PM_{10} (DECCW 2010). The extent to which people would choose to burn domestic waste and vegetation if the controls provided by the existing Regulation were to be repealed is not known. For the purposes of this analysis, the effect of an increase from 5 t/year to 10 t/year of PM_{10} in the current contribution of open burning was assessed.

A conversion factor of 0.95, being the proportion of PM_{10} emissions that are of $PM_{2.5}$ size, has been applied to determine the amount of $PM_{2.5}$ emissions to which the damage costs are applied.

Costs

The quantifiable costs of controls on burning are the costs of government administration and waste collection costs to residents (see Table C8).

Government administration encompasses the cost to councils of administering the controls on burning.

Less burning means that more waste has to be collected and disposed of at a cost to residents. Using an average collection and disposal cost of $75/t of waste going to landfill or organics recycling, it is estimated that the cost to residents of controls on burning is $3,975/t of PM_{10} avoided.

Table C8 Part 3: Costs.

Variable	Assumption
Cost to government	$187,216 per year
Cost to residents	$3,975 per year

Notes:

1. The 2010 RIS estimated government cost to be equivalent to two full-time employees across all councils listed on the schedules at an estimated $80,000 per employee per year including 30% on-costs (DECCW 2010). Those estimates were adjusted for inflation.
2. The emission factor for municipal waste is estimated to be 53 t of waste to 1 t of PM_{10} (i.e. $75 x 53 = $3,975) derived from Eastern Research Group (2001).

Sensitivity tests

Because there is a degree of uncertainty in some of the assumptions, a number of sensitivity tests were undertaken. The tests found that the results are sensitive to some of the key assumptions.

Central case

Table C9 shows the central case, as described in Section 3.

Table C9 CBA result, 20-year analysis period, 7% discount rate (central case).

Cost and benefit elements	Option 2 (present values, $m)
Health impact ($PM_{2.5}$)	2.56
PV total cost	**2.56**
Saving to government	1.98
Saving to residents	0.21
PV total benefits	**2.19**
NPV	**–0.36**
BCR	**0.86**

Discount rates

In accordance with the NSW Government Guidelines for Economic Appraisal (TPP17-03), the stream of costs and benefits (in real terms) has been discounted using a real discount rate of 7%; sensitivity testing used real discount rates of 3% and 10%.

Table C10 shows that different discount rates change the NPV, but do not materially change the BCR and overall result. In each scenario, Option 1 (retaining the existing Regulation) is strongly preferred to Option 2 (repealing the existing Regulation).

Table C10 CBA result, 20-year analysis period, 3–10% discount rates.

Cost and benefit elements	Option 2 Discount rate = 3% (present values, $m)	Option 2 Discount rate = 7% (present values, $m)	Option 2 Discount rate = 10% (present values, $m)
Health impact ($PM_{2.5}$)	3.65	2.56	2.03
PV total cost	**3.65**	**2.56**	**2.03**
Saving to government	2.79	1.98	1.59
Saving to residents	0.30	0.21	0.17
PV total benefits	**3.09**	**2.19**	**1.76**
Net PV	**–0.57**	**–0.36**	**–0.27**
BCR	**0.85**	**0.86**	**0.87**

Administrative and enforcement cost and health impact

Both benefits and costs resulting from a policy change are uncertain. Although the assumptions for the base analysis are already conservative, the following sensitivity analyses assume even less favourable conditions:

- a 20% increase in administrative and enforcement costs
- health impacts of pollutants being approximately one-third lower, in accordance with the lower bound identified from the prevailing literature.

Table C11, Table C12 and Table C13 show that high costs and lower benefits change the NPV from negative to positive, and the BCR from slightly below 1 to slightly above 1, thus changing the overall result. Under the assumptions of the base analysis, Option 1 (retaining the existing Regulation) is preferred; however, either higher administrative and enforcement costs or lower health impacts are sufficient to change the overall result. These findings are driven by the benefits and costs of the Regulation being of similar magnitudes, meaning that relatively small changes to either of these values can change the overall result. It should be noted that the base analysis has used conservative estimates of benefits and costs.

Table C11 CBA result, 20-year analysis period, high administrative and enforcement cost.

Cost and benefit elements	Option 2 (present values, $m)
Health impact ($PM_{2.5}$)	2.56
PV total cost	**2.56**
Saving to government	2.38
Saving to residents	0.21
PV total benefits	**2.59**
NPV	**0.03**
BCR	**1.01**

Table C12 CBA result, 20-year analysis period, low health impact.

Cost and benefit elements	Option 2 (present values, $m)
Health impact ($PM_{2.5}$)	1.63
PV total cost	**1.63**
Saving to government	1.98
Saving to residents	0.21
PV total benefits	**2.19**
Net PV	**0.56**
BCR	**1.34**

Table C13 CBA result, 20-year analysis period, high administrative and enforcement cost and low health impact.

Cost and benefit elements	Option 2 (present values, $m)
Health impact ($PM_{2.5}$)	1.63
PV total cost	**1.63**
Saving to government	2.38
Saving to residents	0.21
PV total benefits	**2.59**
NPV	**0.96**
BCR	**1.59**

Part 4: Motor vehicles and motor vehicle fuels

Petrol volatility

Benefits

The quantifiable benefits of the limits on petrol volatility over summer result from:

- lower emissions of VOCs resulting in less ozone at ground level and less damage to human health
- less fuel lost to the atmosphere, benefiting motorists and petrol distributors.

Reductions in pollutants

Lower petrol volatility over summer reduces the amount of petrol vapour lost during petrol distribution and the transfer of petrol to motor vehicles at service stations. The lower petrol volatility also reduces both the amount of petrol vapour that evaporates from a car's petrol tank and the amount that is emitted in the car's engine exhaust.

Table C14 sets out the projected reductions in VOC emissions in 2021–22. Emissions reductions are assumed to decline over time due to changes in the vehicle fleet and efficiency measures.

Table C14 Avoided summer VOC emissions.

Emissions source	Avoided VOC emissions (t/year) in 2021–22		
	Option 1	Option 2	Option 3
Evaporative VOC emissions from vehicles	312	0	372
Exhaust VOC emissions from vehicles	118	0	214
VOC emissions at distribution	1,364	0	1,587
VOC emissions from off-road sources	177	0	222

Source: NSW EPA

Fuel savings for motorists and industry

Savings from evaporative emissions have been calculated on the basis that 1 t of emissions is equivalent to 1361.37 litres of fuel, based on averaged Australian Institute of Petroleum 1997 densities.

Petrol savings (Table C17) for motorists were estimated using the retail petrol price, excluding any taxes and margins. In 2021–22, the retail petrol price was estimated at 79.3 cents/litre. Petrol savings to the industry were estimated using the wholesale petrol price, excluding any taxes or margins. In 2021–22, the wholesale petrol price was estimated at 74.3 cents/litre.

Costs

The quantifiable costs of the limits on petrol volatility over summer are the costs to industry and the costs of government administration.

Costs to government are those associated with monitoring supplier compliance with the volatility limits, either through reviewing industry reports or checking compliance at retail outlets, refineries or terminals, and any enforcement activities that result. These annual government costs are estimated to be $58,505, based on the 2010 RIS estimate of $50,000, adjusted for inflation.

Costs to industry to comply with petrol volatility limits consist of reformulating petrol to meet the current petrol volatility limits and/or importing lower volatility fuels. The CBA assumes that 20% of summer petrol is reformulated locally and 80% is imported. Since the closure of refineries in NSW, it is estimated that, at most, only 20% of the petrol consumed in the GMR, and therefore subject to the summer volatility limit, is produced by domestic refineries, principally in Victorian refineries (Fueltrac 2018).

Refiners are readily able to reformulate petrol to meet the current petrol volatility limits without additional capital costs, as the requisite management systems have been developed. This reformulation results in more of the lighter hydrocarbons, such as butane, being separated out during the refining of oil to petrol. The cost to industry represents forgone profit from redirecting butane away from its highest value end-product (petrol) and instead selling it as fuel gas. These costs are very dependent on prevailing oil prices and exchange rates. Under a general assumption that the price of oil will increase over the next few years, the costs to industry would increase.

The premium on imported petrol that meets the summer volatility limit is estimated to be zero, since the volatility of gasoline imported from efficient, large-scale export refineries in Asia is typically limited to 60 kPa throughout the year (Fueltrac 2018).

Smoky vehicles and tampering with anti-pollution devices

Benefits

The quantifiable benefit of the smoky vehicles provisions are lower health costs as a result of a decrease in emissions of pollutants from vehicles repaired in response to an infringement notice or notice to repair a smoky vehicle.

Reductions in pollutants

A smoky vehicle emits higher concentrations of pollutants than an average vehicle. Avoided emissions are based on the number of smoky vehicles repaired each year, as well as the number of tampered vehicles repaired each year. The estimated avoided emissions per year are presented in Table C15.

Table C15 Avoided emissions from the smoky vehicle provisions.

Air pollutant	Petrol vehicles	Diesel vehicles
Smoky vehicles (no.)	3	32
Tampered vehicles (no.)	4	0
Average vehicle kilometres travelled/year	15,340	23,165
Avoided emissions (g/km)		
NO_x	2.3	
VOCs	1.7	
PM_{10}		2.37
Avoided emissions (t/year)		
NO_x	0.229	
VOCs	0.170	
PM_{10}		1.729

Source: NSW EPA staff (personal communication, 2018)

Costs

The quantifiable costs of the smoky vehicles provisions are the costs of government administration and the costs of repairing vehicles.

Typical repairs to a smoky diesel vehicle include tuning, filter replacements, new injectors and possibly engine reconditioning. Typical repairs to a smoky petrol vehicle include retuning, head gasket replacement and possibly engine reconditioning or rebuilding.

Defective vehicle notices require the vehicle owner to undertake the necessary mechanical repairs or else have the vehicle's registration cancelled. Penalty infringement notices may also be issued for smoky vehicles.

The average repair costs of smoky or tampered vehicles are presented in Table C16.

Table C16 Repair costs of smoky vehicles.

	Average repair cost per vehicle
Cost of tampering repair	$245.00
Cost of petrol repair	$1,050.00
Cost of diesel repair	$1,106.50

Source: NSW EPA staff (personal communication, 2018)

The estimated annual cost of enforcing the smoky vehicle and anti-tampering provisions of the Regulation is $80,401 (NSW EPA staff personal communication, 2018). This cost includes staff salaries and on-costs, provision of vehicles for use in enforcement activities, costs of stationery and postage, administration of the website reporting system, training of authorised officers and prosecutions.

Sensitivity tests

Because there is a degree of uncertainty in some of the assumptions, a number of sensitivity tests were undertaken. The tests found that the results are robustly positive.

Central case

Table C17 shows the central case, as described in Section 4. For the purpose of a sensitivity analysis, the results outlined below should be compared to those in Table C17.

Table C17 CBA result, 20-year analysis period, 7% discount rate (central case).

	Option 2	Option 3
Summer petrol volatility limits ($m)		
Cost to industry	–21.50	5.54
Cost to government	–0.62	0.00
PV total cost	**–22.12**	**5.54**
Value of health impact	–142.32	25.06
Motorist savings	–3.67	0.70
Distributor savings	–2.31	0.58
PV total benefits	**–148.30**	**26.34**
NPV	**–126.17**	**20.80**
BCR	**n.a.**	**4.76**
Smoky vehicles ($m)		
Cost to motorist	0.00	–0.41
Cost to government	0.00	–0.85
PV total cost	**0.00**	**–1.26**
Value of health impact	0.00	–4.96
PV total benefits	**0.00**	**–4.96**
NPV	**0.00**	**–3.70**
BCR	**n.a.**	**n.a.**

[a] In this and subsequent similar tables a BCR marked "n.a." is one that could not be calculated because benefits and/or costs are negative.

Discount rates

In accordance with the NSW Government Guidelines for Economic Appraisal (TPP07-5), the stream of costs and benefits (in real terms) has been discounted using a real discount rate of 7%; sensitivity testing used real discount rates of 3% and 10%.

Table C18 shows that different discount rates change the NPV, but do not materially change the BCR and overall result. In each scenario, Option 3 (changing the timing of summer, as defined in the Regulation) is strongly preferred to Option 1 (retaining the current timing for use of summer fuel).

Petrol volatility import premium and health impact

Both benefits and costs resulting from a policy change are uncertain. Although the assumptions for the base analysis are already conservative, the following sensitivity analyses assume even less favourable conditions:

- a 20% increase in administrative and enforcement costs
- health impacts of pollutants being approximately one-third lower, in accordance with the lower bound identified from the prevailing literature.

Table C18 CBA result, 20-year analysis period, 3% and 10% discount rates.

	Option 2		Option 3	
	3%	10%	3%	10%
Summer petrol volatility limits ($m)				
Cost to industry	–30.92	–16.99	7.96	4.37
Cost to government	–0.87	–0.50	0.00	0.00
PV total cost	**–31.79**	**–17.49**	**7.96**	**4.37**
Value of health impact	–207.03	–111.67	36.40	19.68
Motorist savings	–5.21	–2.93	0.99	0.56
Distributor savings	–3.31	–1.82	0.84	0.46
PV total benefits	**–215.55**	**–116.42**	**38.23**	**20.70**
NPV	**–183.76**	**–98.93**	**30.27**	**16.32**
BCR	**n.a.**	**n.a.**	**4.80**	**4.73**
Smoky vehicles ($m)				
Cost to motorists	0.00	0.00	–0.57	–0.33
Cost to government	0.00	0.00	–1.20	–0.68
PV total cost	**0.00**	**0.00**	**–1.77**	**–1.01**
Value of health impact	0.00	0.00	–7.15	–3.91
PV total benefits	**0.00**	**0.00**	**–7.15**	**–3.91**
NPV	**0.00**	**0.00**	**–5.38**	**–2.90**
BCR	**n.a.**	**n.a.**	**n.a.**	**n.a.**

Table C19, Table C20 and Table C21 show that higher petrol volatility import premiums (modelled as a factor of 3.21) (Fueltrac 2018) make a significant difference to the NPV and BCR estimates. However, this increase alone is not enough to change the overall result, and Option 3 remains strongly preferred to Option 1. Importantly, only when higher petrol volatility import premiums coincide with low health impacts will there be a change in the overall result, making Option 3, very slightly, the preferred option, with very little separating all other options considered.

Table C19 CBA result, 20-year analysis period, high petrol volatility import premium.

	Option 2	Option 3
Summer petrol volatility limits ($m)		
Cost to industry	–89.73	23.10
Cost to government	–0.62	0.00
PV total cost	**–90.35**	**23.10**
Value of health impact	–142.32	25.06
Motorist savings	–3.66	0.70
Distributor savings	–2.31	0.58
PV total benefits	**–148.29**	**26.34**
NPV	**–57.95**	**3.24**
BCR	**n.a.**	**1.14**
Smoky vehicles ($m)		
Cost to motorists	0.00	–0.41
Cost to government	0.00	–0.85
PV total cost	**0.00**	**–1.26**
Value of health impact	0.00	–4.96
PV total benefits	**0.00**	**–4.96**
NPV	**0.00**	**–3.70**
BCR	**n.a.**	**n.a.**

Table C20 CBA result, 20-year analysis period, low value of health impact.

	Option 2	Option 3
Summer petrol volatility limits ($m)		
Cost to industry	–21.50	5.54
Cost to government	–0.62	0.00
PV total cost	**–22.12**	**5.54**
Value of health impact	–94.88	16.71
Motorist savings	–3.67	0.70
Distributor savings	–2.31	0.58
PV total benefits	**–100.85**	**17.99**
NPV	**–78.73**	**12.45**
BCR	**n.a.**	**3.25**
Smoky vehicles ($m)		
Cost to motorists	0.00	–0.41
Cost to government	0.00	–0.85
PV total cost	**0.00**	**–1.26**
Value of health impact	0.00	–3.17
PV total benefits	**0.00**	**–3.17**
NPV	**0.00**	**–1.91**
BCR	**n.a.**	**n.a.**

Table C21 CBA result, 20-year analysis period, high petrol volatility import premium and low value of health impact.

	Option 2	Option 3
Summer petrol volatility limits ($m)		
Cost to industry	–89.73	23.10
Cost to government	–0.62	0
PV total cost	**–90.35**	**23.10**
Value of health impact	–94.88	16.71
Motorist savings	–3.67	0.70
Distributor savings	–2.31	0.58
PV total benefits	**–100.85**	**17.99**
NPV	**–10.51**	**–5.12**
BCR	**n.a.**	**0.78**
Smoky vehicles ($m)		
Cost to motorists	0.00	–0.41
Cost to government	0.00	–0.85
PV total cost	**0.00**	**–1.26**
Value of health impact	0.00	–3.17
PV total benefits	**0.00**	**–3.17**
NPV	**0.00**	**–1.91**
BCR	**n.a.**	**n.a.**

Part 5: Industrial emissions from plants and activities

Introduction

Scheduled premises

The NSW EPA estimates there are currently 259 sources that fit into the Group 3 and 4 category by nature of the date the facility was commissioned or significantly modified, upgraded or replaced. The current emission limit for a facility emission source was determined based on a limit prescribed in the facility's environment protection licence or the regulation limit (that is the Groups 3 and 4 limit). The licence limits are more stringent than limits in the Regulation and, therefore, in some cases the facility may already meet Group 5 or 6 limits.

Based on the data described above, the emission reduction required to go from Groups 3 and 4 to Groups 5 and 6 was estimated for each source. As some sources with existing Group 3 and 4 limits would already meet Group 5 or 6 limits, some assumptions were made to screen out those sources, as follows:

- If the source has an existing control for particulate matter (PM) (that is, baghouse or electrostatic precipitator) it is assumed the source already meets Group 6 limits for PM.
- If the source burns natural gas, it is assumed the source already meets Group 6 limits for PM.
- If the source has an existing control for NO_x, it is assumed the source already meets Group 5 limits (low NO_x burner, NO_x abater, dry low NO_x).

Table C22 provides a summary of the number of sources and the emission reduction potential for the transition from Groups 3 and 4 to Groups 5 and 6, excluding sources where the current limit already meets Group 5 or 6 limits and those additional sources screened out based on the assumptions above.

It is noted that not all sources have reported emissions data and, therefore, if an emission reduction potential exists in going to Group 5 or 6, the actual emission reduction value could not be calculated for these facilities.

Table C22 Summary of Group 3 and 4 sources and emission reduction potential.

Measure	PM	NO_x	VOC
Number of GMR sources with current Group 3 and 4 limits	249	237	–
Total emissions for these Group 3 and 4 sources (kg/year)	2,845,764	90,727,718	1,238,304
Number of Group 3 and 4 sources that require emission reduction to Group 5 (% of total Group 3 and 4 sources)	69 (28%)	196 (83%)	–
Number of Group 3 and 4 sources that require emission reduction to Group 6 (% of total Group 3 and 4 sources)	69 (28%)	228 (94%)	–

Notes:

1. VOC limits do not apply for Groups 3 and 4; therefore, an emission reduction for moving to Group 5 or 6 has not been quantified.
2. For PM, the estimated emission reductions are based on a transition from Group 3 and 4 limits to Group 5 or 6 limits. However, baghouse control, required for both Groups 5 and 6, would likely achieve control efficiencies in excess of 99%, so the actual emission reduction would be higher.

Source: NSW EPA 2019

Non-scheduled premises

It is estimated that non-scheduled facilities would emit 200 t of $PM_{2.5}$ per year from point sources across NSW in the absence of the Regulation, and that amount is expected to increase by about 2 t/year over the next 20 years. The emissions modelling also found that the Regulation results in an approximate emissions reduction of 30%.

These emission reductions have been used to calculate the benefits and costs of limits on PM emissions from non-scheduled industry.

Abatement cost estimates for particulate matter

The required control efficiency to move from Groups 3 and 4 to Group 5 is 60% and to move to Group 6 is 80%. To achieve this level of control, it is assumed that fabric filters (baghouse) would offer the least cost option applicable to the majority of sources (US EPA 2012). As noted above, it is assumed that sources with existing controls (baghouse or electrostatic precipitator) or that burn natural gas are already achieving Group 6 emission limits, and therefore no 'real' emission reduction potential exists.

It is noted that this abatement option may not be applicable to some sources and may not be required for some sources. However, a review of the technical feasibility of control options for each emission source was not feasible for this study. Some specific source types (for example, flares, diesel generators) were screened out of the analysis, as they were clearly not relevant for this abatement control option.

A total of 69 potential sources were identified for baghouse control, with a total emission reduction potential of 107 t/year (assuming 99% control of the reported existing emissions). It is noted that this is a small percentage of the total emissions for Group 3 and 4 sources; however, a number of large sources were not included in the analysis on the basis that they already meet Group 5 or 6 limits.

Of the 69 facilities included in the analysis, four sources alone account for 98% of the total emission reduction potential. As described above, some sources, such as those with a very small emission reduction requirement, probably do not need a baghouse to achieve Group 5 or 6 limits. When those sources are included in the analysis, the abatement cost is modest; however, the resultant cost-effectiveness ($/t abated) is unrealistically high (by nature of the very small emission reduction requirement).

It was therefore preferable to derive an indicative abatement cost estimate for the top four sources only (98% of the emissions reduction) and use that to derive an average cost-effectiveness ($/t abated). This cost-effectiveness was then applied to the total emission reduction, which added a degree of conservativeness for the CBA.

It was not feasible for this study to develop original abatement cost estimates for baghouse control so the cost estimates have been made based on cost curves provided in the *EPA air pollution control cost manual* (US EPA n.d., accessed 30 August 2018). While local estimates for abatement costs are preferable, the US EPA estimates provide a comprehensive review of the control technology options available. Limitations of applying these costs such as transferring to facilities with similar characteristics and outdated values have been adjusted for the NSW context as described below.

To estimate baghouse size (expressed as gross cloth area), an estimate of the source exhaust gas flow rate is required, combined with the gas-to-cloth ratio for the type of fabric selected.

Stack parameters were developed by the EPA for all sources, and an average gas-to-cloth ratio was selected based on the values reported in US EPA (n.d., accessed 30 August 2018) for a variety of baghouse types and fabric combinations. Using those parameters, a cost was estimated for three different baghouse types and the least cost option was selected. The bag cost and ancillary equipment costs were added and total capital investment was estimated (including other direct and indirect costs, such as installation and instrumentation). An annual capital recovery cost was estimated from the total capital investment based on an equipment life of 25 years and an interest rate of 7%.

Operation and maintenance (O&M) costs were estimated for replacement bags and electricity consumption. The power demand (kWh) was estimated based on the exhaust gas flow rate and a nominal pressure drop, for which a high value was assumed as per the worked example in US EPA (n.d., accessed 30 August 2018). The annual electricity cost was based on operating hours of 8,000 per year and an indicative electricity cost. The assumed electricity cost was per the worked example in US EPA (n.d., accessed 30 August 2018) because the adjustment to current prices and from US$ to A$ was applied later to the total annual cost.

The total annual cost is a sum of the capital recovery cost and the O&M cost and is adjusted to current prices using an inflation adjustment factor, and converted from US$ to A$. A summary of the estimated baghouse cost for the top four emission reductions is provided in Table C23.

Table C23 Abatement cost estimates for baghouse control.

Source	Emission reduction (kg)	Abatement cost ($)	Cost-effectiveness ($/t abated)
1	55,330	$445,018	$8,043
2	39,872	$1,412,887	$35,436
3	8,187	$224,892	$27,469
4	1,562	$33,800	$21,639
Total	**104,951**	**$2,116,597**	**$20,168**

Abatement cost estimates for oxides of nitrogen

Selection of the abatement options

The required control efficiency to move from Groups 3 and 4 to Group 5 is generally 20% for most sources. Regulatory limits for power stations are varied in their licences for electricity generation. The change in the standard of concentration for power stations to meet Group 5 standards ranges from 27–47%.

The reported control efficiencies that can be achieved with low NO_x burners (LNBs) range from 25% (cement manufacturing) to 84% (natural gas turbines). However, controls greater than 50% are generally not achieved (US EPA 2012). Our analysis therefore assumed that LNBs are needed to achieve Group 5 limits, although it is noted that other combustion controls (such as adjusting the air:fuel ratio) may be sufficient for those sources with a lower emission reduction requirement. However, the assumption of LNBs for all sources would be likely to result in a higher cost to industry and is therefore a more conservative assumption for the CBA.

The required control efficiency to move from Group 3 and 4 limits to Group 6 limits is generally greater than 70%. For power stations the control efficiencies needed to move from Group 3 and 4 to Group 6 limits range from 55–67% based on licence limits; however, based on current performance (NSW EPA 2018a), the required control efficiency reduces to less than 35%.

The reported control efficiencies that can be achieved with SNCR range from 35% (utility boilers) to 75% (fluidised bed combustion); however, control efficiencies greater than 60% are generally not reported (US EPA 2012).

The reported control efficiencies that can be achieved with SCR range from 75% to greater than 90%. Our analysis therefore assumes that SCR is required to achieve Group 6 limits for most sources.

Power stations may achieve the required emission reduction with lower cost LNBs or SNCR; however, consistent with the analysis for Group 5, an assumption of SNCR would result in a higher cost to industry overall and is therefore a more conservative assumption for the CBA.

Low NO_x burners

A review of the literature identified a range for capital cost factors for LNBs; however, direct comparisons of costs across various resources was not always straightforward, as various metrics are used to describe costs.

The capital cost for LNBs is very much dependent on the size (that is, installed power) of the source. Therefore, to apply cost estimates for this analysis, we required a capital cost, which was reported as a cost factor, expressed, for example, in $/kW. It was not possible to apply reported cost-effectiveness ($/t abated) to specific sources, as this factor varies significantly depending on the type and size of the source.

A sample of capital costs for LNBs is shown in Table C24. The values chosen for this analysis were taken from Table 2-4 of NESCAUM (2008), which presented capital cost factors for small, medium and large boilers in dollars per million British thermal units per hour ($/MMBtu/hr).

Table C24 Capital costs for LNBs.

Source	Size	Capital cost	Reference/source of estimate
ICI boilers	10 MMBtu/hr	US$7,616/MMBTU/hr (US$2006)	NESCAUM (2008)
	50 MMBtu/hr	$3,021/MMBTU/hr	
	150 MMBtu/hr	$1,563/MMBTU/hr	
Solid fuel boilers	250 MW	€1.7 million or €6.8/kW (US$2,312/MMBTU/hr)	EU (2017)
n.a.	n.a.	US$2.0 million (US$2008)	US EPA (2015)
ICI boilers	44–150 MMBtu/hr	$2,595–$1,429/MMBTU/hr	SJVAPCD (2018)
ICI boilers	165–660 MW	$7.6–$2.0/kW ($2,220–$577/MMBTU/hr)	Tran & Frey (1996)
ICI boilers	n.a.	$650–$8,300/MMBTU/hr (US$1993)	US EPA (1999)
	n.a.	US$16.8/kW (US$1997)	

The estimated MMBtu/hr for each source was derived from the reported source size (MW). The total capital cost was derived according to the size of the source. For simplicity, sources greater than 100 MMBtu were assigned the lowest cost factor, sources less than 10 MMBtu were assigned the highest cost factor and sources in between were assigned the medium cost factor.

O&M costs for LNBs were taken to be 1% of the capital costs. An annual capital recovery cost was estimated from the capital cost, based on an equipment life of 15 years and an interest rate of 7%. The total annual cost is a sum of the capital recovery cost and the O&M cost, and is adjusted to current prices using an inflation adjustment factor and converted from US$ to A$.

Selective catalytic reduction

Abatement cost estimates for SCR for large sources have been made based on cost calculations provided in US EPA (n.d., accessed 30 August 2018), which are provided for utility oil-fired and gas-fired units (≥25–500MW) and industrial gas-fired units (≥205 to ≤4,100 MMBtu/hr). Capital costs were made for both these options for the source size ranges provided; the lower cost value was chosen for each relevant source.

For small sources (<20 MW), estimates were made based on US EPA (2000), which presented capital costs for SCR on various engines sizes, as shown in Table C25. The total capital cost was derived according to the size of the source. For simplicity, sources under 3.0 MW were assigned the highest cost factor, and sources between 3.0 MW and 20 MW were assigned the lowest cost factor. O&M costs were taken to be 10% of the capital costs.

Table C25 Capital costs for SCR for small sources.

Engine size (MW)	US$ (1993)	$/kW
1.5	$382,000	256
3.0	$577,000	193
6.0	$967,000	162

An annual capital recovery cost was estimated from the capital cost, based on an equipment life of 15 years and an interest rate of 7%. The total annual cost is a sum of the capital recovery cost and the O&M cost and is adjusted to current prices using an inflation adjustment factor and converted from US$ to A$.

Selective non-catalytic reduction

Abatement cost estimates for SNCR have been made based on capital cost ranges reported in US EPA (n.d., accessed 30 August 2018) for coal-fired electricity generator units and coal-fired boilers. A summary of the cost ranges is provided in Table C26. Capital cost estimates were calculated for each reported range, and the average cost was selected for analysis.

Table C26 Capital costs for SNCR (US$).

Source category	Size	Capital cost range
Electricity generating units (coal)	n.a.	$10–$20/kW (US$2005)
Industrial/commercial boilers (coal)	100–1000 MMBtu/hr	$2,600–$5,300/MMBtu/hr (US$1999)

O&M costs were taken to be 10% of the capital costs. An annual capital recovery cost was estimated from the capital cost, based on an equipment life of 25 years and an interest rate of 7%. The total annual cost is a sum of the capital recovery cost and the O&M cost and is adjusted to current prices using an inflation adjustment factor and converted from US$ to A$.

Summary

A summary of the emissions reduction potentials, total abatement costs and cost-effectiveness for LNBs, SCNR and SCR is provided in Table C27.

Table C27 NO_x abatement cost estimates for LNB, SCNR and SCR.

	Scenario	Abatement measure	Emission reduction (kg)	Total abatement cost	$/t abated
Groups 3 and 4 to Group 5	Power stations excluded	LNB	336,626	$1,897,963	$5,638
Groups 3 and 4 to Group 6		SCR and SNCR	21,788,879	$63,689,080	$2,923

Distributional analysis – central case

Table C28 shows the distributional analysis for the central case, as described in Section 5. Due to the GMR's much higher population densities, the benefits and costs would be more significant in the GMR than in other regions.

A range of sensitivity tests are presented in Table C29 to Table C32, which should be compared to those in the central case presented in Table C28.

Table C28 CBA result, 20-year analysis period, 7% discount rate (central case), $ million.

	Option 2			Option 3		
	GMR	Non-GMR	NSW	GMR	Non-GMR	NSW
Cost to industry						
$PM_{2.5}$	0.00	0.00	0.00	7.34	1.69	9.04
NO_x	0.00	0.00	0.00	208.86	3.90	212.76
Cost to government	8.71	7.18	15.89	6.46	1.49	7.95
PV total cost	**8.71**	**7.18**	**15.89**	**222.66**	**7.08**	**229.74**
Industry savings	0.00	0.00	0.00	0.00	0.00	0.00
Value of health impact						
$PM_{2.5}$	–483.92	–71.55	–555.47	258.21	9.43	267.64
NO_x	–119.46	–1.53	–120.99	625.98	1.70	627.69
PV total benefits	**–603.38**	**–73.08**	**–676.46**	**884.20**	**11.13**	**895.33**
NPV	**–612.09**	**–80.27**	**–692.36**	**661.53**	**4.05**	**665.58**
BCR	**n.a.**	**n.a.**	**n.a.**	**3.97**	**1.57**	**3.90**

Sensitivity tests

Because there is a degree of uncertainty in some of the assumptions used in the analysis of benefits and costs, a number of sensitivity tests were undertaken. The tests found that the results are robustly positive.

Discount rates

In accordance with the NSW Government Guidelines for Economic Appraisal (TPP07-5), the stream of costs and benefits (in real terms) has been discounted using a real discount rate of 7%; sensitivity testing used real discount rates of 3% and 10%.

Table C29 shows that different discount rates change the NPV but do not materially change the BCR and overall result. In each scenario, Option 3 (strengthening the existing Regulation) is strongly preferred to Option 1 (maintaining the existing Regulation), while Option 2 (repealing the existing Regulation) is the least preferred.

Table C29 CBA result, 20-year analysis period, 3–10% discount rates, NSW, $ million.

	Option 2			Option 3		
	3%	7%	10%	3%	7%	10%
Cost to industry	0.00	0.00	0.00	0.00	0.00	0.00
$PM_{2.5}$	0.00	0.00	0.00	14.01	9.04	6.70
NO_x	0.00	0.00	0.00	315.12	212.76	167.43
Cost to government	22.32	15.89	12.77	11.16	7.95	6.39
PV total cost	**22.32**	**15.89**	**12.77**	**340.29**	**229.74**	**180.51**
Industry savings	0.00	0.00	0.00	0.00	0.00	0.00
Value of health impact						
$PM_{2.5}$	–682.12	–555.47	–494.75	421.45	267.64	196.16
NO_x	–169.28	–120.99	–97.50	1,063.49	627.69	431.85
PV total benefits	**–851.41**	**–676.46**	**–592.25**	**1,484.94**	**895.33**	**628.00**
NPV	**–873.72**	**–692.36**	**–605.02**	**1,144.65**	**665.58**	**447.50**
BCR	**n.a.**	**n.a**	**n.a.**	**4.36**	**3.90**	**3.48**

Abatement cost and health impact

There is a degree of uncertainty in both benefits and costs resulting from a policy change. Although the assumptions for the base analysis are already conservative, the following sensitivity analyses assume even less favourable conditions:

- a 20% increase in abatement costs
- health impacts of pollutants being approximately one-third lower, in accordance with the lower bound identified from the prevailing literature.

Table C30, Table C31 and Table C32 show that high costs and lower benefits change the NPV but do not materially change the BCR and overall result. The exception is the NSW non-GMR, where lower health impacts will change the NPV from positive to negative. The key driver is low population density, meaning that lower health benefits (aggregated over the low population base) are outweighed by costs imposed on industry.

Table C30 CBA result, 20-year analysis period, high abatement cost, $ million.

	Option 2			Option 3		
	GMR	Non-GMR	NSW	GMR	Non-GMR	NSW
Cost to industry	0.00	0.00	0.00	0.00	0.00	0.00
$PM_{2.5}$	0.00	0.00	0.00	8.81	2.03	10.84
NO_x	0.00	0.00	0.00	250.63	4.68	255.31
Cost to government	8.71	7.18	15.89	6.46	1.49	7.95
PV total cost	**8.71**	**7.18**	**15.89**	**265.90**	**8.20**	**274.10**
Industry savings	0.00	0.00	0.00	0.00	0.00	0.00
Value of health impact						
$PM_{2.5}$	–483.92	–71.55	–555.47	258.21	9.43	267.64
NO_x	–119.46	–1.53	–120.99	625.98	1.70	627.69
PV total benefits	**–603.38**	**–73.08**	**–676.46**	**884.20**	**11.13**	**895.33**
NPV	**–612.09**	**–80.27**	**–692.36**	**618.29**	**2.93**	**621.22**
BCR	**n.a.**	**n.a.**	**n.a.**	**3.33**	**1.36**	**3.27**

Table C31 CBA result, 20-year analysis period, low value of health impact, $ million.

	Option 2			Option 3		
	GMR	Non-GMR	NSW	GMR	Non-GMR	NSW
Cost to industry	0.00	0.00	0.00	0.00	0.00	0.00
$PM_{2.5}$	0.00	0.00	0.00	7.34	1.69	9.04
NO_x	0.00	0.00	0.00	208.86	3.90	212.76
Cost to government	8.71	7.18	15.89	6.46	1.49	7.95
PV total cost	**8.71**	**7.18**	**15.89**	**222.66**	**7.08**	**229.74**
Industry savings	0.00	0.00	0.00	0.00	0.00	0.00
Value of health impact						
$PM_{2.5}$	–390.19	–58.94	–449.13	165.16	6.03	171.19
NO_x	–55.20	–0.72	–55.92	309.18	0.85	310.03
PV total benefits	**–445.39**	**–59.66**	**–505.05**	**474.34**	**6.88**	**481.22**
NPV	**–454.10**	**–66.84**	**–520.94**	**251.68**	**–0.20**	**251.47**
BCR	**n.a.**	**n.a.**	**n.a.**	**2.13**	**0.97**	**2.09**

Table C32 CBA result, 20-year analysis period, high abatement cost and low value of health impact, $ million.

	Option 2			Option 3		
	GMR	Non-GMR	NSW	GMR	Non-GMR	NSW
Cost to industry	0.00	0.00	0.00	0.00	0.00	0.00
$PM_{2.5}$	0.00	0.00	0.00	8.81	2.03	10.84
NO_x	0.00	0.00	0.00	250.63	4.68	255.31
Cost to government	8.71	7.18	15.89	6.46	1.49	7.95
PV total cost	**8.71**	**7.18**	**15.89**	**265.90**	**8.20**	**274.10**
Industry savings	0.00	0.00	0.00	0.00	0.00	0.00
Value of health impact						
$PM_{2.5}$	–390.19	–58.94	–449.13	165.16	6.03	171.19
NO_x	–55.20	–0.72	–55.92	309.18	0.85	310.03
PV total benefits	**–445.39**	**–59.66**	**–505.05**	**474.34**	**6.88**	**481.22**
NPV	**–454.10**	**–66.84**	**–520.94**	**208.44**	**–1.32**	**207.11**
BCR	**n.a.**	**n.a.**	**n.a.**	**1.78**	**0.84**	**1.76**

Part 6: Control of volatile organic liquids

The analysis of Part 6 assessed the impacts of regulatory and no-regulation options as they relate to petrol stations and large storage tanks. The key assumptions that underpin the analysis are discussed below.

Petrol stations

The key assumptions relating to the petrol station analysis are summarised in Table C33.

Large storage tanks

The key assumptions relating to large storage tanks are summarised in Table C34.

Sensitivity tests

Because there is a degree of uncertainty in some of the assumptions, a number of sensitivity tests were undertaken. The tests found that the results are robustly positive.

Central case

Table C35 and Table C36 show the central case, as described in Section 6. For the purpose of a sensitivity analysis, the results outlined below should be compared to those in Table C35 and Table C36.

Table C33 Key assumptions, petrol stations.

Variable	Assumption
Petrol consumption	
VR1 stations	4,238,594,212 litres/year (2020)
VR2 stations	2,844,182,887 litres/year (2020)
Valve asset life	3 years
Emissions factors	
Uncontrolled emissions	880.0 mg/L
Emission reduction VR1 with PV valve	830.0 mg/L
Emission reduction VR1 without PV valve	729.0 mg/L
Emissions reduction with VR2	1,731.3 mg/L
Petrol stations	
Number of VR1 petrol stations	1,114
Cost of PV valve replacement	$500
Number of VR2 petrol stations	538
Operating cost VR2	$1,733 $/annum/station
VR2 phased out (no regulation)	5 years

Source: NSW EPA 2019

Table C34 Key assumptions, large storage tanks.

Variable	Assumption
Number of tanks	
Number of external floating roof tanks	57
Number of internal floating roof tanks	63
Total	**120**
Tanks included (based on VOL type)	**81**
Source: NSW EPA 2019	
Tank life	**>50 years**
Cost to install secondary seals on external floating roof tank (average $/tank, based on average tank diameter)	$33,461

Variable	Assumption
VOLs included (tank analysis)	**1 = yes, 0 = no**
Alkylate	0
Combined cat naphtha	0
Crude oil	0
D10 diesel	0
Ethanol	0
Ethanol – E100	0
Gasoline blendstock	0
Heavy reformate	0
Heavy straight run (HSR) naphtha	0
High normal naphtha	0
Iso naphtha	0
JET A-1/diesoline	0
Light reformate	0
Light straight run (LSR) naphtha	0
Off-test naphtha	0
Other: Petrol – unleaded 95/98	1
Other: Petrol – unleaded 95, ethanol	1
Petrol – unleaded 91	1
Petrol – unleaded 95	1
Petrol – unleaded 98	1
Polymerate	0
PULP	1
Reformate	0
Slop	0
SLOPS	0
SPULP	1
ULP	1
V-POWER	1
Off-spec	0

Table C35 CBA result for large storage tanks, 20-year analysis period, 7% discount rate (central case).

	Option 2	Option 3
	Value ($m)	
Cost to industry	0.00	0.19
Cost to government	0.00	0.00
PV total cost	**0.00**	**0.19**
Industry savings (recovered product)	–0.02	0.17
Value of health impact	–0.11	0.87
PV total benefits	**–0.13**	**1.03**
Net PV	**–0.13**	**0.84**
BCR	**n.a.**	**5.41**

Table C36 CBA result for petrol stations, 20-year analysis period, 7% discount rate (central case).

	Option 2
	Value ($m)
Cost to industry	–10.96
Cost to government	0.0
PV total cost	**–10.96**
Industry savings (recovered product)	–65.48
Value of health impact	–337.73
PV total benefits	**–403.20**
Net PV	**–392.25**
BCR	**n.a.**

Discount rates

In accordance with the NSW Government Guidelines for Economic Appraisal (TPP07-5), the stream of costs and benefits (in real terms) has been discounted using a real discount rate of 7%; sensitivity testing used real discount rates of 3% and 10%.

Table C37 shows that different discount rates change the NPV but do not materially change the BCR and overall result. In each of the large storage tank scenarios, Option 3 (more stringent emissions limits and control equipment) is strongly preferred to Option 1 (maintaining the existing Regulation), while Option 2 (repealing the existing Regulation) is the least preferred.

Table C38 shows that different discount rates change the NPV but do not materially change the BCR and overall result. Option 1 (maintaining the existing Regulation) is strongly preferred to Option 2 (repealing the existing Regulation).

Table C37 CBA result for large storage tanks, 20-year analysis period, 3–10% discount rates.

	Option 2 Value ($m)			Option 3 Value ($m)		
	3%	7%	10%	3%	7%	10%
Cost to industry	0.00	0.00	0.00	0.27	0.19	0.15
Cost to government	0.00	0.00	0.00	0.00	0.00	0.00
PV total cost	**0.00**	**0.00**	**0.00**	**0.27**	**0.19**	**0.15**
Industry savings (recovered product)	–0.03	–0.02	–0.02	0.27	0.17	0.12
Value of health impact	–0.18	–0.11	–0.08	1.41	0.87	0.62
PV total benefits	**–0.21**	**–0.13**	**–1.00**	**1.68**	**1.03**	**0.74**
Net PV	**–0.21**	**–0.13**	**–0.00**	**1.41**	**0.84**	**0.59**
BCR	**n.a.**	**n.a.**	**n.a.**	**6.23**	**5.41**	**4.95**

Table C38 CBA result for petrol stations, 20-year analysis period, 3–10% discount rates.

	Option 2 Value ($m)			Option 3 Value ($m)		
	3%	7%	10%	3%	7%	10%
Cost to industry	–15.73	–10.96	–8.65	0	0	0
Cost to government	0.0	–0.0	0.0	0	0	0
PV total cost	**–15.73**	**–10.96**	**–8.65**	**0**	**0**	**0**
Industry savings (recovered product)	–95.86	–65.48	–50.96	0	0	0
Value of health impact	–496.77	–337.73	–262.07	0	0	0
PV total benefits	**–592.63**	**–403.20**	**–313.02**	**0**	**0**	**0**
Net PV	**–576.90**	**–392.25**	**–304.37**	**0**	**0**	**0**
BCR	**n.a.**	**n.a.**	**n.a.**	**n.a.**	**n.a.**	**n.a.**

Capital and operating costs and health impacts

Both benefits and costs resulting from a policy change have a degree of uncertainty. Although the assumptions for the base analysis are already conservative, the following sensitivity analyses assume even less favourable conditions:

- a 20% increase in capital and operating costs
- health impacts of pollutants being approximately one-third lower, in accordance with the lower bound identified from the prevailing literature.

Table C39, Table C40 and Table C41 show that, for large storage tanks, high costs and lower benefits change the NPV but do not materially change the BCR and overall result. In each tank storage scenario, Option 3 (more stringent emissions limits and control equipment) is strongly preferred to Option 1 (maintaining the existing Regulation), while Option 2 (repealing the existing Regulation) is the least preferred.

Table C39 CBA result for large storage tanks, 20-year analysis period, high capital and operating cost.

	Option 2 Value ($m)	Option 3 Value ($m)
Cost to industry	0.00	0.23
Cost to government	0.00	0.00
PV total cost	**0.00**	**0.23**
Industry savings (recovered product)	–0.02	0.17
Value of health impact	–0.11	0.87
PV total benefits	**–0.13**	**1.03**
NPV	**–0.13**	**0.80**
BCR	**n.a.**	**4.51**

Table C40 CBA result for large storage tanks, 20-year analysis period, low value of health impact.

	Option 2 Value ($m)	Option 3 Value ($m)
Cost to industry	0.00	0.19
Cost to government	0.00	0.00
PV total cost	**0.00**	**0.19**
Industry savings (recovered product)	–0.02	0.17
Value of health impact	–0.08	0.58
PV total benefits	**–0.10**	**0.74**
Net PV	**–0.10**	**0.55**
BCR	**n.a.**	**3.90**

Table C41 CBA result for large storage tanks, 20-year analysis period, high capital and operating cost and low value of health impact.

	Option 2 Value ($m)	Option 3 Value ($m)
Cost to industry	0.00	0.23
Cost to government	0.00	0.00
PV total cost	**0.00**	**0.23**
Industry savings (recovered product)	–0.02	0.17
Value of health impact	–0.08	0.58
PV total benefits	**–0.10**	**0.75**
Net PV	**–0.10**	**0.52**
BCR	**n.a.**	**3.25**

Table C42, Table C43 and Table C44 show that, for petrol stations, high costs and lower benefits change the NPV but do not materially change the overall result. In each scenario, Option 1 (maintaining the existing Regulation) is strongly preferred to Option 2 (repealing the existing Regulation).

Table C42 CBA result for petrol stations, 20-year analysis period, high capital and operating cost.

	Option 2 Value ($m)
Cost to industry	–13.12
Cost to government	0.0
PV total cost	**–13.12**
Industry savings (recovered product)	–65.48
Value of health impact	–337.73
PV total benefits	**–403.20**
NPV	**–390.08**
BCR	**n.a.**

Table C43 CBA result for petrol stations, 20-year analysis period, low value of health impact.

	Option 2 Value ($m)
Cost to industry	–10.96
Cost to government	0.0
PV total cost	**–10.96**
Industry savings (recovered product)	–65.48
Value of health impact	–225.15
PV total benefits	**–290.63**
Net PV	**–279.67**
BCR	**n.a.**

Table C44 CBA result for petrol stations, 20-year analysis period, high capital and operating cost and low value of health impact.

	Option 2 Value ($m)
Cost to industry	–13.12
Cost to government	0.0
PV total cost	**–13.12**
Industry savings (recovered product)	–65.48
Value of health impact	–225.15
PV total benefits	**–290.63**
Net PV	**–277.50**
BCR	**n.a.**

References

ABS (Australian Bureau of Statistics) 2014, *Environmental issues: energy use and conservation*, cat. no. 4602.0.55.001, ABS, Canberra, March, www.abs.gov.au/ausstats/abs@.nsf/mf/4602.0.55.001.

ABS (Australian Bureau of Statistics) 2016, *Australian Statistical Geography Standard: volume 4 – Significant urban areas, urban centres and localities, section of state*, cat. no. 1270.0.55.004, ABS, Canberra, July www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/1270.0.55.004July%202016?OpenDocument.

Access Economics 2008, *The health of nations: The value of a statistical life,* prepared for the Australian Safety and Compensation Council, Canberra, July.

AEA Technology Environment 2005, *Damages per tonne emission of $PM_{2.5}$, NH_3, SO_2, NOx and VOCs from each EU25 member state (excluding Cyprus) and surrounding seas*, DG Environment, European Commission.

AECOM 2014, *Wood smoke control measures: Cost benefit analysis*, State of NSW and Environment Protection Authority, Sydney.

AQEG (Air Quality Expert Group) 2009, *Ozone in the United Kingdom*, prepared for the Department for Environment, Food and Rural Affairs, UK.

Azzi M, Tibbett A, Angove D, Carras J & Quigley S 2007, *Measurements of volatile organic compounds (VOCs) in the ambient air of selected sites in the Sydney Basin*, CSIRO, Sydney.

Broome RA, Fann N, Navin Cristina TJ, Fulcher C, Duc H & Morgan G 2015, The health benefits of reducing air pollution in Sydney, Australia, *Environmental Research*, vol.143, pp.19–25.

COMEAP (Committee on the Medical Effects of Air Pollutants) 2018, *Associations of long-term average concentrations of nitrogen dioxide with mortality*, Public Health England, Chilton.

Cope M, Lee S, Physick B, Abbs D, Nguyen K & McGregor J 2008, *A methodology for determining the impact of climate change on ozone levels in an urban area*, report by CSIRO, Division of Marine and Atmospheric Research, for the Clean Air Research Program, Department of the Environment, Water, Heritage and the Arts, Canberra.

Dean M & Ferrari L 1990, *Reduction in Sydney's brown haze from refuse burning controls*, State Pollution Control Commission of NSW, Sydney.

DEC (Department of Environment and Conservation) 2005, *Air pollution economics: Health costs of air pollution in the Greater Sydney Metropolitan Region*, NSW Department of Environment and Conservation, Sydney, www.environment.nsw.gov.au/research-and-publications/publications-search/air-pollution-economics-health-costs-of-air-pollution-in-the-greater-sydney-metropolitan-region

DECC (NSW Department of Environment and Climate Change) 2007, *Current and projected air quality in NSW: A technical paper supporting the Clean Air Forum 2007*, NSW Department of Environment and Climate Change, Sydney.

DECCW (NSW Department of Environment, Climate Change and Water) 2010, *Regulatory Impact Statement: Proposed Protection of the Environment Operations (Clean Air) Regulation 2010*, NSW Department of Environment, Climate Change and Water, Sydney.

Defra (UK Department for Environment, Food and Rural Affairs) 2011, *Air quality appraisal damage cost methodology: interdepartmental group on costs and benefits*, Air Quality Subject Group, UK Department for Environment, Food and Rural Affairs, London, UK, February.

Defra (UK Department for Environment, Food and Rural Affairs) 2015a, *Air quality economic analysis: Damage costs by location and source*, UK Department for Environment, Food and Rural Affairs, London, UK.

Defra (UK Department for Environment, Food and Rural Affairs) 2015b, *Valuing impacts on air quality: Updates in valuing changes in emissions of oxides of nitrogen (NO_x) and concentrations of nitrogen dioxide (NO_2)*, UK Department for Environment, Food and Rural Affairs, London, UK.

Eastern Research Group 2001, 'Open Burning', vol. III, ch. 16, *EIIP Guidance for Emissions Inventory Development*, US EPA

EU (European Union) 2017, *Best available techniques (BAT) reference document for large combustion plants,* EUR 28836 EN, doi:10.2760/949.

Fueltrac 2018, *Advice for NSW EPA: Gasoline RVP*, prepared 10 May 2018.

Jerrett M, Burnett RT, Arden Pope C, Ito K, Thurston G, Krewski D, Shi Y, Calle E & Thun M 2009, Long-term ozone exposure and mortality, *New England Medical Journal*, vol.360, pp.1085–95.

MJA (Marsden Jacob Associates) 2017, *Revised fuel quality standards: Economic analysis*, prepared for the Department of the Environment and Energy, Canberra.

MJA (Marsden Jacob Associates) 2018, *Valuing the health impacts of NO_x emissions in NSW*, prepared for NSW Environment Protection Authority, Sydney.

Morgan G, Broome R & Jalaludin B 2013, *Summary for policy makers of the health risk assessment on air pollution in Australia*, prepared for the National Environment Protection Council, Canberra.

NEPC (National Environment Protection Council) 1998, *National environment protection measure and revised impact statement for ambient air quality*, National Environment Protection Council, Canberra.

NEPC (National Environment Protection Council) 2013, *Consultation regulation impact statement for reducing emissions from wood heaters*, National Environment Protection Council, Canberra, www.nepc.gov.au/resource/consultation-regulation-impact-statement-reducing-emissions-wood-heaters.

NESCAUM (Northeast States for Coordinated Air Use Management) 2008, *Applicability and feasibility of NO_x, SO_2, and PM emissions control technologies for industrial, commercial, and institutional (ICI) boilers*, Northeast States for Coordinated Air Use Management, Boston, November.

NSW EPA (NSW Environment Protection Authority) 2016a, *EPA licensing guideline: Environmental risk levels*, NSW Environment Protection Authority, Sydney, www.epa.nsw.gov.au/licensing-and-regulation/licensing/environment-protection-licences/risk-based-licensing.

NSW EPA (NSW Environment Protection Authority) 2016b, *NSW local government waste and resource recovery data report 2014–15 and appendix*, State of NSW and NSW Environment Protection Authority, Sydney.

NSW EPA (NSW Environment Protection Authority) 2017, *Standards and best practice guidelines for vapour recovery at petrol service stations*, State of NSW and NSW Environment Protection Authority, Sydney.

NSW EPA (NSW Environment Protection Authority) 2018a, *NSW Environmental Protection Authority review of coal fired power stations air emissions and monitoring*, NSW Environment Protection Authority, Sydney, March.

NSW EPA (NSW Environment Protection Authority) 2018b, *NSW State of the Environment 2018*, NSW Environment Protection Authority, Sydney, www.soe.epa.nsw.gov.au.

NSW EPA (NSW Environment Protection Authority) 2019, *Air emissions inventory for the Greater Metropolitan Region in New South Wales: Consolidated natural and human-made emissions – Results*, NSW Environment Protection Authority, Sydney.

NSW Government 2011, *Air pollution: Particulate matter* $PM_{2.5}$, Office of Environment and Heritage, Sydney, June, www.epa.nsw.gov.au/resources/air/110456Airpollution.pdf.

NSW Government 2016, *Clean air for NSW: consultation paper*, NSW Environment Protection Authority and Office of Environment and Heritage, Sydney, www.epa.nsw.gov.au/your-environment/air/clean-air-nsw.

NSW Government 2017, *Wood smoke: Clean air for NSW*, NSW Government, Sydney, June, www.epa.nsw.gov.au/your-environment/air/clean-air-nsw.

NSW Government 2019, *TPP 19-01 NSW Government Guide to Better Regulation*, NSW Government, Sydney, January, www.treasury.nsw.gov.au/sites/default/files/2019-09/TPP19-01%20-%20Guide%20to%20Better%20Regulation.pdf.

NSW Treasury 2007, *TPP07-5: NSW Government Guidelines for Economic Appraisal*, NSW Treasury, Sydney, arp.nsw.gov.au/tpp07-05-nsw-government-guidelines-economic-appraisal.

NSW Treasury 2019. *TC19-02: Guide To Better Regulation,* NSW Treasury, Sydney, January www.treasury.nsw.gov.au/sites/default/files/2019-01/TC19-02%20-%20Guide%20to%20Better%20Regulation_0.pdf.

OPBR (Office of Best Practice Regulation) 2014, *Best practice regulation guidance note: Value of statistical life*, Office of Best Practice Regulation, Department of the Prime Minister and Cabinet, Canberra, December.

Pacific Environment 2016a, *Air quality impact assessment: Independent review of the Fuel Quality Standards Act 2000*, prepared for Marsden Jacob Associates, Sydney, March.

Pacific Environment 2016b, *Health risk assessment for the cost benefit analysis: Independent review of the Fuel Quality Standards Act 2000*, prepared for Marsden Jacob Associates, May.

PAE Holmes 2013, *Methodology for valuing the health impacts of changes in particle emissions: Final report*, NSW Environment Protection Authority, Sydney.

Pope C & Dockery D 2006, Health effects of fine particulate air pollution: lines that connect, *Journal of the Air and Waste Management Association*, vol.56, pp.709–42.

SJVAPCD (San Joaquin Valley Air Pollution Control District) 2018, *ICI boiler* NO_x *control cost estimates: final draft staff report*, 9/18/08, San Joaquin Valley Air Pollution Control District.

Smith KR, Jerrett M, Anderson HR, Burnett RT, Stone V, Derwent R, Atkinson RW, Cohen A, Shonkoff SB, Krewski D, Pope CA 3rd, Thun MJ & Thurston G 2009, Public health benefits of strategies to reduce greenhouse-gas emissions: Health implications of short-lived greenhouse gases, *The Lancet*, vol.374, no.9707, pp.2091–103.

Tran LK & Frey HC 1996, *Methods for evaluating the costs of utility NOx control technologies*, Air and Waste Management Association, Nashville, Tennessee, www.researchgate.net/publication/251419571_Methods_for_Evaluating_the_Costs_of_Utility_NO_x_Control_Technologies.

US EPA (United States Environmental Protection Agency) 1999, *Nitrogen oxides (NO_x): Why and how they are controlled*, US Environmental Protection Agency, Washington DC.

US EPA (United States Environmental Protection Agency) 2000, *NO_x emissions control costs for stationary reciprocating internal combustion engines in the NO_x SIP call state*, report prepared by Pechan-Avanti Group, US Environmental Protection Agency, Washington DC, August.

US EPA (United States Environmental Protection Agency) 2006, *Air quality criteria for ozone and related photochemical oxidants: Final report*, EPA/600/R-05/004aF-cF, US Environmental Protection Agency, Washington DC.

US EPA (United States Environmental Protection Agency) 2009, *Integrated science assessment (ISA) for particulate matter: Final report*, EPA/600/R-08/139F, US Environmental Protection Agency, Washington DC.

US EPA (United States Environmental Protection Agency) 2012, *Menu of control measures for NAAQS implementation*, US Environmental Protection Agency, Washington DC, www.epa.gov/air-quality-implementation-plans/menu-control-measures-naaqs-implementation.

US EPA (United States Environmental Protection Agency) 2015, *Assessment of non-EGU NO_x emission controls, cost of controls, and time for complianc*e, US Environmental Protection Agency, Washington DC.

US EPA (United States Environmental Protection Agency) 2016, *Integrated science assessment for oxides of nitrogen: Health criteria, EPA/600/R-15/068*, US Environmental Protection Agency, Washington DC.

US EPA (United States Environmental Protection Agency) n.d. (accessed 30 August 2018), *EPA air pollution control cost manual*, US Environmental Protection Agency, Washington DC, www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/cost-reports-and-guidance-air-pollution#cost%20manual.

Watkiss P 2002, *Fuel taxation inquiry: The air pollution costs of transport in Australia,* Report No. ED44525 to Commonwealth of Australia, AEA Technology Environment, Oxford, UK.

WHO (World Health Organization) 2006, *WHO air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide: Global update 2005 – Summary of risk assessment*, World Health Organization, Geneva.

WHO (World Health Organization) 2013, *Health risks of air pollution in Europe: HRAPIE project – Recommendations for concentration–response functions for cost–benefit analysis of particulate matter, ozone and nitrogen dioxide*, WHO Regional Office for Europe, Copenhagen.

Shortened forms

ADR	Australian Design Rule
AHHA	Australian Home Heating Association
BCR	benefit:cost ratio
CBA	cost–benefit analysis
CO	carbon monoxide
EPA	Environment Protection Authority (NSW)
GDP	gross domestic product
GMA	Greater Metropolitan Area, which incorporates Sydney, Illawarra and Newcastle
GMR	Greater Metropolitan Region
LBL	load-based licensing
LNB	low NO_x burner
LPG	liquefied petroleum gas
mg/L	milligrams per litre or parts per million
mg/m^3	milligrams per cubic metre
MMBtu	million British thermal units
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NHVR	National Heavy Vehicle Regulator
NO_2	nitrogen dioxide
NO_x	oxides of nitrogen
NPV	net present value
O&M	operation and maintenance
O_3	ozone
PAH	polycyclic aromatic hydrocarbon
PM	particulate matter
POEO Act	*Protection of the Environment Operations Act 1997*
PTAP	principal toxic air pollutant
PV	present value
PV valve	pressure vacuum relief valve
RIS	regulation impact statement
RMS	Roads and Maritime Services

SCR	selective catalytic reduction
SNCR	selective non-catalytic reduction
SO_2	sulfur dioxide
$\mu g/m^3$	micrograms per cubic metre; 1µg = 1 millionth of a gram
µm	micrometre or micron; 1 µm = one thousandth of a millimetre
VOC	volatile organic compound
VOL	volatile organic liquid
VOLY	value of a life year
VOSL	value of statistical life
VR	vapour recovery
VDU	vapour disposal unit
VR1	Stage 1 vapour recovery
VRU	vapour recovery unit
WHO	World Health Organization
WTP	willingness to pay
YoLL	years of life lost