Draft Regulation Impact Statement

for

Review of Euro 5/6 Light Vehicle Emissions Standards

Prepared by the

Department of Infrastructure, Transport
Regional Development and Local Government

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GLOSSARY OF TERMS

ADR	Australian Design Rule
ATC	Australian Transport Council
BCA	Benefit-cost analysis
BCR	Benefit-cost ratio
CO	Carbon monoxide
CO_2	Carbon dioxide
EC	European Commission
EPHC	Environment Protection and Heritage Council
EU	European Union
GVM	Gross vehicle mass
HC	Hydrocarbons
LCV	Commercial vehicles (utilities, vans etc) ≤3.5 tonnes GVM
Light vehicles	All 4 wheeled road vehicles ≤3.5 tonnes GVM
LPG	Liquefied petroleum gas
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NO_2	Nitrogen dioxide
NOx	Oxides of nitrogen (nitric oxide and nitrogen dioxide)
NPV	Net present value
OBD	On-board diagnostics
PM	Particulate matter, particulates, particles
PM_1, $PM_{2.5}$, PM_{10}	PM with diameter less than 1, 2.5 and 10 microns, respectively
ppm	Parts per million
PULP	“Premium” unleaded petrol (minimum 95RON)
RON	Research octane number (a parameter of petrol)
UFP	Ultra-fine particle
ULP	“Regular” unleaded petrol (minimum 91RON)
UN ECE	United Nations Economic Commission for Europe
VKT	Vehicle kilometres travelled

INTRODUCTION

Emissions from road vehicles are significant contributors to key air pollutants in Australia's cities. National actions to strengthen vehicle emissions standards and improve fuel quality are accepted as key measures to reduce urban air pollution from the road transport sector and deliver associated health benefits.

In Australia, vehicle emissions standards are set via the Australian Design Rules, which are legislative instruments under the *Motor Vehicle Standards Act 1989*. Fuel standards are set under the *Fuel Quality Standards Act 2000*.

The Australian Government has a policy of harmonising Australia's vehicle standards wherever possible with the international standards established by the United Nations Economic Commission for Europe (UN ECE) and the current emissions ADRs adopt the standards known as Euro 4. New Euro 5 and Euro 6 standards have recently been agreed for light duty vehicles, and this draft Regulation Impact Statement (RIS) has been prepared to consider the merits of adopting these latest standards in Australia.

This RIS has been prepared by the Department of Infrastructure, Transport, Regional Development and Local Government (DITRDLG).

The RIS incorporates a benefit-cost analysis undertaken by Bureau of Infrastructure, Transport and Regional Economics (BITRE). DITRDLG also acknowledges the assistance of the Department of the Environment, Water, Heritage and the Arts (DEWHA) and a number of State environment agencies in the preparation of the RIS.

This draft RIS is provided for a minimum 60 day public scrutiny and comment, prior to the presentation of a final RIS for consideration by decision makers.

Details regarding the submission of comments are set out in Section 5 (Consultation).

The following matters are **outside** the scope of this RIS:

- in-service vehicle emissions measures, which are primarily the responsibility of State and Territory Governments ;
- the parameters of existing vehicle and fuel standards, except to the extent that the impact of existing standards are evaluated to establish a base case; and
- consideration of carbon dioxide (CO_2) emissions standards, which are the subject of a separate regulatory assessment process agreed by Council of Australian Governments in July 2009.

1 ASSESSING THE PROBLEM

1.1 The Nature of the Problem - Urban Air Pollution

While urban air quality in Australia is generally good, there are still significant health concerns in relation to the concentrations of air pollutants. The air pollutants relevant to this RIS are particulate matter (PM) - especially fine and ultrafine particles - nitrogen oxides, and ground level ozone - an indicator of photochemical smog. Motor vehicles are a major contributor to these pollutants in urban air, and vehicle numbers and usage continue to rise.

PM from motor vehicle exhaust in particular is the subject of increasing concern amongst health researchers, with linkages between adverse health effects and PM exposure being demonstrated at increasingly lower levels of PM in the atmosphere. These associations are observed even when air pollutant concentrations are below national standards. New research suggests the risks of cardiovascular effects may be particularly great for exposure to fine (<2.5μm) and ultrafine (<0.1μm) exhaust particles[1]. The current consensus is that there is no safe level of exposure to PM and that any reduction in particle concentrations would improve population health outcomes[2,3,4,5].

Ozone is a secondary pollutant formed from the interaction of hydrocarbons (HCs), often referred to as volatile organic compounds (VOCs), and NOx. As with particulates, it is not possible to detect a distinct threshold for ozone, below which no individual would experience a given adverse health effect, especially given some members of a population are sensitive even at very low concentrations[6].

There are also strong associations between levels of oxides of nitrogen, (usually measured as NO_2) and daily mortality, hospital admissions for asthma, chronic obstructive pulmonary disease and heart disease.

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[1] Yue W; Schneider A; Stolzel M; Ruckerl R; Cyrys J; Pan X; Zareba W; Koenig W; Wichmann HE; Peters A (2007). *Ambient source-specific particles are associated with prolonged repolarization and increased levels of inflammation in male coronary artery disease patients*, Journal Mutation Research: Fundamental and Molecular Mechanisms of Mutagenesis, 621:50-60.

[2] Daniels MJ; Dominici F; Zeger SL; Samet JM (2004). The national morbidity, mortality, and air pollution study Part III: PM10 concentration-response curves and thresholds for the 20 largest US cities. Report.

[3] Samoli E; Analitis A; Touloumi G; Schwartz J; Anderson HR; Sunyer J; Bisanti L; Zmirou D; Vonk JM; Pekkanen J; Goodman P; Paldy A; Schindler C; Katsouyanni K (2005). Estimating the exposure-response relationships between particulate matter and mortality within the APHEA multicity project, Journal Environmental Health Perspectives, 113:88-95.

[4] Schwartz J; Coull B; Laden F; Ryan L (2008). The effect of dose and timing of dose on the association between airborne particles and survival, Journal Environmental Health Perspectives, 116:64-69.

[5] Schwartz J (2004). The effects of particulate air pollution on daily deaths: a multi-city case crossover analysis, Journal Occupational and Environmental Medicine, 61:956-961.

[6] U.S. EPA (2006). *Air quality criteria for ozone and related photochemical oxidants*. Volume I. United States Environmental Protection Agency.

A more detailed discussion of the health effects of these urban air pollutants is at Appendix A.

In June 1998, the NEPC made the National Environment Protection Measure for Ambient Air Quality (the AAQ NEPM), which set Australia's first national ambient air quality standards. The AAQ NEPM sets national standards for the six criteria pollutants specified in Table 1. The goals for each pollutant set out in Table 1 apply in the Commonwealth and each State and Territory of Australia and must be met by the year 2008.

Table 1 Australia's Ambient Air Quality NEPM Standards

Criteria Pollutant	Averaging Period	Maximum (ambient) Concentration	Air Quality Goal (maximum allowable exceedences)
Carbon monoxide (CO)	8 hours	9.0ppm	1 day a year
Nitrogen dioxide (NO_2)	1 hour 1 year	0.12ppm 0.03ppm	1 day a year None
Photochemical oxidants (as ozone)	1 hour 4 hours	0.10ppm 0.08ppm	1 day a year 1 day a year
Sulfur dioxide (SO_2)	1 hour 1 day 1 year	0.20ppm 0.08ppm 0.02ppm	1 day a year 1 day a year None
Lead	1 year	0.50 µg/m3	None
Particles as PM_{10}	1 day	50 µg/m3	5 days a year
Particles as $PM_{2.5}$	1 day 1 year	25 µg/m3 8 µg/m3	Goal is to gather sufficient data nationally to facilitate a review of the standard as part of the review of this Measure, which commenced in 2005.

A review of the AAQ NEPM standards is underway.

1.2 Current Status of Urban Air Quality in Australia

As noted earlier, the quality of air in Australian cities is generally good, but some pollutants remain a concern, including some of those derived from motor vehicle emissions. The status of those AAQ NEPM criteria pollutants which are relevant to the standards being considered in this RIS (*viz* ozone and PM) are summarised below.

Ozone

High solar radiation levels, high summer temperatures and location in coastal basins surrounded by hills make Australia's largest urban areas susceptible to photochemical smog and to its recirculation over areas of the airshed. Ozone concentrations are monitored under the AAQ NEPM as an indicator of photochemical smog. Ozone is not directly emitted from motor vehicles, but direct emissions of HCs and NOx react in the presence of sunlight to form ozone. Ozone levels remain a problem in Sydney and represent a potential problem in some of our other larger cities. Under unfavourable meteorological conditions, Sydney, Melbourne, Brisbane and Perth can experience ozone levels above the NEPM standards.

Particulates

Particle emissions are monitored in Australian cities, and some regional areas (as both PM_{10} and $PM_{2.5}$). Multiple exceedences of the PM_{10} standard occur every year in many cities in Australia. In most cases vehicles are not the principal contributors to the exceedences, which are triggered by extreme weather events such as bushfires and dust storms. Nevertheless, vehicle emissions, particularly from diesel vehicles, significantly elevate the background level of particulates in the urban atmosphere and can be a significant contributing factor to exceedences of the standards.

1.3 Contribution of Motor Vehicles to Air Pollution

Motor vehicles are one of the major emitters of air pollutants in urban Australia, contributing more than 80% of the CO emissions, 60-70% of the NOx and up to 40% of the HCs. Light petrol vehicles are the major transport contributors to CO, HC and NOx emissions, with diesel vehicles making a disproportionate contribution to NOx emissions. For example, in the Sydney airshed, diesel vehicles make up only 8% of the fleet, but are responsible for an estimated 22% of NOx emissions from transport.

While vehicles are not the major source of particle emissions in most urban airsheds, fuel combustion sources such as motor vehicles are a significant contributor to the overall particle load in urban airsheds. In Sydney for example, it is estimated that road transport contributes around 12% of annual anthropogenic PM_{10} emissions[7]. A recent study found motor vehicles contribute about 30% of particulate pollution in Melbourne. PM levels tend to be highest near busy roads and levels sometimes do not meet the PM standards[8].

Significantly, particulate emissions from diesel vehicles are almost all from the ultrafine fraction, and, as noted earlier, it is these fine particles that are considered to present the most significant human health risk.

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[7] NSW DECC (2007) *Current and projected air quality in NSW* at: http://www.environment.nsw.gov.au/resources/air/07529cpairqual.pdf

[8] EPA Victoria (2006). *Review of air quality near major roads*. Publication 1025. February 2006. Environment Protection Authority Victoria.

1.4 Future Air Pollution Trends

Although there have been considerable improvements in emissions performance of the vehicle fleet in Australia, motor vehicles continue to be an ongoing threat to Australian urban air quality, principally due to the growth in vehicle numbers and use. Recent Bureau of Infrastructure, Transport and Regional Economics estimates (BITRE, unpublished) imply growth in total motor vehicle travel (VKT) of 45% between 2000 and 2020 under business as usual conditions, with passenger car VKT growth at 37% and light commercials at 73%. This VKT growth is expected to occur even though projections of car ownership rates (number of cars per person) are predicted to essentially plateau by around 2015. Some urban regions face more rapid growth rates, with increasing VKT putting pressure on the capacity to meet some NEPM air quality standards in certain urban airsheds.

The BITRE emissions projections to 2040 undertaken for this RIS concluded that under a “business as usual” scenario, which includes the emissions standards being introduced over the 2006-2010 period, emissions of ozone precursors (HC and NOx) from the light vehicle sector will decline significantly until about 2025, after which they stabilise and then trend slightly upward. In contrast, PM emissions from light vehicles are expected to fall significantly until about 2016, then trend steeply upward. Refer to section 3.2 to view the relevant charts for NOx and PM.

While these emissions projections demonstrate the benefits of new vehicle emissions standards, the pattern and scale of urban development in parts of Australia, and the associated increase in vehicle use, is clearly having an effect on the long term trends and will place increasing pressure on the challenge to maintain improvements in urban air quality, particularly ozone and PM. More specific information on particular airsheds can be found in Appendix A.

1.5 Current Vehicle and Fuel Standards

1.5.1 Australian Vehicle Standards

Australia regulates its vehicle emissions through Australian Design Rules (ADRs). The ADRs set the standards that new vehicles are required to meet prior to their first supply to the Australian market. The ADRs are enforced as national standards under the *Motor Vehicle Standards Act 1989* and set standards for both safety and environmental performance.

Australia’s motor vehicle emissions standards have been highly effective in reducing air pollution for more than 30 years. Over that period, emissions standards have been periodically tightened in response to:

- vehicle technology advances and availability of suitable fuels;

- increasing international concern over air pollution problems, as more scientific knowledge has highlighted detrimental effects on human health; and
- increases in the size of vehicle fleets and vehicle usage, particularly in urban areas.

In recent years there has been a greater international alignment with the vehicle emissions standards set by the UN ECE[9]. The Australian Government has committed to adopting UN ECE standards as this approach provides the desired environmental outcome and facilitates international trade in motor vehicles. Globalisation of the motor vehicle industry, and the small size of the vehicle market in Australia make the development of unique Australian standards undesirable from both a government and manufacturing perspective.

The UN ECE is the only body for vehicle safety and emissions regulations that meets the definition of an international standardising body under the World Trade Organisation's Agreement on Technical Barriers to Trade. In April 2000, the Australian Government made a commitment to harmonising with UN ECE vehicle standards by acceding to the UN ECE's international agreement on harmonised automotive safety and emissions standards (known as the *1958 Agreement*). The Agreement provides a framework for mutual recognition of automotive product (including vehicles) approved by contracting parties that have adopted the ECE Regulations. This agreement does not require Australia to adopt particular UN ECE standards in Australia, but in considering the case for vehicle standards regulation, UN ECE regulations are the preferred approach.

Through its participation in international activities, the Australian government also promotes the UN ECE as *the* international technical regulations setting body for the global automotive industry and encourages other APEC economies to harmonise their national technical regulations with the ECE Regulations. It is not proposed to revisit the arguments regarding the decision to align with UN ECE standards in this RIS, as this has previously been addressed in the 1999 RIS accompanying the package of 2002/3 standards.

The current ADR for light vehicle emissions set limits on the emissions of hydrocarbons (HCs), oxides of nitrogen (NOx), carbon monoxide (CO) and particulate matter (PM).

In 2005, the Australian Government gazetted a package of new emissions ADRs for light and heavy vehicles. While aligned with the technical requirements of the UN ECE standards, the Australian emissions standards have delayed introduction dates.

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[9] The UN Economic Commission for Europe includes body known as the International Forum for the Harmonization of Vehicle Standards, which sets the UN ECE vehicle standards. The Forum is a body open to representation by all member countries of the UN. Australia is represented on the Forum.

The commencement dates for ADRs commonly involve a 1 year phase in period, which usually requires new models to comply with the standard from the implementation date of 1 January of the first year, with existing models complying by 1 January of the following year.

1.5.2 International Vehicle Standards

Given Australia’s policy to harmonise with UN ECE vehicle standards, the focus of this analysis is on the costs and benefits of the Euro 5 and Euro 6 emissions standards for light vehicles which will begin to take effect in the EU from September 2009[10]. Table 2 illustrates the planned introduction dates for the Euro 5/6 standards in the EU[11].

Table 2 Implementation Dates for Euro 5/6 Standards in Europe

Euro 5

1/9/09 – new model passenger cars and N1* vehicles < 1305kg ref mass

1/9/10 – new model commercial vehicles (N1 >1305kg ref mass)

1/1/11 – all model passenger cars and N1 vehicles < 1305kg ref mass

1/1/12 – all model commercial vehicles (N1 >1305kg ref mass)

Euro 6

1/9/14 – new model passenger cars and N1 vehicles < 1305kg ref mass

1/9/15 – new model commercial vehicles (N1 >1305kg ref mass)

1/9/15 – all model passenger cars and N1 vehicles < 1305kg ref mass

1/9/16 – all model commercial vehicles (N1 >1305kg ref mass)

*N1 = light commercial (goods carrying) vehicles

Table 3 compares the emissions limits in the Euro 5/6 light vehicle standards relative to Euro 4 (the current standard).

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[10] In the context of this Statement, references to the Euro 5/6 emission standards for light vehicles cover all 4-wheeled road vehicles $\leq$ 3.5 tonnes GVM which operate on petrol, diesel, LPG or NG.

[11] The updated version of the ECE Regulation for emissions from light vehicles (ECE R83/06) which adopts the Euro 5 standards is currently being finalised. The basic timing for Euro 5 specified in the draft ECE R83/06 matches that applying in the EU. R83/06 also includes the particle number standards previously identified for introduction in Europe between Euro 5 and Euro 6, but delays their introduction until 2 years after the start date for the “base” Euro 5. Particular OBD requirements also take effect from later dates.

Table 3 Comparison of Euro 4, 5 and 6 re: HC, NOx and PM Emission Limits under the Type I Test for Passenger Cars[12]

Standard	Limits on Emissions (Type I Test)					
	Petrol, LPG & NG Vehicles		Diesel Vehicles			
	HC (g/km)	NOx (g/km)	HC (g/km)	NOx (g/km)	PM (g/km)	Particles (no.)
Euro 4	0.1	0.08	0.045	0.25	0.25	NA
Euro 5	0.1	0.06	0.035	0.18	0.005	$6x10^{11}$
Euro 6	0.1	0.06	0.026	0.08	0.005	$6x10^{11}$

In addition to lowering the HC, NOX and PM emissions limits under the Type I test, the Euro 5/6 standards:

- apply longer durability requirements for emissions control systems (increased to 160,000km from 100,000km in Euro 4) which are designed to more closely align with the expected life of vehicles and ensure that these systems continue to function throughout the life of the vehicle;
- enhance the on-board diagnostics (OBD) requirements to provide greater assurance of in-service compliance;
- extend the low temperature emissions (Type VI) test (albeit with less stringent emissions limits) to all light vehicle categories - Euro 4 only applies this test to passenger vehicles and the lighter categories of goods vehicles. This test ensures quicker catalyst operation on vehicles which are started from a cold condition (not just at the -7^{o}C test condition);
- require all passenger vehicles, regardless of mass, to meet the same emissions limits under the Type I test (Euro 4 allowed vehicles over 2,500 kg to meet the more lenient standards applicable to the heaviest category of light goods vehicles);
- introduce a particle number standard (on a delayed timeframe), which is designed to reduce the emissions of ultrafine particles which are of greatest health concern. The introduction of this new requirement is expected to ensure that manufacturers fit high efficiency particulate traps to diesel vehicles; and
- extend the PM mass limit to direct injection petrol engines (previously only applied to diesel vehicles).

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[12] A full listing of all Type I test emission limits for light vehicles under Euro 2-6 is at Appendix A. The Type I test is the core exhaust emissions test in the standard.

1.5.3 Australian & European Fuel Standards

In recognition of the importance of fuel quality in reducing the overall environmental impact of the vehicle fleet, the Australian Government enacted the *Fuel Quality Standards Act 2000* (FQS Act). The Act provides the framework for the establishment of national fuel standards for automotive use. The main objects of the Act are to regulate the quality of fuel supplied in Australia in order to:

a) reduce the level of pollutants and emissions arising from the use of fuel that may cause environmental and health problems;

b) facilitate the adoption of better engine technology and emissions control technology; and

c) allow more effective operation of engines.

The first set of standards under the FQS Act for petrol and diesel came into effect on 1 January 2002. This RIS considers those fuel parameters that may be critical to enabling the adoption of vehicle technology required to meet new emissions standards. In the context of this RIS, the sulfur content of petrol and LPG is considered the only relevant parameter.

Australia adopted sulfur limits that link to Euro 3 equivalent sulfur limits for petrol (150ppm) from 1 January 2005 and the Euro 4 equivalent sulfur limit for diesel (50ppm) from 1 January 2006, to support the introduction of the equivalent vehicle emissions standards. From 1 January 2008, a 50ppm limit was applied to higher octane grades of unleaded petrol (95 RON PULP)[13] to support Euro 4 petrol vehicles. The maximum sulfur level allowable in LPG is currently 100ppm and is currently under review. Since 1 January 2009, the sulfur limit in diesel was further reduced to 10ppm, primarily to support the introduction of new emissions standards for heavy diesel vehicles.

While a further sulfur reduction from the levels already legislated would be beneficial, the fuel sulfur reductions embodied in the national fuel quality standards to 2006 would have already delivered the majority of direct air quality benefits available from sulfur reduction. The indirect impact of fuel sulfur relates to the sulfur sensitivity of certain vehicle technologies that could be employed to meet emissions standards. It is these indirect technology-enabling effects of low sulfur fuels that may be relevant to the standards under consideration in this RIS, and this interaction is discussed in section 1.5.4.

This RIS focuses solely on the sulfur limit standards for petrol, as diesel sulfur levels have already been reduced to 10ppm in line with international best practice and no further changes are considered necessary in the context of this review. In relation to sulfur, the European fuel standards currently specify a sulfur limit of 10ppm for both petrol and diesel vehicles.

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[13] RON = Research Octane Number; ULP = Unleaded Petrol (minimum 91 RON); PULP = Premium Unleaded Petrol (minimum 95 RON)

1.5.4 Fuels and Technology Context

While there is not a direct legislative link between the UN ECE vehicle emissions standards and European fuel standards, there is a clear recognition of the relationship between fuel quality and vehicle technology. In this context, where necessary, changes are made to fuel standards on an appropriate timeframe to support the introduction on new vehicle emissions standards.

In broad terms, the sulfur content of petrol in Europe was set at 150ppm to support the Euro 3 standards, and 50ppm for Euro 4. The decision to adopt 10ppm standards was made primarily to support carbon dioxide emissions standards by assisting improvements in fuel efficiency, not to support air pollution standards such as Euro 5/6.

The use of fuel with low sulfur levels enables the adoption of improved engine and emissions control technologies and increases the longevity of that technology. Apart from a 25% reduction in NOx emissions, the emissions limits for petrol and LPG vehicles in Euro 5/6 do not change relative to those in the Euro 4 standards, but the durability requirements are significantly increased.

Petrol engined vehicles rely largely on the three-way catalytic converter, in combination with the engine management system, to control emissions. While these catalysts operate effectively at current sulfur levels (150ppm or less), it is widely recognised that in-service catalyst durability is affected by fuel sulfur. The durability question becomes more critical in the context of Euro 5/6 as these standards would require manufacturers to demonstrate compliance with the emissions standards at 160,000km (compared to 100,000km in Euro 4).

There is considerable variability in the sulfur tolerance of advanced emissions control technologies , and their performance at various sulfur levels. A 2000 report prepared for the European Commission[14] concluded that that Euro 4 compliant vehicles will function properly on 50ppm sulfur petrol, noting that the advantages of even lower sulfur levels were linked to improved fuel consumption/greenhouse outcomes, not emissions compliance.

In Australia, the sulfur content of PULP is 50ppm, while the sulfur content of ULP remains at 150ppm. When these standards were set, there was an expectation that with the introduction of Euro 3 and Euro 4 emissions standards, there would be a significant shift to higher octane fuel (95 RON PULP) for new vehicles, and that 91 RON ULP would essentially become a "legacy" fuel for older technology vehicles.

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[14] AEA (2000) *Consultation on the Need to Reduce the Sulphur content of Petrol and Diesel Fuels below 50*ppm:- *A Policy Makers Summary* report prepared for the European Commission, DG Environment, by Marsh, G, Hill, N and Sully, J of AEA Technology, November 2000.

However, the use of PULP has grown only slowly from 11% of petrol sales in 2003 to 17% in 2008. This reflects changes in the vehicle fleet, with older vehicles using ULP being retired, and the introduction of a larger, but still relatively low, number of new vehicles into the fleet which require operation on PULP. There is no evidence to suggest that the proportion of new vehicles requiring PULP is likely to significantly increase under current policy settings. To illustrate this, all but one (the VW Golf) of the top 20 selling light vehicles on the Australian market in June 2009 were supplied as suitable for operation on ULP[15].

In broad terms, lagging in key fuel quality parameters can negatively impact on the development of the vehicle industry. As the Productivity Commission's 2002 Review of Automotive Assistance noted "… lower [laxer] fuel standards might well be a further constraint on the industry's uptake and development of engine technologies necessary to remain competitive in global markets"[16].

Based on the European approach, it would appear that a 50ppm sulfur level would be adequate to support Euro 5/6 petrol and LPG vehicle technologies. However, the impact on the emissions performance of Euro 5/6 vehicles operating on petrol with sulphur levels greater than 50ppm, and/or using petrol with an octane level less than 95 RON is unclear.

While it is well understood that sulfur in fuels can accelerate degradation of catalytic converters, the review was not able to access any definitive information to assess the impact of this particular level of sulfur on technologies likely to be used for Euro 5 standards.

1.6 Why is Government Action Required?

Urban communities have an expectation that the level of air pollution in Australia's major cities does not endanger their immediate and long term health, and are concerned about the impact of vehicles on the environment[17]. Vehicles are significant contributors to key urban air pollutants which at sufficiently levels of exposure can adversely affect acute and chronic health conditions. While Australia's urban air quality is generally good, concerns remain regarding the contribution of vehicle emissions to photochemical smog (particularly in Sydney) and the health impacts of PM and NO_2 emissions, particularly in an environment of increasing population growth in our major urban centres and resultant increases in vehicle numbers.

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[15] Source: www.greenvehicleguide.gov.au Note: In some cases, some variants of models listed as ULP compatible (usually higher performance versions) required operation on PULP.

[16] Productivity Commission (2002) *Review of Automotive Assistance – Inquiry Report No.25,* August 2002 at: http://www.pc.gov.au/__data/assets/pdf_file/0003/25284/auto.pdf

[17] ANOP (2005) *National Survey of Motorists' Attitudes* Report prepared for the Australian Automobile Association at: http://www.aaa.asn.au/documents/opinion%2F2005%2FANOP_exec_05.pdf

In economic analysis terms, noxious vehicle emissions are an externality which can lead to significant health impacts on people, particularly in urban areas, and which are not effectively addressed by the operation of market forces. Government actions to strengthen vehicle emissions standards and improve fuel quality are internationally recognized[18] as very effective measures to reduce urban air pollution – and such standards have managed to deliver improvements in urban air quality despite growth in vehicle use. As stated in a 2004 World Bank report[19] on reducing urban air pollution, "…the imposition and enforcement of (vehicle emissions) standards have proven a very effective environmental policy in many countries."

While the technology and manufacturing steps required to comply with the Euro 5/6 emissions standards are well known, there are nevertheless costs associated with making those changes which inhibit their voluntary adoption by manufacturers (particularly for diesel vehicles). As discussed in section 4.2 of this RIS, estimating actual costs can be difficult. However taking the European Commission estimates from Table 6 (see section 4.2) as an guide, the average cost increase of $980 for a diesel vehicle to comply with Euro 6 standards relative to the current standards (Euro 4), if fully passed on to the consumer, would represent a price increase of around 4.5% for a $22,000 vehicle and 2.5% for a $40,000 vehicle[20].

If a case is made for further reductions in emissions from the vehicle fleet, voluntary standards, or other approaches based on industry self-regulation, are unlikely to be effective in delivering those reductions, as there is no clear market incentive for manufacturers to provide vehicles meeting emissions outcomes that do not have a high profile in the mind of new vehicle consumers (unlike vehicle safety, for example). As noted by the EC in its consideration of the case for Euro 5/6 emissions standards, "self-regulation would imply a significant departure from an approach that is well established all over the world and has proven its effectiveness and proportionality in the past"[21]. The EC also noted that to measure compliance under a voluntary approach, governments and manufacturers would need to establish processes which would essentially duplicate those which already operate under the type approval system for mandatory standards, thus increasing cost and complexity. These issues are discussed in more detail in Section 3 (Option 1).

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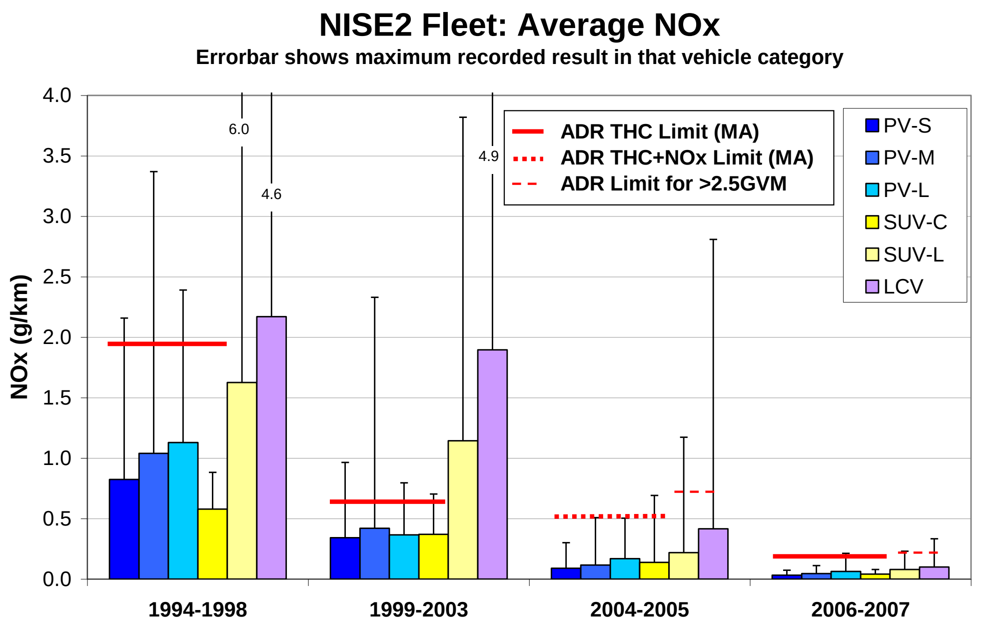
[18] For example, see OECD (2004) *Can Cars Come Clean? Strategies for Low Emission Vehicles* at: http://www.oecdbookshop.org/oecd/display.asp?k=5LMQCR2JFM24&lang=en ; ECMT (2001) *Vehicle Emission Reductions* at: http://www.internationaltransportforum.org/europe/ecmt/pubpdf/01VehEmis.pdf

[19] World Bank (Gwilliam, K, Kojima, M & Johnson, T) (2004) *Reducing Air Pollution from Urban Transport* World Bank, Washington DC, June 2004 at: http://www.cleanairnet.org/cai/1403/article-56396.html

[20] These estimates should be considered as indicative only, as the cost of emission control systems (such as particle traps) can vary with the engine exhaust output. This may not necessarily be linked to the vehicle's price, although vehicles with larger engines will generally be more expensive.

[21] Commission of the European Communities SEC (2005) 1745, COM(2005)683 Final 21.12.2005 at: http://www.europarl.europa.eu/registre/docs_autres_institutions/commission_europeenne/sec/2005/1745/COM_SEC(2005)1745_EN.pdf

In the Australian context, the effectiveness of a strategy based on mandatory standards can be illustrated by the data in Figure 3, which is an extract from the 2nd National In-service Emissions Study (NISE 2)[22]. The study tested a large sample of in-service vehicles in the Australian fleet, and the results illustrate the dramatic improvements in emissions performance of petrol light vehicles in Australia, using a "real world" test cycle based on Australian urban driving patterns. The age groupings utilised in Figure 1 reflect the timeline for changes in mandatory emissions standards for new vehicles.



Note: no ADR limit line shown for older SUV-L and LCV categories as some vehicles in the 1994-2003 age groups were built to ADR36/00.

Note: PV-S, PV-M, PV-L = small, medium and large passenger vehicles;, SUV-C, SUV-L = compact and large sports utility vehicles; LCV = light commercial vehicles

Source: DEWHA (NISE 2)

Figure 1 NOx Emissions of In-service Light Petrol Vehicles (1994-2007)

In considering this data, it is important to recognise that the overwhelming contributor to this improvement is the adoption of vehicle emissions control technologies implemented to meet mandatory emissions standards – there have been no changes to state based in-service emissions requirements over this period.

As noted above, emissions control technologies – particularly those introduced in recent years – also require suitable quality fuel in order to

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[22] DEWHA (2009) *Second National In-service Emissions Study (NISE 2) - Final Report* at: http://www.environment.gov.au/atmosphere/transport/nise2.html

deliver the reductions in emissions expected from the standards. More stringent fuel standards can also deliver benefits across the fleet as a whole, not just from new vehicles. However, with the significant improvements in fuel quality that have already been delivered since 2002, the principal reasons for considering the case for further tightening of fuel standards are linked to emissions performance of new technology vehicles, including the operation and durability of emissions control equipment.

The sulfur content of petrol is the only fuel parameter considered relevant to this RIS, which is examining the case for adopting Euro 5/6 standards. Diesel standards are already largely in line with latest international standards, particularly on the key parameter of sulfur, which is set at a maximum of 10ppm.

2 OBJECTIVES OF GOVERNMENT ACTION

The objective of Government action is to improve urban air quality and reduce the adverse impacts of urban air pollution on human health.

3 DESCRIPTION OF OPTIONS

3.1 Summary

Vehicle Standards

When considering a possible approach for Australia to reduce noxious emissions levels from new light vehicles, the options are effectively to maintain the current ADRs (the status quo or “do nothing” option) or adopt the Euro 5 and/or Euro 6 standards (under a range of potential timelines). As noted in section 1.6, consideration of voluntary standards are not appropriate in the context of this review.

In broad terms, the aim of emissions standards is to reduce emissions from vehicles to as low a level as practical to assist Australia’s major urban airsheds to achieve compliance with the Air NEPM Standards identified in Table 1 (section 1.1). It is not possible to identify a specific optimal emissions level for the contribution from motor vehicles alone, as compliance with the NEPM standards is also affected by other, non-vehicle, sources of emissions. In addition, as noted in section 1 (and Appendix A), continuing research into the impacts of key pollutants such as PM, has yet to conclude a safe threshold level for these pollutants, and some NEPM standards are likely to become more stringent over time.

As indicated in section 1.5.2, the Euro 5 light vehicle emissions standards begin to take effect in Europe from late 2009, and the Euro 6 standards from 2014. If the case is made for adopting these standards in Australia, a balance needs to be found between the earliest possible introduction, which would maximise emissions benefits, and a delayed introduction, which allows vehicle manufacturers sufficient time to amortise their investment in achieving compliance with one standard before being required to upgrade to meet the next.

In relation to light vehicles, Australia has already adopted the Euro 4 standards for both petrol and diesel vehicles, with the Euro 4 standards fully implemented for diesels by the end of 2006, and for petrol vehicles by mid 2010. As noted earlier, the “basic” Euro 5 standards commence implementation from September 2009 in Europe, with some later start dates for elements relating to the new particle number measurement and OBD requirements. These base timings are also reflected in the revised ECE Regulation 83/06 which would be the standard the ADRs would reference to adopt the Euro 5/6 emissions standards.

In considering the international situation, and the lead time question, it would appear that 2012 would be the earliest feasible date for mandating compliance with the Euro 5 light duty vehicle standards. Given the later implementation of Euro 4 for petrol vehicles in Australia, some consideration could be given to a later timeframe for petrol vehicles. This timing question is explored in the options set out in this section 3.

This Options section of the RIS considers:

- the emissions and air quality benefits expected from the emissions and fuel standards already in place;
- the additional benefits that would derive from the adoption of more stringent standards, specifically the Euro 5 and Euro 6 emissions standards for light vehicles;
- the costs associated with the adoption of the Euro 5 and Euro 6 emissions standards; and
- the most appropriate timing for the introduction of any new standards.

In broad terms the options can be described as follows:

Option 1	No change to vehicle or fuel standards
Option 2	Introduction of Euro 5/6 on earliest practical timeframes
Option 3	As for Option 2, except delayed timeframe for petrol and LPG vehicles
Option 4	As for Option 2, except apply to diesel vehicles only (no change to petrol standards)
Option 5	Introduction of Euro 5 only on earliest practical timeframes
Option 6	Introduction of Euro 6 only on earliest practical timeframes

Table 4 outlines the key elements of each of the six options, which are considered in detail in sub-sections 3.2 – 3.7. These options also form the basis of the cost benefit analysis discussed in Section 4 of this RIS. All references to years in the options below assume a 1 January start date.

Table 4 Summary of Options

Option No.	Vehicle Standards			
	Euro Level	Vehicle Group	Date of Effect (1 January....)	
			New Models	All Models
1	No Change (Euro 4)	All light vehicles	NA	NA
2	Euro 5	All light vehicles	2012	2013
	Euro 6	All light vehicles	2016	2017
3	Euro 5	Petrol & LPG vehicles	2013	2014
		Diesel vehicles	2012	2013
	Euro 6	All light vehicles	2016	2017
4	Euro 5	Diesel Vehicles	2012	2013
	Euro 6	Diesel vehicles	2016	2017
5	Euro 5	All light vehicles	2012	2013
	Euro 6	N/A	N/A	N/A
6	Euro 5	N/A	N/A	N/A
	Euro 6	All light vehicles	2016	2017

Note: The 2 year date combinations for the vehicle standards refer to the dates applicable to new model vehicles and all model vehicles, respectively. For example, in the case of 2012 - 2013, this means that from 1 January 2012 any new model (type) first produced with a date of manufacture after 1 January 2012 must comply with the new standard, and from 1 January 2013 all new vehicles (regardless of the first production date for that particular model) must comply.

Fuel Standards

As noted in section 2.3, there is a risk that current sulfur levels in both petrol and LPG may impact on the durability of the emissions control systems utilised for Euro 5/6 vehicles. This RIS has not attempted to undertake a benefit-cost analysis of fuel sulfur reductions, as the determination of fuel quality standards is subject to a separate regulatory assessment process under the *Fuel Quality Standards Act 2000*. Consequently, the options considered in this review do not specifically address the fuel sulphur issue.

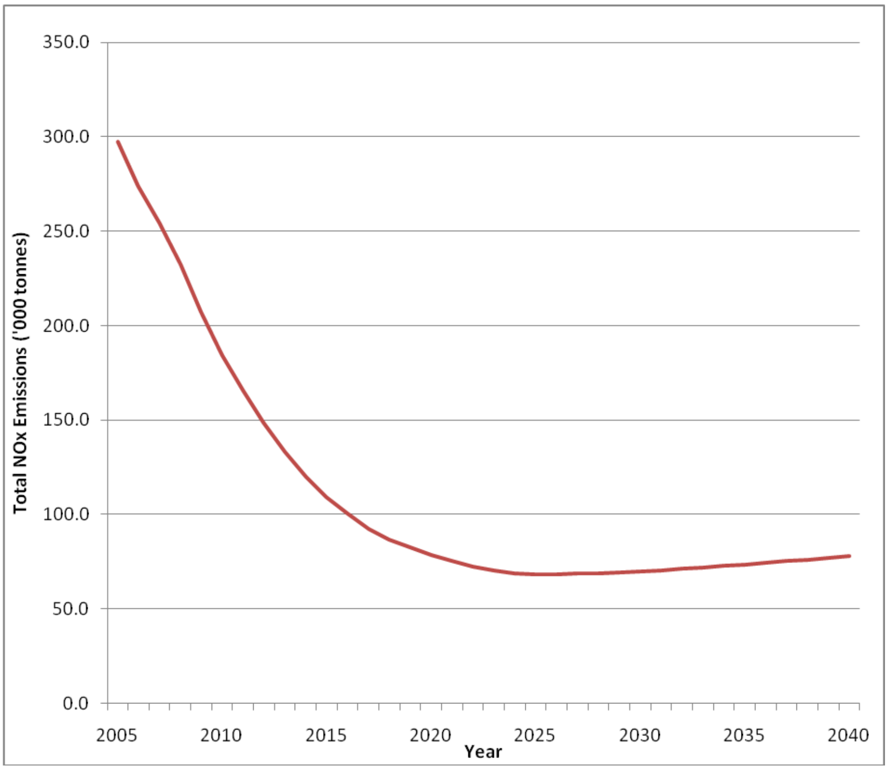
3.2 Option 1: Status Quo

A status quo or "do nothing" approach would simply rely on the existing emissions and fuel standards to deliver lower fleet emissions and improvements in air quality. The standards introduced over the 2002-2010 period will deliver reductions in those emissions which contribute to air pollution, with the most significant being the:

- reduction in NOx and PM emissions from the introduction of Euro 2 and Euro 4 standards for light diesel vehicles
- reduction in NOx and PM emissions from the introduction of Euro 3, 4 and 5 standards for heavy diesel vehicles; and
- reduction in NOx and HC emissions from the introduction of the Euro 3 and Euro 4 standards for light petrol engined vehicles.

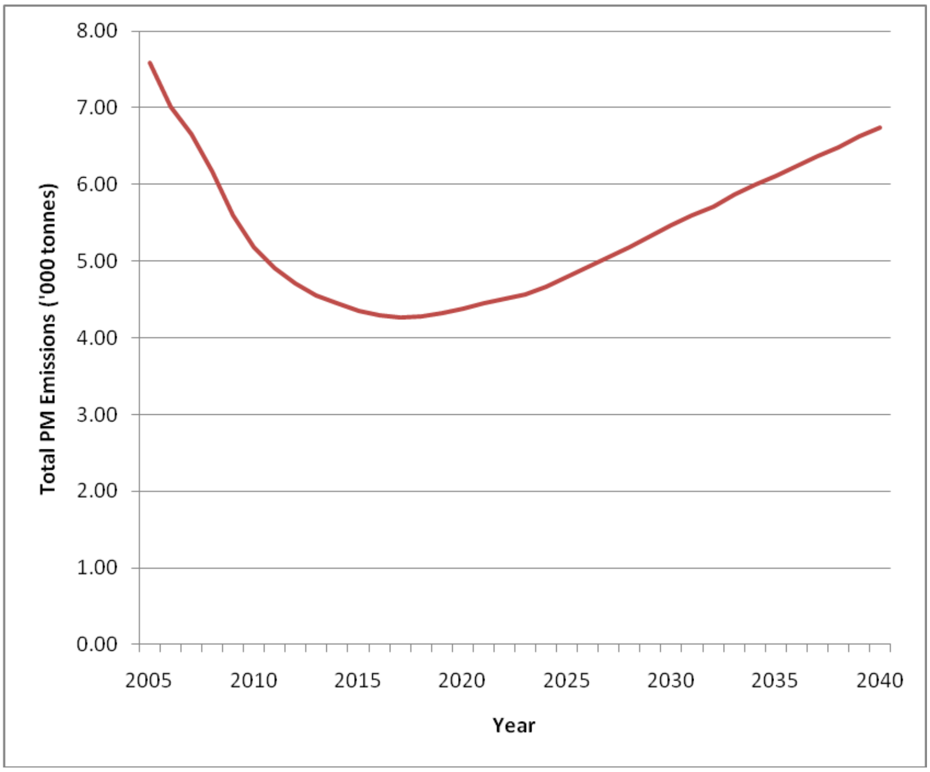
The BITRE emissions projections undertaken for this RIS out to 2040, indicate that in the light vehicle sector:

- NOx emissions reductions will fall significantly until about 2025 after which they will slowly trend upwards (Figure 2); and
- PM emissions will fall significantly until about 2016, after which they are predicted to rise steeply (Figure 3).



Source: BITRE Estimates (2009)

Figure 2 **Projected Impact on NOx Emissions of the Light Vehicle Fleet from Existing Standards**



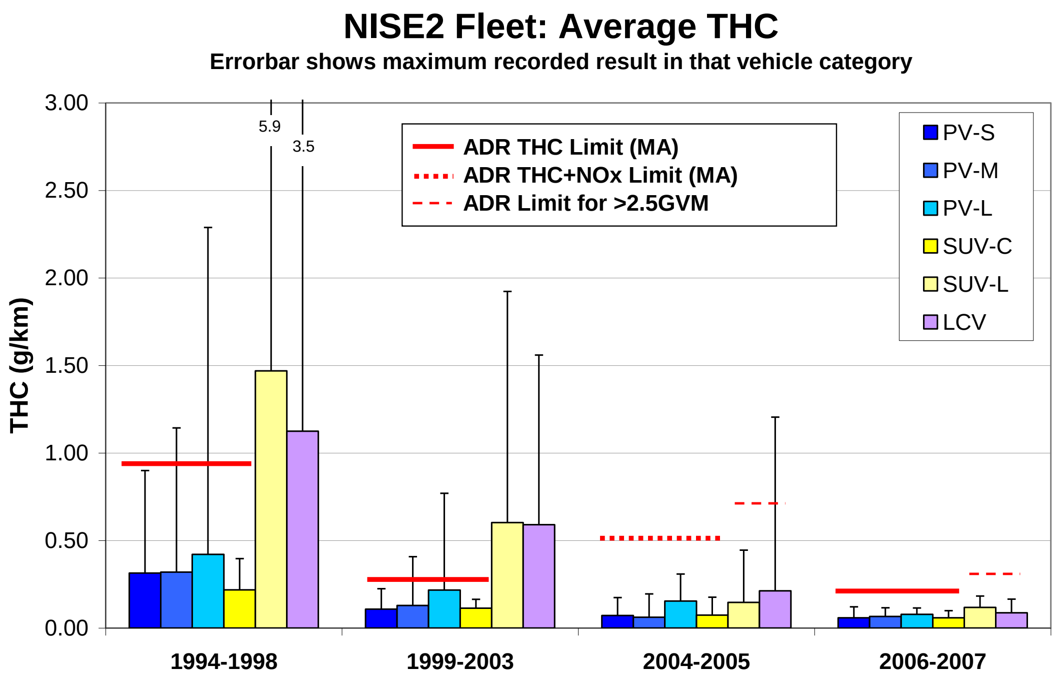
Source: BITRE Estimates (2009)

Figure 3 **Projected Impact on PM Emissions of the Light Vehicle Fleet from Existing Standards**

So this existing package of standards will provide air quality benefits, but the projections indicate it may be insufficient in the longer term in delivering reductions in levels of photochemical smog (NOx emissions are a precursor to smog formation) and most particularly PM emissions. This is largely attributable to significant increases in vehicle numbers and vehicle kilometres travelled, particularly in light commercial vehicles.

In the absence of any new vehicle standards, a proportion of imported vehicles will comply with one of the more stringent overseas standards in place at the time of their manufacture, even though those standards have not been adopted in Australia. Thus Australia will benefit, to some extent, from the more stringent overseas standards, even without adopting them in Australia. The magnitude of this “free rider” benefit is difficult to measure accurately, as it depends on decisions by individual manufacturers on the economics of “de-specifying” and re-certifying a model for the Australian market. However, previous experience indicates that many models are not upgraded to meet more stringent standards until the latest practical timeframe.

It is also reasonable to conclude that where it is cost effective to provide older technology vehicles for markets with less stringent standards, some manufacturers will also choose to provide those models to the Australian market in the absence of more stringent mandatory standards. This practice has been clearly illustrated from the test data collected in the recent 2nd National In-service Emissions Study (NISE 2) where light commercial and large 4WD models were subject to a significantly less stringent standard (ADR36/00) than other light vehicles, and many models continued the use of older engine technology and minimal emissions controls until the introduction of tighter mandatory standards in 2002/3, even though such technology had not been in common use in other light vehicles for many years. Figure 4 from NISE 2 illustrates this circumstance for HC emissions whereby large SUVs and light commercial vehicles did not provide comparable emissions performance as other light vehicles until they were brought in under the same standards umbrella as other light vehicles from 2004 (similar patterns are also observed for CO and NOx emissions).



Note: no ADR limit line shown for older SUV-L and LCV categories as some vehicles in the 1994-2003 age groups were built to ADR36/00.

Note: PV-S, PV-M, PV-L = small, medium and large passenger vehicles;, SUV-C, SUV-L = compact and large sports utility vehicles; LCV = light commercial vehicles; THC = total hydrocarbons

Source: NISE 2

Figure 4 HC Emissions of In-service Light Petrol Vehicles (1994-2007)

This practice is particularly likely with respect to standards controlling urban air pollution, as such emissions do not have a high profile in the mind of new vehicle consumers (unlike vehicle safety for example), and thus consumers are less likely to drive demand for vehicles meeting more stringent emissions standards.

In broad terms, the ‘do nothing’ approach is also inconsistent with the Government’s policy to harmonise with international standards and could have negative ramifications for the international competitiveness of the Australian vehicle manufacturing industry.

3.3 Option 2: Introduction of Euro 5/6 on earliest practical timeframes

Action:	**Mandate Euro 5/6 standards for light vehicles**
Timeframe[23]*:*	**2012-13 (Euro 5)** **2015-17 (Euro 6)**

In terms of air quality, the adoption of the Euro 5/6 light vehicle standards would build on the NOx emissions benefits of the status quo scenario outlined in Option 1, and reverse the projected growth in PM emissions (see comparative analysis in section 4.1 for more detail).

At a vehicle level, the adoption of the Euro 5/6 standards would deliver the following key benefits in the new light vehicle fleet (relative to the current Euro 4 standards embodied in Option 1):

- For all vehicles:
    - an increase in the durability requirement for vehicle emissions control systems from 100,000km to 160,00km;
    - the removal of concessional limits for heavy passenger vehicles; and
    - enhanced on board diagnostics (OBD) requirements to detect emissions related faults in-service.
- For petrol vehicles:
    - a 25% reduction in NOx emissions;
    - the extension of low temperature test to all light petrol vehicles; and
    - the application of PM emissions limits to direct injection petrol engines (in recognition of the significantly higher rate of PM emissions from these engines relative to conventional petrol engines).
- For diesel vehicles:
    - a 25% reduction in HC emissions at the Euro 5 level, and 40-50% by Euro 6;

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[23] See Note to Table 4 for explanation of dates

- a 30% reduction in NOx emissions at the Euro 5 level, and 70% by Euro 6;
- a 80-90% reduction in PM mass limits from Euro 5 (no change for Euro 6) with all light vehicle categories meeting the same limit; and
- a particle number standard as a second stage element for Euro 5 and continuing for Euro 6.

As the formal determination of any new ADR to adopt Euro 5 would not occur until early 2010, a new model start date of 1 January 2012 is considered the earliest practical date for manufacturers to achieve without unduly disrupting business planning.

It is logical to consider Euro 5 and Euro 6 as a package of progressive linked standards. The petrol and LPG emissions limits do not change from Euro 5 to Euro 6, except for the introduction of PM number limits at a second stage of Euro 5 and progressive changes to on board diagnostics (OBD) elements. In the case of diesel vehicles, Euro 6 also tightens the HC and NOx limits relative to Euro 5. If the case is made for introducing the standards, establishing a timeframe for both Euro 5 and Euro 6 now, will assist vehicle manufacturers in planning for compliance.

For manufacturers, the steps required to achieve compliance with the Euro 5/6 standards will vary between petrol and diesel vehicles, and are more significant for diesel vehicles.

For petrol vehicles, there are no major technological/manufacturing process changes required and compliance is likely to be achieved by upgrading existing catalyst performance through the use of increased precious metal loadings and/or refinements of engine/fuel management systems.

For diesel vehicles also, there are no major changes to manufacturing processes, but the new standards will effectively require the fitment of high efficiency particulate filters, which are, in most cases, not necessary to achieve compliance with current Euro 4 standards. Diesel vehicles are also likely to require adjustments to engine/fuel management systems, and in some cases, improved oxidation catalyst performance.

All of the technology required to achieve compliance is fully commercialized and the engineering processes to achieve these emissions reductions are well understood.

These differential impacts on manufacturers are reflected in the estimated costs. From a cost perspective relative to Euro 4, in 2005/6 the EC[24] estimated the incremental cost of a petrol vehicle complying with the

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[24] Original EC 2005/6 cost estimates in Euros converted to A$ at exchange rate of A$ 1.00 = € 0.6 - sourced from Commission of the European Communities SEC (2005) 1745, COM(2005)683 Final 21.12.2005 at: http://www.europarl.europa.eu/registre/docs_autres_institutions/commission_europeenne/sec/2005/1745/COM_SEC(2005)1745_EN.pdf **and** European Commission, Impact Assessment for Euro 6 emission limits for light duty vehicles 20.09.2006 at: http://ec.europa.eu/enterprise/automotive/pagesbackground/pollutant_emission/impact_assessment_euro6.pdf

Euro 5/6 standards was around $85, with significantly higher costs for diesel vehicles around $630 for Euro 5 and an additional $355 for Euro 6. The costs and benefits of this option are discussed in detail in the comparative analysis in section 4.2 of this RIS.

3.4 Option 3: As for Option 2, with delayed timeframe

Action:	**Mandate *Euro 5/6* standards for light vehicles**
Timeframe[25]:	**2012-13 (Euro 5 - diesel vehicles)** **2013-14 (Euro 5 - petrol & LPG vehicles)** **2015-17 (Euro 6 – all vehicles)**

Option 3 is identical to Option 2, except that a 1 year delay is applied to petrol and LPG vehicles for compliance with Euro 5.

For petrol and LPG vehicles, this relaxed timeframe would provide a larger gap (3.5-4.5 years) between implementation of the current standards (Euro 4) and the Euro 5 standards. The Euro 4 standards for diesel vehicles were fully implemented in Australia by the end of 2007, so the 2012 date already provides a 5-6 year gap between the change in standards.

This delay would provide manufacturers supplying petrol and LPG models that achieved compliance with the Euro 4 standards relatively late in the allowable timeframe, more time to amortise development costs for those vehicles, ahead of the introduction a Euro 5 compliant model. The delay would not have a noticeable impact on the long term emissions outcomes. The costs and benefits of this option are discussed in detail in the comparative analysis in section 4.2 of this RIS.

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[25] See Note to Table 4 for explanation of dates.

3.5 Option 4: As for Option 2, except apply to diesel vehicles only

Action:	**Mandate *Euro 5/6* standards for diesel vehicles only**
Timeframe[26]:	**2012-13 (Euro 5 - diesel vehicles)** **2015-17 (Euro 6 - diesel vehicles)**

Option 4 is identical to Option 2, except that the new standards only apply to diesel vehicles. Under this option, petrol emissions standards would remain at Euro 4.

It is clear that the substantial reduction in PM emissions from diesel vehicles from the introduction of the Euro 5/6 standards dominate the overall health benefits. And as noted in Option 2, the diesel standards also deliver HC and NOx benefits, as well as other improvements in durability and in-service compliance. Thus in overall terms, this option will deliver health benefits almost as large as Option 2, despite the removal of any benefits attributable to the application of Euro 5/6 emissions standards to petrol vehicles (which provide a 25% reduction in NOx emissions relative to Euro 4.

This is a consequence of the relatively low avoided health cost values assigned to NOx emissions which in the BCA are not sufficient to offset the vehicle costs in the first 20 years (even though those costs are also relatively low).

Nevertheless, petrol vehicles remain the dominant source of NOx emissions from the light vehicle fleet (even though on a per vehicle basis, diesel vehicles emit higher levels of NOx). In addition, as noted in Option 2, the adoption of Euro 5 for petrol vehicles will remove some concessions available under Euro 4, and like diesel vehicles, will deliver improvements in durability and in-service compliance. Exclusion of petrol vehicles from the application of the Euro 5 standards would also mean that direct injection petrol engines, which are known to produce much higher levels of PM emissions than conventional petrol engines, would not be subject to any limits on PM emissions (as these emissions are currently not regulated under the Euro 4 standards for petrol vehicles).

From a vehicle cost perspective, the major per vehicle costs are significantly higher for diesel vehicles than petrol vehicles. The costs and benefits of this option are discussed in detail in the comparative analysis in section 4.2 of this RIS.

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[26] See Note to Table 4 for explanation of dates.

3.6 Option 5: Introduction of Euro 5 only on earliest practical timeframes

Action:	**Mandate Euro 5 standards only for light vehicles**
Timeframe[27]:	**2012-13 (all vehicles)**

Option 5 is identical to Option 2, except that only the Euro 5 standards are adopted for both petrol and diesel vehicles.

This most significant impact of this approach, relative to Option 2, is that the HC and NOx emissions reductions from diesel vehicles under Euro 6 would not be delivered.

As noted in the discussion of Option 2, it is logical to consider Euro 5 and Euro 6 as a package of progressive linked standards. The primary (but not sole) objective of the Euro 5/6 standard is to address the emissions from light diesel vehicles. It was recognised by the European Commission that the availability of high efficiency PM traps enabled the PM issue to be largely tackled in a single step (Euro 5) – although more time was need to address the PM number aspects. However, it was also acknowledged that the industry needed more time to develop and implement the technology required to lower NOx emissions from diesel vehicles, and thus it was decided to effectively set a two stage target for NOx (30% reduction by Euro 5, 70% by Euro 6).

From a vehicle cost perspective, the incremental cost of complying with Euro 6 is estimated to be significantly less than the step from Euro 5 to Euro 6. If the case is made for introducing the standards, establishing a timeframe for both Euro 5 and Euro 6 now (rather than revisiting the Euro 6 issue in a few years time), will assist vehicle manufacturers in planning for compliance. The long lead time for compliance with Euro 6 (at least 5 years), would also assist in ameliorating the costs of compliance for manufacturers.

In conclusion, there would appear to be significant merit in considering Euro 5 and Euro 6 as linked standards, and for a decision on their joint implementation to be made in the context of this RIS (and not deferred).

This RIS does not propose to evaluate this option further.

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[27] See Note to Table 4 for explanation of dates

3.7 Option 6: Introduction of Euro 6 only on earliest practical timeframes

Action: **Mandate Euro 6 standards only for light vehicles**

Timeframe[28]*:* **2015-17 (all vehicles)**

Under Option 6, the Euro 5 standards would not be adopted, and Australia would move to adopt the Euro 6 standards at the earliest possible timeframe (2015-2017, depending on vehicle type).

By “skipping” Euro 5, this approach would delay the health benefits which would have otherwise been delivered by the Euro 5 standards (under Option 2) for 3-5 years. It would defer compliance costs for some manufacturers where it was cost-effective to continue to manufacture Euro 4 compliant models until the introduction of the Euro 6 standards.

In the case of light diesel vehicles, Australia’s current standards (Euro 4) are closely aligned with the UN ECE standards timeframe – consistent with Australia’s policy to harmonise with international standards where possible. The delay inherent in this Option would mean that Australia’s light diesel emissions standards will have remain unchanged for almost 10 years (Euro 4 for diesels was fully implemented on 1 January 2007), and place Australia’s diesel emissions standards well behind UN ECE standards (where Euro 5 began to take effect from September 2009).

On balance, provided industry is provided with adequate lead time to comply with Euro 5, there does not appear to be a strong case for skipping the Euro 5 standard and simply implementing Euro 6 in 5-7 years time. Such an approach would delay significant health benefits and be inconsistent with the Australian Government’s broad vehicle standards harmonisation policy.

This RIS does not propose to evaluate this option further.

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[28] See Note to Table 4 for explanation of dates

4 COMPARATIVE ANALYSIS OF OPTIONS

To assist the assessment of the implications for strengthening vehicle emissions and fuel quality standards post-2010, the Bureau of Infrastructure, Transport and Regional Economics (BITRE) undertook a range of analyses to underpin a benefit-cost analysis (BCA) for the options described in Section 3 of this draft RIS. The full details of the BCA are at Appendix C.

Under this benefit-cost analysis, the base and price year is set to 2009 with the evaluation period extending to 2040. Following the recommendations in the *Best Practice Regulation Handbook* published by the Office of Best Practice Regulation[29], the discount rate used to estimate the net present value is 7%. The key indicators for economic viability are net benefit expressed as Net Present Value (NPV) and the Benefit-Cost Ratio (BCR). The BCA also includes a number of sensitivity analyses.

4.1 Impact on Vehicle Emissions

The main pollutants of concern for air quality are HC, NO_x and PM (particulates).

As summarised in Table 5, if adopted, the Euro 5/6 light vehicle standards would lead to significant reductions in NOx emissions from petrol vehicles, and HC and NOx emissions from diesel vehicles, and dramatic reductions in PM emissions from diesel vehicles. The introduction of the new particle number limit standard and the other measures listed in section 1.5.1 will further enhance the emissions impact of the Euro 5/6 standards.

Table 5 **Emissions Reduction from Adoption of Euro 5 and Euro 6 Light Vehicle Standards**

Vehicle Fuel Type	Emissions Reduction (%)*					
	Euro 4 ⇨ Euro 5			*Euro 5 ⇨ Euro 6*		
	HC	NOx	PM	HC	NOx	PM
Petrol/LPG	-	25	NA	-	-	-
Diesel (and DI petrol)	25	30	80-90	26-40	55	-

* To nearest 5%; a range indicates that the percentage reduction varies with vehicle category; "-" indicates no change

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[29] OBPR (2007) Best Practice Regulation Handbook at: http://www.finance.gov.au/obpr/docs/handbook.pdf

The European Commission has concluded[30] that the introduction of the Euro 5/6 standards would have a negligible impact on fuel consumption and CO_2 emissions.

For this RIS, emissions of these pollutants from the Australian light vehicle fleet were modelled using a suite of BITRE fleet and projection models. These models are described in a variety of BITRE publications (refer to Appendix B for more information). These BITRE models allow for the effects of increasing traffic congestion levels within our urban areas, which leads not only to higher rates of fuel consumption than would otherwise have occurred, but also to higher rates of urban air pollutants being emitted from the affected vehicles.

The BITRE estimated the impacts of Options 2, 3 and 4 on total light vehicle fleet emissions, relative to the Option 1. All options incorporate the following "base case" assumptions:

- oil prices remain at current levels ($60-70 US per barrel);
- population grows according to the mid-range 'Series B' scenario values of the latest ABS population projections;
- income grows in line with the Treasury's latest Budget statements for short term and the Inter-generational report for longer term;
- average fleet travel behaviour remains roughly the same as now (e.g. cars average about 15000 km per annum), but with overall per capita travel approaching saturation levels with respect to average income levels;
- new vehicle sales growth is driven by overall (i.e. economy-wide) travel demand and annual vehicle scrappage rates[31];
- no change to current fuel standards;
- diesel vehicles continue to increase their market share in line with current growth trends, so that they will dominate LCV sales by 2040. They are a major component of SUV sales, but still account for only a small proportion of sedan sales. By 2040, diesel vehicles are forecast

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[30] Commission of the European Communities SEC (2005) 1745, COM(2005)683 Final 21.12.2005 at: http://www.europarl.europa.eu/registre/docs_autres_institutions/commission_europeenne/sec/2005/1745/COM_SEC(2005)1745_EN.pdf **and** European Commission, *Impact Assessment for Euro 6 emission limits for light duty vehicles* 20.09.2006 at: http://ec.europa.eu/enterprise/automotive/pagesbackground/pollutant_emission/impact_assessment_euro6.pdf

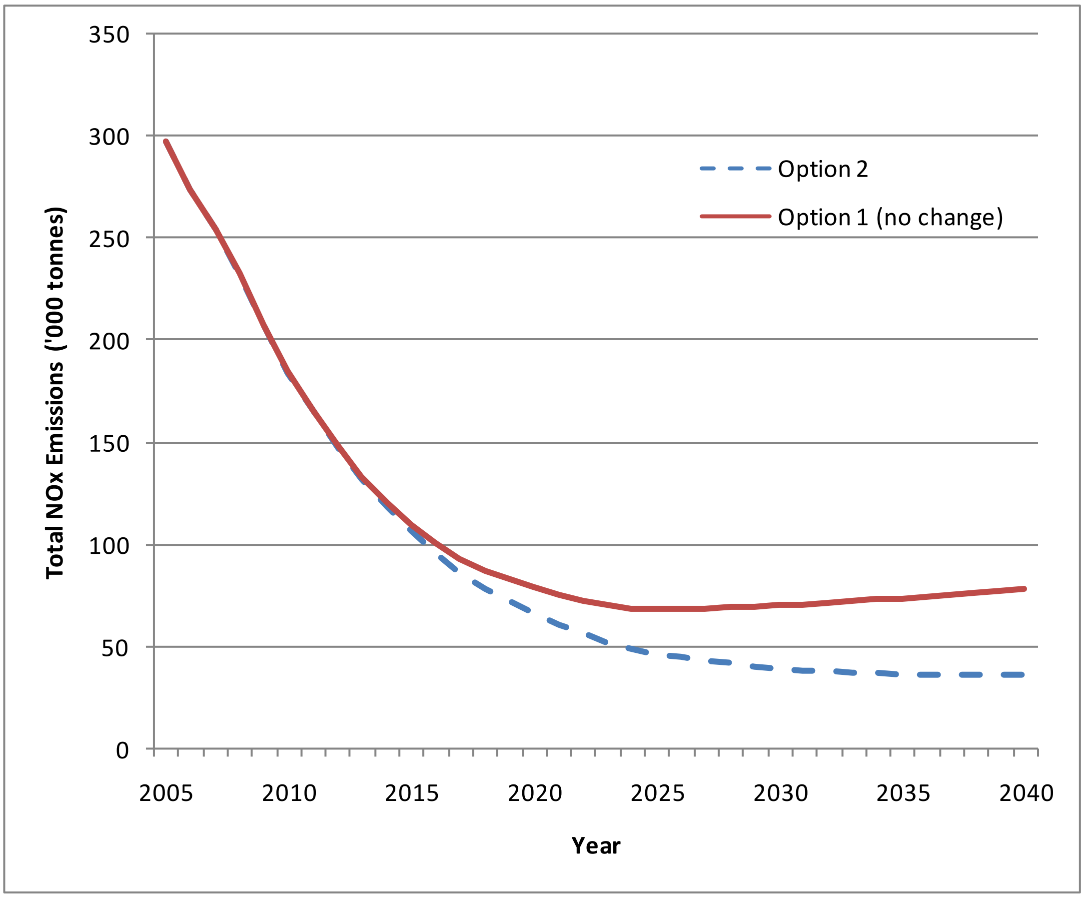
[31] Estimates of total daily travel demand by Australians for each forecast year are based on relevant demographic and economic conditions, projected out to the end-year using ABS projections of national population and Treasury projections of economic growth. Mode split models estimate the amount of this total (annual) travel to be performed by light vehicles, which in turn (using trends in average travel per vehicle) estimate the aggregate car stock required to perform the estimated total VKT task for that year. Models of vehicle fleet dynamics estimate how many cars will leave the fleet each year (with estimated survival curves applied to each vintage – such that older vehicles are much more likely to be scrapped in any particular year than newer vehicles). New sales in any particular projection year are then estimated as the difference between that year's required vehicle stock, and last year's stock less the intervening scrappage amount.

to achieve an overall market share of about 36% of annual light vehicle sales; and

- emissions control technologies experience mid-range deterioration rates, such that most vehicles are still within the standards after about 10 years. A small proportion of the fleet, growing with vehicle age, will be high emitters, accounting for vehicles with poor service records or malfunctioning emissions control systems.

The only difference between Option 3 and Option 2, is a one year delay in the introduction of petrol and LPG vehicle standards, so not unexpectedly, the BITRE analysis indicates that Option 3 delivers almost identical emissions outcomes to Option 2 over the analysis period. Consequently, the values for Option 2 displayed in the charts below can be considered to mirror the expected outcomes from Option 3.

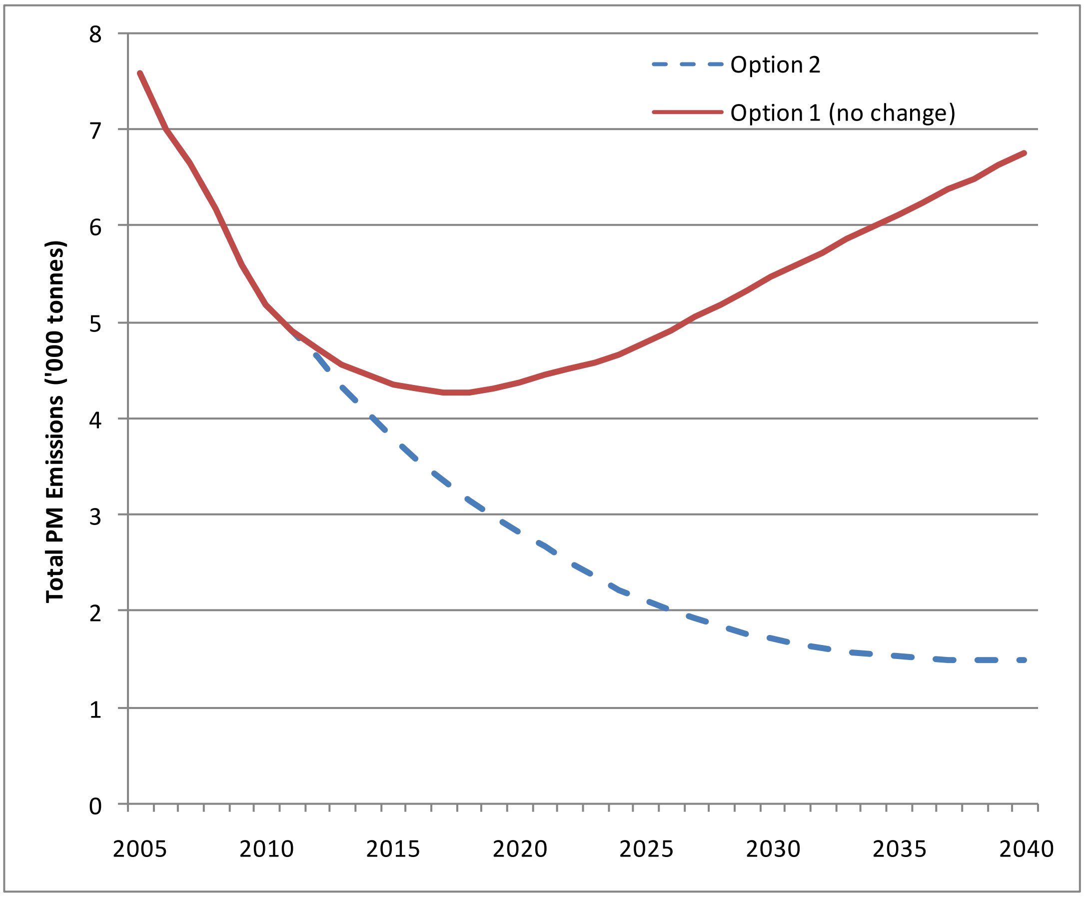
As indicated in Figure 5, the BITRE analysis indicates that introduction of Euro 5/6 emissions standards for light vehicles would begin to deliver net emissions reductions in total NOx emissions in the light vehicle fleet from about 2015 and in the longer term result in a significant reduction in total annual emissions - 53% lower in 2040 relative to Option 1 (no change).



Source: BITRE Estimates (2009)

Figure 5 Projected Impact on NOx Emissions of the Light Vehicle Fleet from the Introduction of Euro 5/6 Emissions Standards

Figure 6 also indicates net reductions in PM emissions from the introduction of the standards from around the same time frame, but over the longer term the magnitude of the reductions is much more significant - 78% lower in 2040 relative to Option 1 (no change). In addition, the PM reductions from the introduction of the standards would be delivered against an otherwise steeply rising trend predicted in the absence of any new standards.



Source: BITRE Estimates (2009)

Figure 6 **Projected Impact on PM Emissions of the Light Vehicle Fleet from the Introduction of Euro 5/6 Emissions Standards**

4.2 Costs

Starting Costs

The starting point cost estimates for compliance with the Euro 5/6 emissions standards (Table 6) were sourced from the impact statements prepared by the European Commission (EC) to support the introduction of these specific standards[32]. These EC estimates were converted to Australian-dollar estimates using the average exchange rate over the past few years.

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[32] Original EC 2005/6 cost estimates in Euros converted to A$ at exchange rate of A$ 1.00 = € 0.6 - sourced from Commission of the European Communities SEC (2005) 1745, COM(2005)683 Final 21.12.2005 at: http://www.europarl.europa.eu/registre/docs_autres_institutions/commission_europeenne/sec/2005/1745/COM_SEC(2005)1745_EN.pdf **and** European Commission, Impact Assessment for Euro 6 emission limits for light duty vehicles 20.09.2006 at: http://ec.europa.eu/enterprise/automotive/pagesbackground/pollutant_emission/impact_assessment_euro6.pdf

Table 6 Incremental Vehicle Costs (€ and A$ / vehicle)

	€		A$		
	Euro 4 to Euro 5	Euro 5 to Euro 6	Euro 4 to Euro 5	Euro 5 to Euro 6	Euro 4 to Euro 6
Petrol vehicle	51	0	85	0	85
Diesel vehicle	377	213	628	355	983

Note: A$1=€0.60.

The applicability of the cost estimates in Table 6 to the Australian context is difficult to judge, however they are based on the most detailed technology assessment conducted to determine the costs of compliance with the Euro 5/6 standards, and represent the best available international figures. For the purposes of this draft RIS, it is reasonable to use these estimates as the starting point, particularly given that approximately 85% of light vehicles supplied to the Australian market (and 100% of diesels) are fully imported. If domestic manufacturers are able to supply more accurate estimates during the public consultation phase on this RIS, these can be taken into account in the BCA undertaken for the final RIS.

The EC estimates reflect the estimated costs to manufacturers assuming vehicles are in full production. These costs directly relate to the technology improvements required to meet the tighter emissions limits under the Euro 5/6 standards (see discussion under Option 2). The EC concluded that the increased durability requirements and OBD provisions would not incur any significant additional costs.

In general terms, obtaining reliable cost estimates for emissions technology and resultant vehicle on-costs to consumers is very difficult as both component and vehicle manufacturers consider such information commercially sensitive – this problem was noted by the consultant engaged by the EC to develop cost estimates for the Euro 5 standards[33].

The European Automobile Manufacturers' Association (ACEA) was critical of the EC analysis, and commissioned a report[34] into the basis for the cost assumptions. The report concluded that there was a lack of adequate cost data available to enable a reliable assessment of the Commission's conclusions.

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[33] TNO (2005) Euro 5 technologies and costs for Light-Duty vehicles, TNO Report 05.OR.VM.032.1/NG at: http://ec.europa.eu/environment/air/pdf/euro_5.pdf

[34] Nieuwenhuis and Wells (2006) *Study of the Euro 5 Impact Assessment SEC (2005) 1745* Centre for Automotive Industry Research, Cardiff University and ESRC centre for Business Relationships, Accountability, Sustainability and Society at: http://www.brass.cf.ac.uk/projects/Sustainable_Mobility/towards-sustainable-mobility--Environmental-Regulation.html

In contrast, the industry association representing emissions control technology manufacturers (Association for Emissions Control by Catalyst) concluded that for both petrol and diesel vehicles the limits were "readily achievable by currently available technology" and in relation to petrol vehicles, could be achieved at "very limited on-cost"[35].

A US report[36] examining the cost of emissions standards compliance noted that "...vehicles are designed as integrated systems and a single vehicle part may serve multiple functions. Thus, accurately apportioning the costs of emissions systems to only actual emissions control can be difficult." The report also noted that "increases in capital costs resulting from regulation were partially offset by corresponding increases in quality related to developments in emissions technology."

Cost Adjustments Over Time

For the purposes of this draft RIS, the EC estimates have been adopted as the starting point in the BCA. However, international experience[37] suggests early cost estimates tend to overstate actual costs, due to the rapid decline in unit costs as technology matures and production volumes increase. This is often known as the "experience curve".

The presence of this phenomenon appears to be supported by previous experience in Australia. In recent years, Green Vehicle Guide[38] data illustrate that significant numbers of vehicle models meeting more stringent standards than the minimum specified, have been supplied to the Australian market ahead of the implementation dates for later, more stringent standards. Many of these models are price competitive with models meeting the mandatory minimum standard only. Some of these were high volume models, indicating that the additional cost of complying with Euro 4 (for example) did not have a significant impact on vehicle prices when Euro 3 was the minimum standard. There have also been upgrades of models from one emissions standard to the next without increases in the vehicle price.

Thus, in estimating the additional unit vehicle cost over time, the BCA assumes that the incremental vehicle technology costs (reported in Table 6) decline as the market expands for the new technology. The EC estimates include a 33% cost reduction in its analysis, but this is only projected to 2020. As noted earlier, a report[39] commissioned by the European vehicle

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[35] AECC (2005) *AECC Response to Stakeholder Consultation on Euro 5 Emission Limits for Light Duty Vehicles* at: http://www.aecc.be/content/pdf/AECC%20Response%20to%20Stakeholder%20for%20Light-duty%20Vehicles%20070905.pdf

[36] Chen et al (2004) *Effect of Emissions Regulation on Vehicle Attributes, Cost and Price*, University of California, Davis at: http://www.its.ucdavis.edu/publications/2004/UCD-ITS-RR-04-38.pdf

[37] See, for example: King (2008) *The King Review of low carbon cars Part II – recommendations for action* at: http://www.hm-treasury.gov.uk/budget/budget_08/reviews/bud_bud08_king.cfm **and** ITF (2008) *Transport and Energy - The Challenge of Climate Change, Research Findings*, Leipzig May 2008 at: http://www.internationaltransportforum.org/Topics/Workshops/WS1Conclusions.pdf

[38] See www.greenvehicleguide.gov.au

[39] Nieuwenhuis and Wells (2006) *Study of the Euro 5 Impact Assessment SEC (2005) 1745* Centre for Automotive Industry Research, Cardiff University and ESRC centre for Business Relationships, Accountability, Sustainability

manufacturers questioned the reasoning behind this cost reduction estimate, but the report nevertheless notes that "there is plenty of evidence to suggest that mass production has the effect of reducing unit costs".

Other reports suggest that the actual cost reduction over time could be significantly higher than the EC estimate. For example, a 2006 Dutch report[40] which reviewed actual (ex-post) costs for a range of emissions standards concluded that cost estimates made at the time of standards development were in general double the observed costs following full implementation (within 10 years). A US report[41] notes that the US EPA assumed that costs would fall by 80% for Tier 2 emissions standards after two years in production.

Taking the above factors into account, the assumed cost adjustment process for this analysis follows the path shown in Figure 7, that is, the additional unit vehicle costs to comply with the standards are kept constant to 2020, then drop by half by 2030 and remain at that level after 2030.

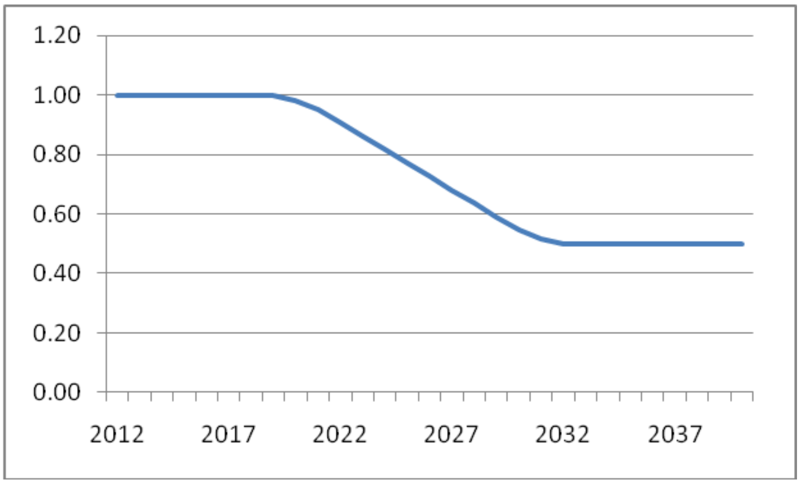

Figure 7 **Assumed cost adjustment path**

Delayed Benefits

Emissions-reducing technology on vehicles purchased during the latter part of the evaluation period 2009 to 2040 will continue to generate benefits beyond the end of the evaluation period in 2040. In benefit-cost analyses, where assets generate benefits beyond the evaluation period, the usual approach is to estimate the benefits from those assets over their entire lives

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and Society at: http://www.brass.cf.ac.uk/projects/Sustainable_Mobility/towards-sustainable-mobility--Environmental-Regulation.html

[40] Jantzen and van der Woerd (2006) *Ex-post Estimates of Costs to Business of EU Environmental Policies, Institute for Applied Environmental Economics (TME)* at: http://ec.europa.eu/environment/enveco/ex_post/pdf/transport.pdf

[41] Board on Environmental Studies and Toxicology (2006) *State and Federal Standards for Mobile-Source Emissions* The National Academies Press at: http://books.nap.edu/openbook.php?record_id=11586&page=196

and to include, as a 'residual value', the present value of benefits that accrue after the end of the evaluation period. For the present application, such an approach would entail a heavy calculation burden. Since the benefits from emissions-reducing technology are fairly constant over the lives of the vehicles, a good approximation is obtained by prorating the cost of the technology over the lives of the vehicles, then only counting costs attributed to the years before 2041.

The average vehicle life was assumed to be 17 years. For vehicles purchased during the last 16 years of the evaluation period, the cost of the emissions-reducing technology was annuitised over 17 years at the discount rate. The annual costs for the years before 2041 were discounted to the present as implementation costs. Annual costs for years 2041 onward were omitted, consistent with the benefits for years 2041 onward being absent.

The 'pro-rata' curves in Figure 8 (P1 and D1) show the effects on costs per vehicle of excluding annualised costs after 2040 of emissions-reducing technology for vehicles purchased over the last 16 years of the evaluation period. The pro-rata curves approach zero by the end of the period, with vehicles purchased in 2040 having only one year of cost included.

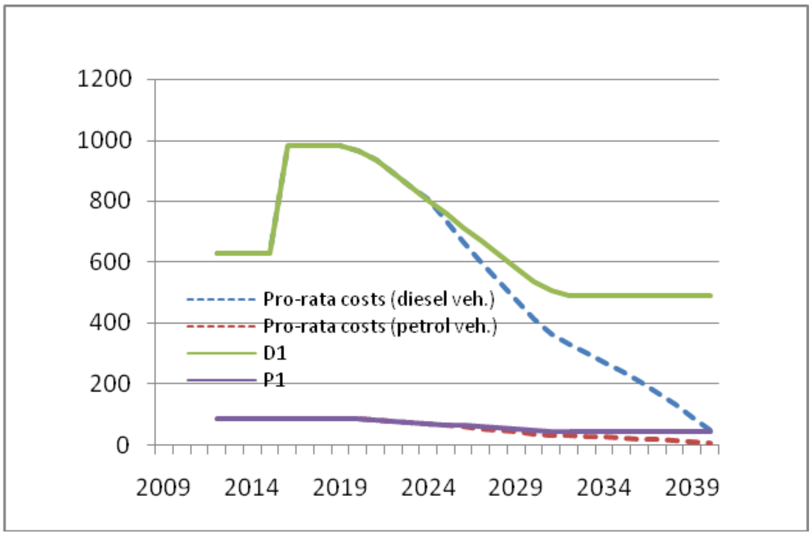

Figure 8 **Additional Vehicle Cost Estimates (A$/vehicle)**

<u>Compliance Levels</u>

In estimating the total implementation costs, two further assumptions were made regarding the proportion of vehicles complying with the new standard.

First, it was assumed that around half of the vehicles sold in the introduction year of each standard would already comply with the new standard, so only 50 % of the new sales would attract an additional cost.

Second, it was assumed for all other years that some proportion of new vehicles would have met the lower emissions level even without the new standards implementation. For petrol vehicles, the proportion was set to

30% throughout the evaluation period. For diesel vehicles, the proportion was set to 30% when moving from Euro 4 to Euro 5 standards and to 5% from Euro 5 to Euro 6 standards (Figure 9). The benefits from the lower emissions of these vehicles were not included in the benefits of introducing the new standards because these benefits accrue regardless.

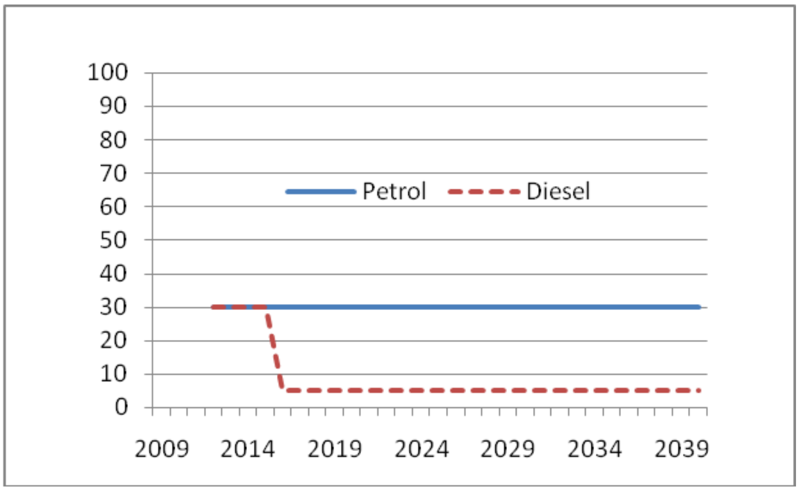

Figure 9 **Proportion of New Vehicles Already Complying with the New Standards (%)**

4.3 Health Benefits

In the vehicle emissions context, an accepted method to measure the health benefits from lower emissions is to use an "avoided health cost" approach. In such an approach, monetary values (measured as $/tonne) are assigned to individual pollutants (in this case HC, NOx and PM). These dollar values are derived from an assessment of human morbidity and mortality impacts from exposure to these pollutants, and the monetary costs associated with addressing those impacts.

The methodology employed to estimate the health benefits is described by the following formula:

Avoided Health Cost ($) = Emissions Saved (tonnes) x Unit Health Cost ($)

The first step is to quantify the emissions of pollutants for the scenarios under investigation and estimate tonnes of emissions saved for each vehicle standards option (relative to the base case). The second step is to establish a value for an average health cost ($ per tonne of emissions) from existing studies. The final step is to calculate the total health benefit (or health cost avoided) by multiplying tonnes of emissions saved by unit value(s) for health costs.

The emissions estimates for the first step are provided by the analysis outlined in section 4.1 of this RIS.

In determining unit health costs, the ideal methodology is to use a "bottom-up approach" to analyse the health impact of the proposed new emissions standards. Such an approach would follow the methodology recommended by Jalaludin, et al[42] and would comprise a series of steps to quantify and value air pollution in each major city, taking into account the effects of technology. However, the simplified approach outlined below is considered adequate for this analysis.

The approach adopted for this study is to utilise the existing studies to derive plausible estimates of $/tonne health costs from air pollution. Table 7 presents estimates of $/tonne health costs obtained from a number of transport-related health impact studies for Australia. Two general observations can be made with respect to Table 7 - first, unit cost estimates exhibit a considerable range of variation; second, more recent estimates tend to be much higher than those prior to the year 2000.

Table 7 Average Capital City Health Cost (A$/tonne of emissions)

Source	Health Cost by Emissions Type (A$/tonne)			
	CO	HC	NO_x	PM_{10}
Coffey Geosciences (2003)	13	2,200	59	232,000
Watkiss (2002)[a]	2	875	1,750	217,415
Beer (2002) – Ozone included				
Upper bound	9	72,500	900	221,100
Best estimate	3	19,331	870	147,429
Lower bond	2	11,700	280	108,300
Beer (2002) – Ozone excluded	3	18,719	11	147,429
BTRE (2005)	na	na	na	167,626 [b]
Environment Australia (2000)	12	1,440	1,385	17,600
NSW EPA (1998)	na	na	68	310
NSW EPA (1997)	25	960	1,490	1,810

Notes: [a] Simple average for inner and outer areas of major capital cities (see Table 3 of Appendix B for detailed Watkiss (2002) results).

[b] Estimate for the year 2000, derived from results reported in BTRE (2005).

Source: Coffey Geosciences (2003), Watkiss (2002) and BTRE (2005) [refer to reference list in Appendix C for details]

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[42] Jalaludin B., Salkeld G., Morgan G., Beer T. and Nisar Y. B. 2009, *A Methodology for Cost-Benefit Analysis of Ambient Air Pollution Health Impacts,* Final Report, funded by the Department of the Environment, Water, Heritage and the Arts though the Clean Air Research Program.

Unit health costs vary from location to location and according to population and meteorological factors. To analyse the impact of the proposed new vehicle standards on emissions (in terms of tonnes of pollutants emitted), the best disaggregation of the location – given the available data – is to split the total emissions into those for capital cities and the rest of Australia. To calculate the total health benefit, estimates of unit health costs are required for each of the two areas concerned.

The procedure employed to estimate unit health cost values included the following steps:

- Only the three most recent studies listed in Table 7 (excluding BTRE (2005)) were selected as input for estimation - Coffey Geosciences (2003), Watkiss (2002) and Beer (2002);
- Unit values for capital cities were calculated by taking the simple average of the estimates from the three studies;
- Unit values for the rest of Australia were based on the simple average of the estimates for Band 3 and Band 4 contained in Watkiss (2002);
- Given the uncertainties surrounding the unit value estimates, an upper bound and a lower bound were established (an average ±50%) on the basis of observations made by Coffey Geosciences (2003); and
- Unit values presented in Table 7 were assumed to be in 2003 prices, and were updated to 2009 prices using the CPI.

Table 8 presents the recommended unit values for calculating the health benefit and undertaking sensitivity analyses for this BCA.

Table 8 Updated Average Health Cost ($/tonne of emissions) by Area (in 2009 prices)

Area & Sensitivity	Health Cost by Emissions Type ($/tonne)		
	HC	NOx	PM10
Central			
Capital cities	8,832	1,056	235,261
Rest of Australia	103	154	55,827
Upper bound + 50%			
Capital cities	13,248	1,584	352,891
Rest of Australia	155	231	83,740
Lower bound -50 %			
Capital cities	4,416	528	117,630
Rest of Australia	52	77	27,913

Source: Derived from the results from Coffey Geosciences (2003), Watkiss (2002) and Beer (2002).

The introduction of a particle number standard, while not quantified will also deliver significant health benefits as it will directly reduce the number of ultrafine particles emitted from Euro 5/6 vehicles. Of all the vehicle pollutants reduced by the new standards, ultrafine particles have the strongest association with adverse health effects.

The health benefits are dominated by the PM reductions delivered by the new vehicle emissions standards, with the reductions in NOx also contributing to total benefits.

It is not possible to isolate and quantify the benefits from the increased durability standards and the upgraded OBD requirements for both petrol and diesel vehicles under the new standards, and thus these have not directly factored into the health benefit estimates. Nevertheless, as noted in the EC impact assessment, increasing the durability requirements (reinforced by the OBD provisions) will provide a greater level of assurance that emissions control systems on vehicles will continue to function over the expected life of the vehicle. The value of increased durability in emissions control systems is illustrated by the sensitivity analyses (see Section 4.5), where the sensitivity testing for deterioration rates (the corollary of durability) indicates that increased rates of deterioration in emissions control systems can significantly impact emissions outcomes.

4.4 Summary of Net Benefit

As illustrated in Tables 9 and 10, the BCA results show that both Option 2 and Option 3 provide net benefits over the 2010-2040 period under the base case assumptions identified in sections 4.1 – 4.3.

A further analysis was conducted to assess the impact of removing petrol (and LPG) vehicles from the application of the Euro 5/6 standards. This was undertaken by apportioning the costs and benefits applicable to petrol vehicles under Option 2 as accurately as possible, and undertaking the BCA under the same assumptions for Option 2. This is presented as Option 4 (see section 3.5). As illustrated in Table 11, the BCA results show that net benefit of Option 4 (the diesel only option) relative to Option 2 or 3, is approximately $300 million higher over the 2010-2040 period.

Table 9 Summary of Net Benefit for Option 2

Year	Undiscounted Cash Flow ($m, in 2009 prices)			Discount Factor	Discounted Cash Flow ($m) ($m, in 2009 prices)		
	Cost	Benefit	Net benefit	(7%)	Cost	Benefit	Net benefit
2009	0.0	0.0	0.0	1.0000	0.0	0.0	0.0
2010	0.0	0.0	0.0	0.9346	0.0	0.0	0.0
2011	0.0	0.0	0.0	0.8734	0.0	0.0	0.0
2012	-79.1	12.7	-66.4	0.8163	-64.6	10.4	-54.2
2013	-162.7	38.5	-124.2	0.7629	-124.1	29.3	-94.8
2014	-167.6	66.2	-101.4	0.7130	-119.5	47.2	-72.3
2015	-172.5	95.4	-77.1	0.6663	-114.9	63.6	-51.3
2016	-185.4	127.3	-58.1	0.6227	-115.5	79.3	-36.2
2017	-336.2	162.0	-174.3	0.5820	-195.7	94.3	-101.4
2018	-347.2	198.9	-148.3	0.5439	-188.9	108.2	-80.7
2019	-357.6	238.2	-119.4	0.5083	-181.8	121.1	-60.7
2020	-362.8	278.7	-84.1	0.4751	-172.4	132.4	-40.0
2021	-360.0	320.1	-39.9	0.4440	-159.8	142.1	-17.7
2022	-350.7	360.1	9.4	0.4150	-145.5	149.4	3.9
2023	-340.8	399.7	58.8	0.3878	-132.2	155.0	22.8
2024	-330.4	442.6	112.2	0.3624	-119.7	160.4	40.7
2025	-308.7	485.7	177.0	0.3387	-104.6	164.5	60.0
2026	-285.6	528.5	242.9	0.3166	-90.4	167.3	76.9
2027	-261.5	569.5	308.0	0.2959	-77.4	168.5	91.1
2028	-236.7	609.1	372.4	0.2765	-65.5	168.4	103.0
2029	-211.4	647.2	435.8	0.2584	-54.6	167.3	112.6
2030	-186.3	683.4	497.2	0.2415	-45.0	165.1	120.1
2031	-166.2	717.7	551.4	0.2257	-37.5	162.0	124.5
2032	-151.0	750.0	599.0	0.2109	-31.9	158.2	126.4
2033	-139.6	784.8	645.2	0.1971	-27.5	154.7	127.2
2034	-127.0	812.4	685.4	0.1842	-23.4	149.7	126.3
2035	-113.1	838.7	725.5	0.1722	-19.5	144.4	124.9
2036	-98.1	866.5	768.4	0.1609	-15.8	139.4	123.7
2037	-81.6	892.5	810.9	0.1504	-12.3	134.2	122.0
2038	-63.7	914.7	851.0	0.1406	-9.0	128.6	119.6
2039	-44.2	941.3	897.1	0.1314	-5.8	123.7	117.8
2040	-23.0	963.7	940.7	0.1228	-2.8	118.3	115.5
Total	**-6,050.9**	**14,746.1**	**8,695.2**		**-2,457.5**	**3,707.0**	**1,249.5**
Benefit–cost Ratio =			**1.51**	**NPV =**			**$1,250m**

Table 10 Summary of Net Benefit for Option 3

Year	Undiscounted Cash Flow ($m, in 2009 prices)			Discount Factor	Discounted Cash Flow ($m) ($m, in 2009 prices)		
	Cost	Benefit	Net benefit	(7%)	Cost	Benefit	Net benefit
2009	0.0	0.0	0.0	1.0000	0.0	0.0	0.0
2010	0.0	0.0	0.0	0.9346	0.0	0.0	0.0
2011	0.0	0.0	0.0	0.8734	0.0	0.0	0.0
2012	-56.4	12.3	-44.2	0.8163	-46.1	10.0	-36.1
2013	-140.0	37.2	-102.8	0.7629	-106.8	28.4	-78.4
2014	-167.6	64.6	-103.0	0.7130	-119.5	46.1	-73.5
2015	-172.5	93.9	-78.6	0.6663	-114.9	62.6	-52.4
2016	-185.4	125.8	-59.7	0.6227	-115.5	78.3	-37.2
2017	-336.2	160.4	-175.8	0.5820	-195.7	93.4	-102.3
2018	-347.2	197.4	-149.8	0.5439	-188.9	107.4	-81.5
2019	-357.6	236.7	-120.9	0.5083	-181.8	120.3	-61.5
2020	-362.8	277.3	-85.6	0.4751	-172.4	131.7	-40.6
2021	-360.0	318.7	-41.3	0.4440	-159.8	141.5	-18.3
2022	-350.7	358.7	8.0	0.4150	-145.5	148.9	3.3
2023	-340.8	398.4	57.5	0.3878	-132.2	154.5	22.3
2024	-330.4	441.3	111.0	0.3624	-119.7	160.0	40.2
2025	-308.7	484.5	175.9	0.3387	-104.6	164.1	59.6
2026	-285.6	527.4	241.8	0.3166	-90.4	167.0	76.5
2027	-261.5	568.5	307.0	0.2959	-77.4	168.2	90.8
2028	-236.7	608.2	371.5	0.2765	-65.5	168.2	102.7
2029	-211.4	646.4	435.0	0.2584	-54.6	167.0	112.4
2030	-186.3	682.8	496.5	0.2415	-45.0	164.9	119.9
2031	-166.2	717.1	550.8	0.2257	-37.5	161.9	124.3
2032	-151.0	749.5	598.5	0.2109	-31.9	158.1	126.2
2033	-139.6	784.2	644.6	0.1971	-27.5	154.6	127.1
2034	-127.0	812.2	685.2	0.1842	-23.4	149.6	126.3
2035	-113.1	838.5	725.4	0.1722	-19.5	144.4	124.9
2036	-98.1	866.3	768.3	0.1609	-15.8	139.4	123.6
2037	-81.6	892.4	810.8	0.1504	-12.3	134.2	121.9
2038	-63.7	914.6	850.9	0.1406	-9.0	128.6	119.6
2039	-44.2	941.2	897.0	0.1314	-5.8	123.6	117.8
2040	-23.0	963.6	940.6	0.1228	-2.8	118.3	115.5
Total	**-6,005.5**	**14,720.1**	**8,714.5**		**-2,421.7**	**3,695.1**	**1,273.5**
Benefit–cost Ratio =			**1.53**	**NPV =**			**$1,274m**

Table 11 Summary of Net Benefit for Option 4

Year	Undiscounted Cash Flow ($m, in 2009 prices)			Discount Factor	Discounted Cash Flow ($m) ($m, in 2009 prices)		
	Cost	Benefit	Net benefit	(7%)	Cost	Benefit	Net benefit
2009	0.0	0.0	0.0	1.0000	0.00	0.0	0.0
2010	0.0	0.0	0.0	0.9346	0.00	0.0	0.0
2011	0.0	0.0	0.0	0.8734	0.00	0.0	0.0
2012	-56.4	12.60	-43.8	0.8163	-46.07	10.3	-35.8
2013	-117.3	38.03	-79.3	0.7629	-89.53	29.0	-60.5
2014	-122.3	65.32	-57.0	0.7130	-87.22	46.6	-40.6
2015	-127.2	94.14	-33.1	0.6663	-84.78	62.7	-22.1
2016	-140.2	125.30	-14.9	0.6227	-87.32	78.0	-9.3
2017	-291.0	159.07	-132.0	0.5820	-169.39	92.6	-76.8
2018	-302.1	195.28	-106.8	0.5439	-164.32	106.2	-58.1
2019	-312.5	233.76	-78.8	0.5083	-158.88	118.8	-40.0
2020	-318.5	273.57	-44.9	0.4751	-151.30	130.0	-21.3
2021	-316.9	314.26	-2.6	0.4440	-140.70	139.5	-1.2
2022	-309.5	353.56	44.0	0.4150	-128.44	146.7	18.3
2023	-301.6	392.55	90.9	0.3878	-116.98	152.2	35.3
2024	-293.1	434.86	141.7	0.3624	-106.25	157.6	51.4
2025	-274.5	477.37	202.8	0.3387	-93.00	161.7	68.7
2026	-254.6	519.52	264.9	0.3166	-80.61	164.5	83.9
2027	-233.6	560.01	326.4	0.2959	-69.11	165.7	96.6
2028	-211.8	599.04	387.3	0.2765	-58.55	165.6	107.1
2029	-189.3	636.59	447.3	0.2584	-48.92	164.5	115.6
2030	-166.9	672.31	505.4	0.2415	-40.31	162.4	122.1
2031	-149.0	706.05	557.1	0.2257	-33.63	159.4	125.7
2032	-135.4	737.92	602.6	0.2109	-28.55	155.7	127.1
2033	-125.2	772.20	647.0	0.1971	-24.68	152.2	127.6
2034	-113.9	799.40	685.5	0.1842	-20.98	147.3	126.3
2035	-101.5	825.34	723.8	0.1722	-17.48	142.1	124.6
2036	-88.0	852.79	764.8	0.1609	-14.16	137.2	123.1
2037	-73.3	878.54	805.3	0.1504	-11.02	132.1	121.1
2038	-57.2	900.47	843.3	0.1406	-8.04	126.6	118.5
2039	-39.7	926.73	887.0	0.1314	-5.22	121.7	116.5
2040	-20.7	948.90	928.2	0.1228	-2.54	116.5	114.0
Total	**-5,243.4**	**14,505.5**	**9,262.1**		**2,087.95**	**3645.6**	**1557.6**
Benefit–cost Ratio =			**1.75**	**NPV =**			**$1,558m**

4.5 Sensitivity Analyses

Given the inevitable uncertainties with some of the assumptions used in the base case, a number of sensitivity analyses were undertaken on the assumptions for:

- Fleet parameters (diesel penetration and durability of emissions controls);
- Unit health costs;
- Vehicle costs;
- Discount rates; and
- Value of statistical life.

As the BCA results for Options 2 and 3 are so similar (especially over the longer term), sensitivity testing was done for Option 2 only. Sensitivity analyses were also not undertaken for Option 4, as the only sensitivity test which might affect the result (diesel vehicle penetration) was shown to have limited effect on the overall results.

These analyses indicate that Option 2 (and by implication Option 3) deliver net benefits under all circumstances, except where a very low unit health cost value is applied.

Changes to Fleet Parameters

The first set of sensitivity tests (ST1) is for diesel vehicle penetration. The ‘low’ case has new sales remaining roughly at their current proportion of total sales (leading to around 17% of 2040 sales) and the ‘high’ case has strong increases in diesel vehicles sales (with the result that about half of 2040 car sales, and most of LCV sales, are diesels).

The second set of sensitivity tests (ST2) is for durability of the emissions control technology. The ‘low’ case has the deterioration rates set to zero for all post-2010 models, and the ‘high’ case has the default parameter values doubled for all post-2010 models.

If the changed deterioration rates applied only to the Euro 5 and 6 technology, the zero deterioration assumption would lead to higher benefits (the ‘high’ case), and conversely for doubling the deterioration rate parameter (the ‘low’ case). However, the changes to the deterioration rate parameter are applied to the Option 1 case as well as the ‘new standards’ case, and they affect the status quo results more than they affect the ‘new standards’ results. Consequently, the savings in emissions are lower for the sensitivity run with zero deterioration (making it the ‘low’ case) and greater for the run that doubles the deterioration rate (making it the ‘high’ case).[43]

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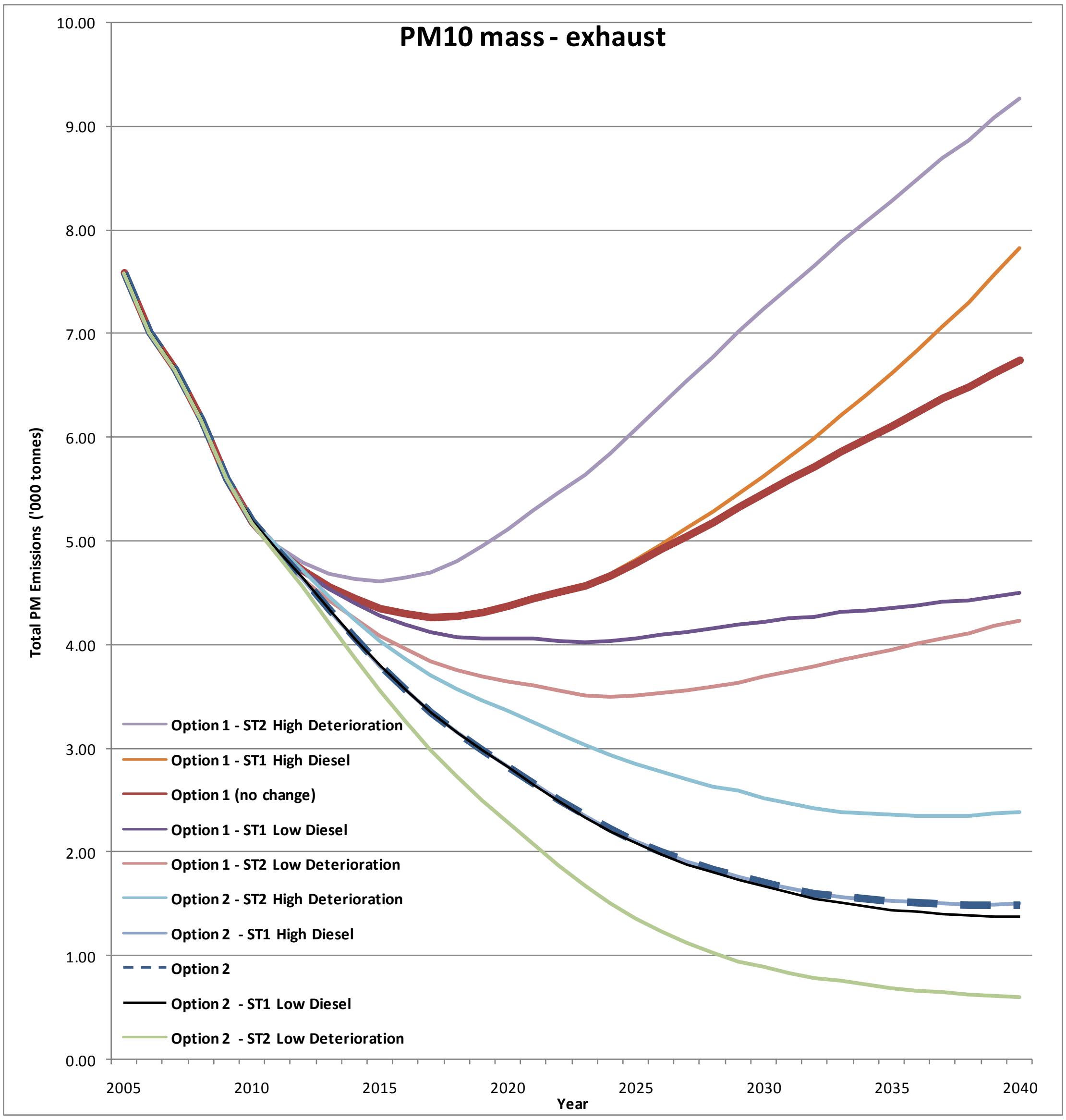
[43] When the changes to the deterioration rate parameters are applied to the ‘new standards’ case only, zero deterioration becomes the ‘high’ case with a BCR of 1.97, and double deterioration becomes the ‘low’ case with a BCR of 1.06.

The impact of these sensitivity tests on PM emissions (which is the dominant emissions factor in the BCA) is illustrated in Figure 10. The chart indicates that under all test conditions, Option 2 (and implicitly Option 3) deliver emissions reductions relative to the base case (Option 1). The chart indicates that PM emissions are more sensitive to changes in deterioration rates than diesel penetration, presumably because the PM emissions rate from diesel vehicles meeting Euro 5 is not markedly different from those of petrol vehicles.



Source: BITRE Estimates (2009)

Figure 10 **Projected Impact on PM Emissions of the Light Vehicle Fleet from the Introduction of Euro 5/6 Emissions Standards under Different Diesel Penetration and Durability Sensitivity Tests**

The results of sensitivity tests for ST1 and ST2 in terms of the BCA are presented in Table 12. While there are still net benefits under all tests, as noted above, it appears that the results are more sensitive to the changes in the deterioration rates than diesel penetration rates.

Table 12 Impact of Changes to Specified Fleet Parameters

Scenarios	Net Benefit ($m)	Benefit–cost Ratio
Base Case	1,250	1.51
ST1 (diesel penetration)		
Low	857	1.47
High	1,331	1.52
ST2 (deterioration rates)		
Low	476	1.19
High	2,037	1.83

Changes to Unit Health Costs

The two tests for health costs were simply to apply a ±50% factor to the base case estimates. As shown in Table 13, under the unlikely scenario where unit health cost values (i.e. the benefits measured in terms of avoided health costs) are reduced by 50%, there is a net cost over the analysis period.

Table 13 Impact of Changes to Unit Health Costs

Scenarios	Net Benefit ($m)	Benefit–cost Ratio
Base Case	1,250	1.51
Low Avoided Cost (– 50%)	– 604	0.75
High Avoided Cost (+ 50%)	3,103	2.26

Changes to Implementation Costs

As noted earlier, there are considerable uncertainties in the assumed cost adjustment process illustrated in Figure 9. An alternative assumption tested in this RIS is to assume no downward cost adjustment over time. The result of the testing is presented in Table 14. Even with this very conservative assumption, there are still net benefits over the analysis period.

Table 14 Impact of Changes to Implementation Costs

Scenarios	Net Benefit ($m)	Benefit–cost Ratio
Base Case	1,250	1.51
High Cost (no downward cost adjustment)	780	1.27

Changes to Discount Rates

The results of sensitivity testing in relation to the discount rates are shown in Table 15. There are net benefits under all three rates, with the 3% discount rate preferred by BITRE delivering a significantly higher net benefit than the base case.

Table 15 Impact of Changes to Discount Rates

Scenarios	Net Benefit ($m)	Benefit–cost Ratio
Base Case (7%)	1,250	1.51
Low (3%)	3,964	2.02
High (11%)	300	1.18

Changes to Value of a Statistical Life

As noted in section 4.3, the estimates for avoided health costs can vary widely, and in part this is affected by the assumed value of a statistical life (VSL). The implied average VSL used by the three most recent studies evaluated in the BCA was $6 million and was derived from a consistent methodology (willingness to pay). This is consistent with a 2008 report[44] for

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[44] Access Economics (2008) *The Health of Nations: The Value of a Statistical Life* Report for the Office of the Australian Safety and Compensation Council at: http://www.safeworkaustralia.gov.au/NR/rdonlyres/AAF0F980-FAA3-410F-837C-47C448DD5EFB/0/Health_national_value_Statistical_life_full_version.pdf

Australian Safety and Compensation Council, which, while also noting the inherent uncertainties in VSL estimates suggested a “ballpark average” of $6 million for VSL, with sensitivity analysis recommended at $3.7 million and $8.1 million. To assess the influence of changes in VSL on the BCA outcomes, a sensitivity test using the VSL estimate preferred by the OBPR ($3.5 million) was conducted. The result of the testing is presented in Table 16. Using this very conservative assumption, the net benefits are considerably reduced, although still positive over the analysis period.

Table 16 Impact of Changes to Value of Statistical Life Estimates

Assumed VSL	Net Benefit ($m)	Benefit–cost Ratio
Medium Case ($6m)	1,250	1.51
Low Case ($3.5m)	191	1.08

5 CONSULTATION

This RIS has been release in draft form for public comment. The release enables industry, motoring associations, transport and environment agencies and the broader community to respond to the options presented in the RIS.

The inclusion of a draft benefit-cost analysis (BCA) as part of the draft RIS enables stakeholders to evaluate the assumptions and estimates of costs and benefits used to derive the net benefit calculation, and ultimately the recommended option. The Australian Government is particularly interested in comments on these assumptions and estimates, and the provision of any alternative data is invited. The Government is also interested in stakeholders' views on the appropriateness of the 30 year time frame adopted in the BCA, including the rationale for any alternative timeframe proposed.

While the fuel sulfur question is not addressed in the BCA, the Government is interested in also receiving any data to improve the understanding of this issue so as to assist any further analysis that may be conducted under the auspices of the *Fuel Quality Standards Act 2000*. This draft RIS will be provided to the Fuel Standards Consultative Committee which has been established under the FQS Act to provide advice to the Minister for the Environment, Heritage and the Arts.

Notification of this draft proposal will also be sent to the World Trade Organisation, consistent with Australia's obligations under the Technical Barriers to Trade agreement.

A summary of the public comment will be included in the final RIS that is used for decision making.

All submissions will be treated as public documents, unless requested to be treated as confidential by the author.

All comments must be in writing and should be directed to:

Euro 5/6 Emissions Review
Energy and Environment Team
Department of Infrastructure, Transport, Regional Development and Local Government
GPO Box 594
CANBERRA ACT 2601

Or email to: E5-6RIS@infrastructure.gov.au

Comments must be received by 1 March 2010.

6 CONCLUSION AND RECOMMENDED OPTION

6.1 Conclusion

The benefit-cost analysis undertaken in the preparation of this draft RIS has demonstrated a net benefit in adopting the Euro 5/6 emissions standards for light vehicles. Sensitivity analyses also indicated a net benefit under all reasonable scenarios.

The review makes no specific recommendations regarding fuel standards, but suggests that the Fuel Standards Consultative Committee consider any potential impacts for fuel quality which may arise from the adoption of Euro 5/6 standards for light vehicles.

6.2 Recommended Option

Subject to any additional information provided via the public consultation process, the review favours the implementation of Option 3 in accordance with the details set out below. This option minimises compliance costs for vehicle manufacturers and provides additional lead time for providing compliant vehicles, without any measurable detriment to the health benefits arising from the introduction of the new standards.

While Option 4 provides greater net benefits that Option 3 (because it is limited to diesel vehicles only), the review notes that Option 3 provides around 82% of the net benefit from Option 4, as calculated by the BCA, and by including petrol vehicles, Option 3 also delivers the additional benefits which would flow from adoption of Euro 5/6 standards for petrol vehicles (and were not quantified in the BCA). These include:

- the increased durability of emissions control systems;
- greater confidence with in-service compliance through enhanced OBD systems;
- removal of current concessional provisions which allow heavier passenger cars to meet more lax emissions limits; and
- controls on PM emissions from direct injection petrol engines.

While data is not available to enable the BCA to quantify the additional benefits from these elements, it is reasonable to conclude they would improve the net benefit over the longer term.

From a cost perspective, the EC estimates which underpinned the BCA either include the costs associated with these measures (such as the removal of concessions for heavier cars) or conclude that they add no additional costs (increased durability).

Petrol vehicles remain the dominant vehicle type in the light vehicle sector, and their exclusion from the Euro 5/6 standards, while allowable under our current treaty obligations under the *1958 Agreement*, would nevertheless be inconsistent with the Australian Government's desire to develop an internationally competitive vehicle industry. As noted in the 2008 Review of Australia's Automotive Industry[45]:

"The harmonisation of Australian Design Rules with United Nations Economic Commission for Europe regulations removes barriers to trade, and facilitates participation in global markets by the Australian automotive industry".

Thus, on balance, the review recommends the implementation of Option 3.

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[45] *Review of Australia's Automotive Industry Final Report* (July 2008) p.90 at: http://www.innovation.gov.au/automotivereview/Documents/aug08%20final%20report_secure.pdf

6.2.1 Euro 5

The review recommends that the Euro 5 vehicle emissions standards be adopted in Australia through:

- determining a new ADR79/03 *Emission Control for Light* Vehicles which adopts the final text of ECE Regulation 83/06; and
- requiring the new ADR79/03 to apply the Euro 5 requirements in a staged manner consistent with a lagged implementation of the timeframes set out in UN ECE Regulation 83/06[46], as set out in Table 17 below:

Table 17 Implementation Timetable for Proposed ADR79/03

ADR 79/03 Implementation Stage	Minimum Requirements	Applicable Vehicle Categories	Date of Effect* (1 January...)	
			New Models	All Models
Stage 1	"Base" Euro 5 (including concessions regarding OBD PM threshold for M and N category vehicles as specified in 3.3.2 of Annex 11 of ECE R83/06 and NOx emissions monitoring as specified in 3.3.3.1 of Annex 11 of ECE R83/06)	Petrol, LPG & NG vehicles	2013	2014
		Diesel vehicles	2012	2013
Stage 2	Stage 1 (with OBD PM threshold concession removed) *plus* PM and Particle Number limits based on new test procedure	Diesel & direct injection petrol vehicles	2013	2014
Stage 3**	Full compliance with ECE R83/06, including all OBD requirements of Annex 11 of ECE R83/06	Petrol, LPG & NG vehicles	2015	2015

* The 2 year date combinations for the vehicle standards refer to the dates applicable to new model vehicles and all model vehicles, respectively. For example, in the case of 2012 - 2013, this means that from 1 January 2012 any new model (type) first produced with a date of manufacture after 1 January 2012 must comply with the new standard, and from 1 January 2013 all new vehicles (regardless of the first production date for that particular model) must comply.

All dates of effect are at least one year later than the equivalent applicability date in ECE83/06.

** To avoid the introduction of a multitude of implementation dates, it is proposed that Stage 3 be implemented at a single "all model" date (1 Jan 2015) reflecting the full implementation of this provision in ECE 83/06 for all models from 1 January 2014.

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[46] Current text of ECE R83/06 is at: http://www.unece.org/trans/doc/2009/wp29/ECE-TRANS-WP29-2009-57e.pdf R83/06 It is anticipated that ECE R83/06 will be agreed by the UN ECE at the December 2009 meeting.

6.2.2 Euro 6

The Euro 6 vehicle emissions standards have been agreed in the European Commission (EC) process, but ECE Regulation 83 has not yet been amended to adopt the emissions limits specified for Euro 6. The review recommends that once ECE R83 is amended to adopt the Euro 6 emissions limits, a new ADR79/04 be introduced to take effect from 2016 for new models and 2017 for all models. This timing is based on the assumption that the current EC timing for Euro 6 (see section 1.5.1) is substantially reflected in ECE R83.

7 IMPLEMENTATION AND REVIEW

The ADRs are national standards under the *Motor Vehicle Standards Act 1989* and are subject to periodic review in light of international developments in the UN ECE regulations adopted in the ADRs. In the case of the emissions standards, such reviews (including this RIS) usually consider the merits of more stringent standards, as ECE regulations for emissions are progressively tightened in line with technology improvements to address potentially adverse impacts on urban air quality from increased vehicle use. However, where it can be demonstrated that technology or fuel changes render an emissions related ADR as no longer being necessary to delivering improved air quality outcomes, a review would be conducted.

Any new emissions ADRs are jointly agreed by the Australian Transport Council (ATC) and the Environment Protection and Heritage Council (EPHC), with formal endorsement being the responsibility of the Ministers of the Australian Transport Council (ATC). Under the *Motor Vehicle Standards Act 1989*, final responsibility for determining an ADR rests with the Commonwealth Minister for Infrastructure, Transport, Regional Development and Local Government.

Given that ECE R83/06 at this stage only adopts the Euro 5 emissions limits, it is proposed that the ADR vehicle emissions package be presented to ATC and EPHC Ministers in two parts as follows:

- Part 1 would ask the Councils to recommend that the Minister for Infrastructure, Transport, Regional Development and Local Government determine as soon as possible a new ADR79/03 which adopts the final text of UN ECE R83/06 (Euro 5) emissions standards for light duty petrol, diesel, LPG and NG vehicles in accordance with the provisions of section 6.2.1; and
- Part 2 would ask the Councils to recommend that the Minister for Infrastructure, Transport, Regional Development and Local Government determine a new ADR79/04 which adopts the version of UN ECE R83 which adopts the Euro 6 emissions standards for light duty petrol, diesel, LPG and NG vehicles (when finalised) in accordance with the provisions of section 6.2.2.

APPENDIX A SUPPLEMENTARY INFORMATION ON URBAN AIR POLLUTION

Health Impacts of Key Urban Air Pollutants

While urban air quality in Australia is generally good, there are still significant health concerns in relation to the concentrations of air pollutants. The air pollutants relevant to this RIS are particulate matter (PM) - especially fine and ultrafine particles - nitrogen oxides, and ground level ozone - an indicator of photochemical smog. Motor vehicles are a major contributor to these pollutants in urban air, and vehicle numbers and usage continue to rise.

Studies conducted in cities in the US, Europe, Australia and New Zealand[47,48,49,50,51,52] have repeatedly found associations between short-term increases in ambient levels of PM_{10} and $PM_{2.5}$[53] and daily mortality, and cardiovascular and respiratory morbidity. The risk of these effects increases with each 10µg/m^3 increase in PM levels. These associations are observed even when air pollutant concentrations are below national standards.

While most research has been conducted using PM_{10} as an indicator, recent research indicates that short-term exposure to $PM_{2.5}$ in urban air is associated with mortality from cardiopulmonary diseases, hospitalization and emergency department visits for cardiopulmonary diseases, increased respiratory symptoms, decreased lung function, and physiological changes or biomarkers for cardiac changes. Long-term exposure to $PM_{2.5}$ is associated with mortality from cardiopulmonary diseases and lung cancer, and effects on the respiratory system such as decreased lung function or the development of chronic respiratory disease.

PM from motor vehicle exhaust in particular is the subject of increasing concern amongst health researchers, with linkages between adverse health

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[47] Barnett AG; Williams GM; Schwartz J; Neller AH; Best TL; Petroeschevsky AL; Simpson RW (2005). *Air pollution and child respiratory health: a case-crossover study in Australia and New Zealand*, Journal American Journal of Respiratory and Critical Care Medicine, 171:1272–1278.

[48] Barnett AG; Williams GM; Schwartz J; Best TL; Neller AH; Petroeschevsky AL; Simpson RW (2006). *The effects of air pollution on hospitalizations for cardiovascular disease in elderly people in Australian and New Zealand cities*, Journal Environmental Health Perspectives, 114:1018-1023.

[49] Jalaludin B; Morgan G; Lincoln D; Sheppeard V; Simpson R; Corbett S (2006). *Associations between ambient air pollution and daily emergency department attendances for cardiovascular disease in the elderly (65+ years), Sydney, Australia*, Journal of Exposure Science and Environmental Epidemiology, 16:225-37.

[50] Rodriguez C; Tonkin R; Heyworth J; Kusel M; De Klerk N; Sly PD; Franklin P; Runnion T; Blockley A; Landau L; Hinwood AL (2007). *The relationship between outdoor air quality and respiratory symptoms in young children*, Journal International Journal of Environmental Health Research, 17(5):351-360.

[51] Simpson R; Williams G; Petroeschevsky A; Best T; Morgan G; Denison L; Hinwood A; Neville G (2005). *The short-term effects of air pollution on hospital admissions in four Australian cities*, Journal Australian and New Zealand Journal of Public Health, 29:213-221.

[52] U.S. EPA. (2004). *Air quality criteria for particulate matter.* U.S. Environmental Protection Agency. Research Triangle Park, NC. EPA/600/P-99/002aF-bF.

[53] PM_{10} and $PM_{2.5}$ refer to particles of diameter of 10 microns and less, and 2.5 microns and less, respectively.

effects and exposure being demonstrated at increasingly lower levels of PM in the atmosphere. New research suggests the risks of cardiovascular effects may be particularly great for exposure to fine (<2.5μm) and ultrafine (<0.1μm) exhaust particles[54].

While the number of studies of exposure to ultrafine particulate (UFPs) is still limited, there is a large body of evidence from controlled human exposure studies using fresh exhaust from diesel engines which demonstrates effects on the cardiovascular system[55]. Diesel exhaust PM is dominated by UFPs. These studies[56,57,58,59,60,61] suggest that exhaust particles affect vascular function in both healthy individuals and those with pre-existing cardiovascular disease.

Many studies also suggest that the surface of particles or substances released from the surface (e.g. transition metals, organics) interact with biological substrates, and that surface-associated free radicals or free radical-generating systems may be responsible for toxicity, resulting in greater toxicity of UFPs per particle surface area than larger particles. Additionally, smaller particles may have greater potential to cross cell membranes and epithelial barriers[62]. For a given mass, the enormous number and large surface area of UFPs highlight the importance of considering the size of the particle in assessing response. For example, UFPs with a diameter of 20 nm, when inhaled at the same mass concentration, have a number concentration that is approximately 6 orders

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[54] Yue W; Schneider A; Stolzel M; Ruckerl R; Cyrys J; Pan X; Zareba W; Koenig W; Wichmann HE; Peters A (2007). *Ambient source-specific particles are associated with prolonged repolarization and increased levels of inflammation in male coronary artery disease patients*, Journal Mutation Research: Fundamental and Molecular Mechanisms of Mutagenesis, 621:50-60.

[55] U.S. EPA (2009). Second External Draft of the Integrated Science Assessment of Particulate Matter. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-08/139B, 2009.

[56] Adar SD; Gold DR; Coull BA; Schwartz J; Stone PH; Suh H (2007). Focused exposures to airborne traffic particles and heart rate variability in the elderly, Journal Epidemiology, 18:95–103.

[57] Lundbäck M; Mills NL; Lucking A; Barath S; Donaldson K; Newby DE; Sandström T; Blomberg A (2009). Experimental exposure to diesel exhaust increases arterial stiffness in man, Journal Particle and Fibre Toxicology, 6:7.

[58] Mills NL; Törnqvist H; Gonzalez MC; Vink E; Robinson SD; Soderberg S; Boon NA; Donaldson K; Sandstrom T; Blomberg A; Newby DE (2007). Ischemic and thrombotic effects of dilute diesel-exhaust inhalation in men with coronary heart disease, Journal New England Journal of Medicine, 357:1075-1082.

[59] Peretz A; Sullivan JH; Leotta DF; Trenga CA; Sands FN; Allen J; Carlsten C; Wilkinson CW; Gill EA; Kaufman JD (2008). Diesel exhaust inhalation elicits acute vasoconstriction in vivo, Journal Environmental Health Perspectives, 116:937-942.

[60] Rodriguez C; Tonkin R; Heyworth J; Kusel M; De Klerk N; Sly PD; Franklin P; Runnion T; Blockley A; Landau L; Hinwood AL (2007). The relationship between outdoor air quality and respiratory symptoms in young children, Journal International Journal of Environmental Health Research, 17(5):351-360.

[61] Tornqvist H; Mills NL; Gonzalez M; Miller MR; Robinson SD; Megson IL; MacNee W; Donaldson K; Soderberg S; Newby DE; Sandstrom T; Blomberg A (2007). Persistent endothelial dysfunction in humans after diesel exhaust inhalation, Journal American Journal of Respiratory and Critical Care Medicine, 176:395-400.

[62] U.S. EPA (2009). *Second External Draft of the Integrated Science Assessment of Particulate Matter*. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-08/139B, 2009.

of magnitude higher than for a 2.5-µm diameter particle. Particle surface area is also greatly increased with ultrafine PM[63].

In recent years there has been an increased focus among the international scientific community on gaining a better understanding of the potential health effects associated with exposure to UFPs, especially from traffic exhaust, and more research is being conducted that examines associations between particle number concentrations and health effects.

The current consensus is that there is no safe level of exposure to PM and that any reduction in particle concentrations would improve population health outcomes[64,65,66,67].

Ozone is a secondary pollutant formed from the interaction of hydrocarbons (HCs), often referred to as volatile organic compounds (VOCs), and NOx. Ambient levels of ozone, below the current standards, are linked with increases in mortality and morbidity, including hospital admissions and emergency department attendances, exacerbation of asthma, decreases in lung function and increases in respiratory symptoms[68,69,70,71] . As with particulates, it is not possible to detect a distinct threshold for ozone, below which no individual would experience a given adverse health effect, especially given some members of a population are sensitive even at very low concentrations[72].

Nitrogen oxides (NOx) emitted from motor vehicles contribute to the formation of both ozone and fine particles. The nitrogen oxides (NOx) are comprised mainly of nitric oxide (NO, approximately 95%) and nitrogen

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[63] U.S. EPA (2009). *Second External Draft of the Integrated Science Assessment of Particulate Matter.* U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-08/139B, 2009.

[64] Daniels MJ; Dominici F; Zeger SL; Samet JM (2004). The national morbidity, mortality, and air pollution study Part III: PM10 concentration-response curves and thresholds for the 20 largest US cities. Report.

[65] Samoli E; Analitis A; Touloumi G; Schwartz J; Anderson HR; Sunyer J; Bisanti L; Zmirou D; Vonk JM; Pekkanen J; Goodman P; Paldy A; Schindler C; Katsouyanni K (2005). Estimating the exposure-response relationships between particulate matter and mortality within the APHEA multicity project, Journal Environmental Health Perspectives, 113:88-95.

[66] Schwartz J; Coull B; Laden F; Ryan L (2008). The effect of dose and timing of dose on the association between airborne particles and survival, Journal Environmental Health Perspectives, 116:64-69.

[67] Schwartz J (2004). The effects of particulate air pollution on daily deaths: a multi-city case crossover analysis, Journal Occupational and Environmental Medicine, 61:956-961.

[68] Barnett AG; Williams GM; Schwartz J; Neller AH; Best TL; Petroeschevsky AL; Simpson RW (2005). *Air pollution and child respiratory health: a case-crossover study in Australia and New Zealand*, Journal American Journal of Respiratory and Critical Care Medicine, 171:1272–1278.

[69] Erbas B; Kelly AM; Physick B; Code C; Edwards M (2005). *Air pollution and childhood asthma emergency hospital admissions: estimating intra-city regional variations*. International Journal of Environmental Health Research, 15:11-20.

[70] Simpson R; Williams G; Petroeschevsky A; Best T; Morgan G; Denison L; Hinwood A; Neville G (2005). *The short-term effects of air pollution on hospital admissions in four Australian cities*, Journal Australian and New Zealand Journal of Public Health, 29:213-221

[71] U.S. EPA (2006). *Air quality criteria for ozone and related photochemical oxidants*. Volume I. United States Environmental Protection Agency.

[72] U.S. EPA (2006). *Air quality criteria for ozone and related photochemical oxidants*. Volume I. United States Environmental Protection Agency.

dioxide (NO_2, approximately 5%). In the atmosphere, nitric oxide oxidises to the more toxic nitrogen dioxide.

There are strong associations between levels of nitrogen dioxide in the air and daily mortality, hospital admissions for asthma, chronic obstructive pulmonary disease and heart disease. Numerous studies[73,74,75] in Australian cities have found increases in NO_2 are associated with increased daily mortality, hospital admissions of children for respiratory disease and of the elderly (>65 years) for cardiovascular disease[76]. These effects are reported at levels below the current air quality standards. A 2004 study in Perth[77] reported increases in cardiovascular mortality with each 1 ppb increase in NO_2.

Australia's Ambient Air Quality Standards

In June 1998, the NEPC made the National Environment Protection Measure for Ambient Air Quality (the AAQ NEPM), which set Australia's first national ambient air quality standards. The AAQ NEPM sets national standards for the six criteria pollutants specified in Table A1. The goals for each pollutant set out in Table A1 apply in the Commonwealth and each State and Territory of Australia and must be met by the year 2008.

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[73] Barnett AG; Williams GM; Schwartz J; Neller AH; Best TL; Petroeschevsky AL; Simpson RW (2005). *Air pollution and child respiratory health: a case-crossover study in Australia and New Zealand*, Journal American Journal of Respiratory and Critical Care Medicine, 171:1272–1278.

[74] Erbas B; Kelly AM; Physick B; Code C; Edwards M (2005). *Air pollution and childhood asthma emergency hospital admissions: estimating intra-city regional variations*. International Journal of Environmental Health Research, 15:11-20.

[75] Simpson R; Williams G; Petroeschevsky A; Best T; Morgan G; Denison L; Hinwood A; Neville G (2005). *The short-term effects of air pollution on hospital admissions in four Australian cities*, Journal Australian and New Zealand Journal of Public Health, 29:213-221

[76] Barnett AG; Williams GM; Schwartz J; Best TL; Neller AH; Petroeschevsky AL; Simpson RW (2006). *The effects of air pollution on hospitalizations for cardiovascular disease in elderly people in Australian and New Zealand cities*, Journal Environmental Health Perspectives, 114:1018-1023.

[77] Hinwood AL; De Klerk N; Rodriguez C; Runnion T; Jacoby P; Landau L; Murray F; Feldwick M; Spickett J (2004). *Changes in daily air pollution and mortality in Perth: A case crossover study*. Environmental Health Perspectives, 4:13-23.

Table A1 Australia's Ambient Air Quality NEPM Standards

Criteria Pollutant	Averaging Period	Maximum (ambient) Concentration	Air Quality Goal (maximum allowable exceedences)
Carbon monoxide (CO)	8 hours	9.0ppm	1 day a year
Nitrogen dioxide (NO_2)	1 hour	0.12ppm	1 day a year
	1 year	0.03ppm	None
Photochemical oxidants (as ozone)	1 hour	0.10ppm	1 day a year
	4 hours	0.08ppm	1 day a year
Sulfur dioxide (SO_2)	1 hour	0.20ppm	1 day a year
	1 day	0.08ppm	1 day a year
	1 year	0.02ppm	None
Lead	1 year	0.50 µg/m3	None
Particles as PM_{10}	1 day	50 µg/m3	5 days a year
Particles as $PM_{2.5}$	1 day 1 year	25 µg/m3 8 µg/m3	Goal is to gather sufficient data nationally to facilitate a review of the standard as part of the review of this Measure, which commenced in 2005.

A review of the AAQ NEPM standards is underway.

Current Status of Urban Air Quality in Australia

As noted earlier, the quality of air in Australian cities is generally good, but some pollutants remain a concern, including some of those derived from motor vehicle emissions. The status of those AAQ NEPM criteria pollutants which are relevant to the standards being considered in this RIS (*viz* ozone and PM) are summarised below.

Ozone

High solar radiation levels, high summer temperatures and location in coastal basins surrounded by hills make Australia's largest urban areas susceptible to photochemical smog and to its recirculation over areas of the airshed. Ozone concentrations are monitored under the AAQ NEPM as an indicator of photochemical smog. Ozone is not directly emitted from motor vehicles, but direct emissions of HCs and NOx react in the presence of sunlight to form ozone. Ozone levels remain a problem in Sydney and represent a potential problem in some of our other larger cities.

Compliance with the AAQ NEPM goal for ozone requires that from 2008, the 1-hour and 4-hour standards are exceeded on no more than one day per year. To a large extent, the frequency of exceedences from year to year is dependent on the seasonal summer conditions. Hot stable weather will produce higher ozone levels, while cooler wetter summers lead to reduced levels. Under unfavourable meteorological conditions, Sydney, Melbourne, Brisbane and Perth can experience ozone levels above the NEPM standards.

The Sydney region in particular faces a significant challenge in complying with the NEPM goal for ozone, as it has exceeded either or both of the 1-hour and 4-hour standards every summer since 1996 (see Figures A1 and A2). In a 2007 report[78], the then NSW Department of Environment and Climate Change (DECC) noted that severe bushfire events clearly contribute to ozone exceedences, but also notes that even in years of little bushfire activity, significant ozone exceedences can still occur. DECC concluded that "...anthropogenic emissions alone are sufficient to cause regular, widespread exceedences of the Air NEPM standards (e.g. the 2000-01 and 2006-07 seasons)". The report also noted that there had been no improvement in ozone since 1998, and that a large area within the Sydney region is susceptible to ozone level exceedences.

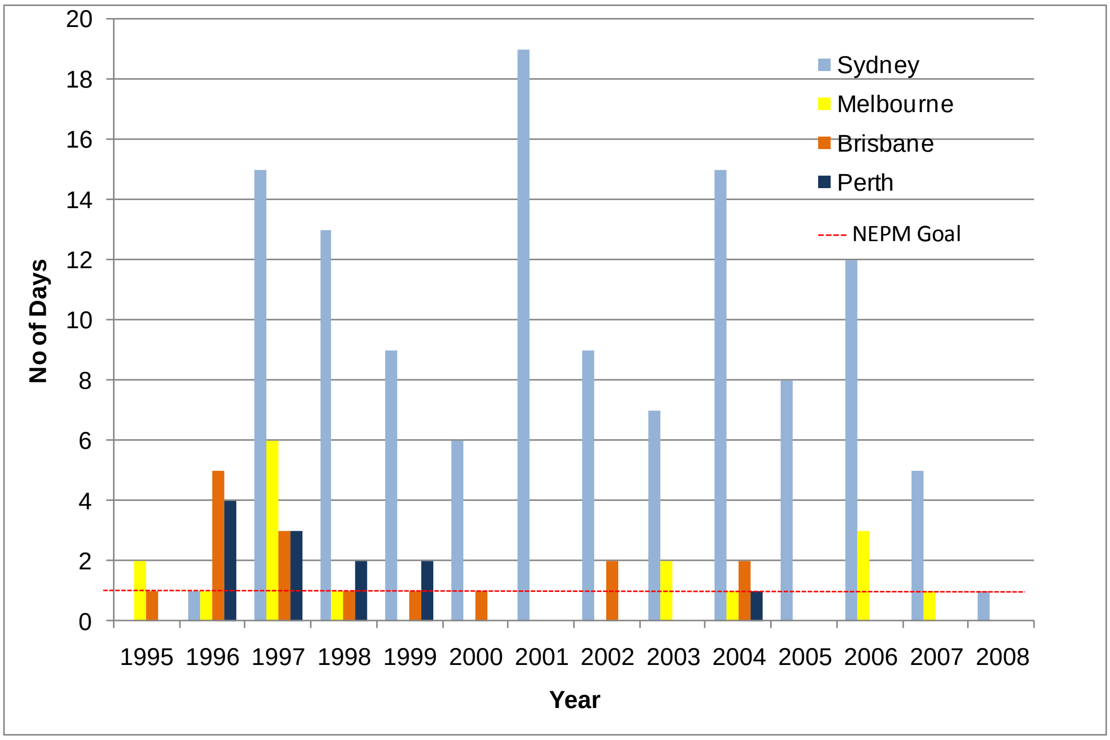

Figure A1 **Number of Days NEPM 1hr Ozone Standard (0.10ppm) Exceeded in Four Australian Cities**

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[78] NSW DECC (2007) *Current and projected air quality in NSW* at: http://www.environment.nsw.gov.au/resources/air/07529cpairqual.pdf

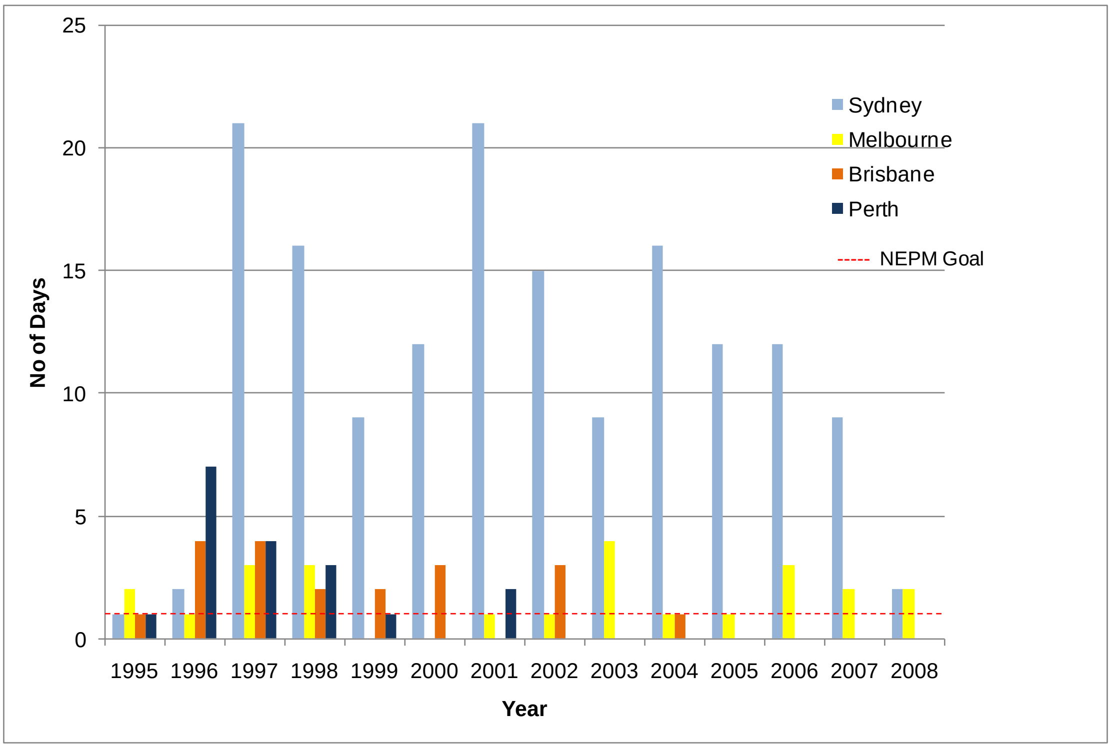

Figure A2 **Number of Days NEPM 4hr Ozone Standard (0.08ppm) Exceeded in Four Australian Cities**

Data from Melbourne indicate that while the number of days on which the 4-hour standard is exceeded is relatively low compared to Sydney there can be a significantly higher number of days in the summer months where the peak ozone levels approach the 4 hour standard, even in years where the standard is not actually exceeded. In 2001 in South East Queensland, the ozone standards were met, but maximum concentrations were up to 94% of the standard. These results highlight the ozone potential of these cities and point to the likelihood of exceedences in future summers where the meteorological conditions are favourable to ozone formation.

Particulates

Particle emissions are monitored in Australian cities, and some regional areas (as both PM_{10} and $PM_{2.5}$). Multiple exceedences of the PM_{10} standard occur every year in many cities in Australia. In most cases vehicles are not the principal contributors to the exceedences, which are triggered by extreme weather events such as bushfires and dust storms. Nevertheless, vehicle emissions, particularly from diesel vehicles, significantly elevate the background level of particulates in the urban atmosphere and can be a significant contributing factor to exceedences of the standards.

There are no Australian standards for ultrafine particles. UFPs are best measured in terms of their number concentration, because their particles numbers are large (usually >10,000/m^3), whereas their mass is small (usually a few µg/m^3) compared with the mass of larger particles. Only rarely is there a correlation between particle number and mass concentrations[79]; therefore on the basis of existing mass concentration data, it is normally not possible to evaluate the health effects of UFPs.

Contribution of Motor Vehicles to Air Pollution

Motor vehicles are one of the major emitters of air pollutants in urban Australia, contributing more than 80% of the CO emissions, 60-70% of the NOx and up to 40% of the HCs. Light petrol vehicles are the major transport contributors to CO, HC and NOx emissions, with diesel vehicles making a disproportionate contribution to NOx emissions. For example, in the Sydney airshed, diesel vehicles make up only 8% of the fleet, but are responsible for an estimated 22% of NOx emissions from transport.

While vehicles are not the major source of particle emissions in most urban airsheds, fuel combustion sources such as motor vehicles are a significant contributor to the overall particle load in urban airsheds. In Sydney for example, it is estimated that road transport contributes around 12% of annual anthropogenic PM_{10} emissions[80]. A recent study found motor vehicles contribute about 30% of particulate pollution in Melbourne. PM levels tend to be highest near busy roads and levels sometimes do not meet the PM standards[81].

Significantly, particulate emissions from diesel vehicles are almost all from the UFP fraction, and, as noted earlier, it is these fine particles that are considered to present the most significant human health risk.

The absolute contribution that vehicles make to urban air pollution is determined by the total emissions from the vehicle fleet and the complex interaction of those emissions with each city's meteorology, topography and overall urban structure. When considering the emissions component of this interaction, the key factors are:

- the emissions standards to which different vehicle types were certified (as new) and the stringency of those standards;
- the distribution of vehicles in the fleet meeting specified emissions standards;
- the age profile of the fleet and the deterioration of emissions control systems over time on emissions performance of vehicles;

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[79] Aalto P; Hameri K; Paatero P; et al. (2005) Aerosol particle number concentration measurements in five European cities using TSI-3022 condensation particle counter over a three-year period during health effects of air pollution on susceptible subpopulations. Journal of the Air & Waste Management Association, 55, 1064-76.

[80] NSW DECC (2007) *Current and projected air quality in NSW* at: http://www.environment.nsw.gov.au/resources/air/07529cpairqual.pdf

[81] EPA Victoria (2006). *Review of air quality near major roads*. Publication 1025. February 2006. Environment Protection Authority Victoria.

- the total VKT of the vehicles in each of these age/emissions standard groups in the fleet; and
- the parameters of the market fuels and the mix of fuel types.

The penetration rate of new vehicles into the fleet means there is a lag of approximately 10 years before new emissions standards begin to have a significant impact on total fleet emissions.

Air Quality Trends in Australian Cities

Although there have been considerable improvements in emissions performance of the vehicle fleet in Australia, motor vehicles continue to be an ongoing threat to Australian urban air quality, principally due to the growth in vehicle numbers and use. Recent Bureau of Infrastructure, Transport and Regional Economics estimates (BITRE, unpublished) imply growth in total motor vehicle travel (VKT) of 45% between 2000 and 2020 under business as usual conditions, with passenger car VKT growth at 37% and light commercials at 73%. This VKT growth is expected to occur even though projections of car ownership rates (number of cars per person) are predicted to essentially plateau by around 2015. Some urban regions face more rapid growth rates, with increasing VKT putting pressure on the capacity to meet some NEPM air quality standards in certain urban airsheds.

The BITRE emissions projections to 2040 undertaken for this RIS concluded that under a “business as usual” scenario, which includes the emissions standards being introduced over the 2006-2010 period, emissions of ozone precursors (HC and NOx) from the light vehicle sector will decline significantly until about 2025, after which they stabilise and then trend slightly upward. In contrast, PM emissions from light vehicles are expected to fall significantly until about 2016, then trend steeply upward. Refer to section 3.2 to view the relevant charts for NOx and PM.

While these emissions projections demonstrate the benefits of new vehicle emissions standards, the pattern and scale of urban development in parts of Australia, and the associated increase in vehicle use, is clearly having an effect on the long term trends and will place increasing pressure on the challenge to maintain improvements in urban air quality, particularly ozone and PM.

The NSW Department of the Environment, Climate Change and Water has concluded that the Sydney Greater Metropolitan Region (GMR) faces an ongoing challenge in meeting the Ambient Air Quality NEPM standards for ozone in the future because of the pressures of population growth, urban expansion and the associated increase in motor vehicle use. Sydney’s population is expected to reach 4.6 million by 2016 and 5 million by 2026 (increases of 19% and 29%, respectively, over 2001 levels), with significant population growth also expected in the Illawarra and the lower Hunter. Additionally, the benefits from cleaner vehicles and fuel standards alone are not expected to be enough to offset the impacts of the increase in total VKT, which will continue to place pressure on air quality in the GMR. Modelling undertaken by the NSW DECC to evaluate how to tackle the ozone challenge also concluded that “ozone formation in the Sydney region is more sensitive to motor vehicle control strategies than to control strategies applied to other sources”[82].

The Port Phillip airshed in Victoria encompasses Melbourne and Geelong. Melbourne is undergoing rapid population growth with the population predicted to reach 5 million before 2030. Melbourne’s population is expected to increase by 1.8 million between 2006 and 2036[83]. Geelong is also predicted to have rapid population growth over that period. This increase in population is likely to result in a significant increase in air pollution in the Port Phillip Region. Modelling conducted by EPA Victoria as part of the development of the draft Air Quality Improvement Plan for the region indicates that reductions in emissions due to improvements in vehicle technology would be offset by increased VKT leading to increases in air pollution out to 2021. Although air quality in the region generally meets air quality standards currently, the pressure on air quality in the region due to increases in population and VKT, as well as changing climatic conditions, may change that situation in the future. Motor vehicles remain the major contributor to air pollution in the Port Phillip Region.

South East Queensland is also predicted to experience significant growth over the next 20 years, with 1996 population in the region of some 2.3 million predicted to increase to 3.8 million by 2021. This will be accompanied by dramatic growth in transport activity, which the Queensland EPA concludes is likely to reduce air quality even allowing for advances in vehicle technology. This is reinforced by the latest estimates for the SE Qld region that expect VKT to increase at more than twice the rate of the population, principally because of trends to greater use of private vehicles, lower vehicle occupancies and longer trip lengths. The Queensland EPA also concludes that while there have been no exceedences of the ozone standards since 1998, under more conducive meteorological conditions the SE Qld region could fail to comply, particularly with the increasing pressure on the airshed from rapidly increasing population and resultant vehicle use.

Similar to other capital cities, it is expected that Perth’s population growth and high vehicle ownership is likely to place increasing pressure on maintaining acceptable air quality. To date, three quarters of the state’s rapid population growth has occurred in the Perth metropolitan area[84]. Perth’s population as at June 2008 was 1.6 million, with projections

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[82] NSW DECC (2007) *Current and projected air quality in NSW* at: http://www.environment.nsw.gov.au/resources/air/07529cpairqual.pdf

[83] Victorian Government (2008) *Melbourne @ 5 Million* at: http://www.dse.vic.gov.au/DSE/nrenpl.nsf/fid/93E1884BDDA65F63CA25762500047CE5

[84] ABS (2009) Cat. 3218.0, 2007-08, Summary at: http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/3218.02007-08?OpenDocument

suggesting this could increase to 2.4 million by 2026, and over 4 million by 2056. In addition, vehicle ownership is also increasing. The ABS motor vehicle census identified Western Australian as having the highest rate of passenger and total vehicle ownership across Australia, with 603 and 813 vehicles per 1000 residents, respectively[85]. The WA Department of Environment and Conservation currently records irregular exceedences of the ozone Ambient Air Quality NEPM standards, with the most recent occurrence in January 2009. As motor vehicles are the single largest source of air pollution in the Perth metropolitan region it is expected that any tightening of the emissions limits will have a positive impact on air quality.

In summary, total emissions from individual motor vehicles are expected to decline steadily over the next twenty years with improving vehicle technology, but will remain high due to increasing traffic and a growing population.

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[85] ABS (2009) Cat. 9309.0, 31 March 2008 SMVU Summary at: http://www.abs.gov.au/ausstats/abs@.nsf/mediareleasesbytitle/28861A19CCDB9441CA25753D001B59DA?OpenDocument

APPENDIX B TABLE OF EMISSIONS LIMITS FOR EURO 2 - EURO 6 LIGHT VEHICLES

Emissions Limits for Euro 2 – Euro 6 (g/km)

Emissions and Vehicle Type	Petrol, LPG & NG Vehicles					Diesel Vehicles				
	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6
Carbon Monoxide Limits										
Passenger Cars	2.200	2.300	1.000	1.000	1.000	1.000	0.640	0.500	0.500	0.500
LCVs with Ref mass < 1305kg	2.200	2.300	1.000	1.000	1.000	1.000	0.640	0.500	0.500	0.500
LCVs with Ref mass 1305-1760kg	4.000	4.170	1.810	1.810	1.810	1.250	0.800	0.630	0.630	0.630
LCVs with Ref mass > 1760kg	5.000	5.220	2.270	2.270	2.270	1.500	0.950	0.740	0.740	0.740
Total Hydrocarbon Limits										
Passenger Cars	0.250	0.200	0.100	0.100	0.100	0.105	0.084	0.045	0.035	0.026
LCVs with Ref mass < 1305kg	0.250	0.200	0.100	0.100	0.100	0.105	0.084	0.045	0.035	0.026
LCVs with Ref mass 1305-1760kg	0.300	0.250	0.130	0.130	0.130	0.15	0.108	0.059	0.044	0.029
LCVs with Ref mass > 1760kg	0.350	0.290	0.160	0.160	0.160	0.18	0.129	0.069	0.053	0.032
Oxides of Nitrogen Limits										
Passenger Cars	0.250	0.150	0.080	0.060	0.060	0.595	0.500	0.250	0.180	0.080
LCVs with Ref mass < 1305kg	0.250	0.150	0.080	0.060	0.060	0.595	0.500	0.250	0.180	0.080
LCVs with Ref mass 1305-1760kg	0.300	0.180	0.100	0.075	0.075	0.850	0.650	0.330	0.235	0.105
LCVs with Ref mass > 1760kg	0.350	0.210	0.110	0.082	0.082	1.020	0.780	0.390	0.280	0.125
Particulate (mass) Limits										
Passenger Cars	NA	NA	NA	NA	NA	0.080	0.050	0.025	0.005	0.005
LCVs with Ref mass < 1305kg	NA	NA	NA	NA	NA	0.080	0.050	0.025	0.005	0.005
LCVs with Ref mass 1305-1760kg	NA	NA	NA	NA	NA	0.120	0.070	0.040	0.005	0.005
LCVs with Ref mass > 1760kg	NA	NA	NA	NA	NA	0.170	0.100	0.060	0.005	0.005

Notes to Appendix B table:

(1) Reference (Ref) mass is a testing parameter defined as the unladen mass of the vehicle + 100kg

(2) Under E1, E2, E3 and E4, passenger vehicles which exceed 2500 kg GVM are subject to the least stringent emissions limits for that standard (i.e. the limits applicable to LCVs with Ref mass >1760). Euro 5 and 6 remove this concession for heavy passenger vehicles.

(3) There is no separate HC limit for diesel vehicles. For Euro 1 and Euro 2 diesels there was only a combined HC+NOx limit. From Euro 3 onwards, diesel vehicles had a combined HC+NOx limit and a separate NOx limit. In diesel vehicles, the NOx emissions are the dominant proportion of the HC+NOx calculation, with observation of certification data suggesting an approximate 1.5:8.5 (HC:NOx) split of the combined HC+NOx limit is appropriate. This ratio has been applied to the HC+NOx emissions limits for light duty diesels to determine all the HC values for diesels in the above table, as well as the NOx values for Euro 2 diesels (the NOx values for the later standards are the actual regulated limits).

(4) ECE 83/06 requires diesel vehicles to meet a particle number limit from 01/01/2013.

APPENDIX C BITRE BENEFIT-COST ANALYSIS

The Department of Infrastructure, Transport, Regional Development and Local Government engaged its Bureau of Infrastructure, Transport and Regional Economics (BITRE) to model the emissions impacts of the introduction of the Euro 5 and Euro 6 emissions standards as proposed in this Regulation Impact Statement, and to prepare the associated benefit-cost analysis.

The comparative analysis in Section 4 of this RIS, is based on the analysis in this Appendix B.

Note: in this Appendix, the BAU, 1A and 1B Scenarios, are identical to RIS Options 1, 2 and 3, respectively. The analysis for Option 4 and the sensitivity analysis for the value of statistical life were derived from the BCA set out in this Appendix (but are not included here).

Benefit–cost Analysis of Euro 5 and 6 Standards

(14 September 2009)

Introduction

This study assesses benefits and costs associated with the introduction of Euro 5 and 6 standards into the Australian light vehicle fleet. Two regulatory options are analysed reflecting variations on the timing of introduction. The description of the two options is contained in Table 1. Sensitivity tests are carried out to deal with uncertainties in the base case scenarios, unit health cost values, implementation costs and discount rate.

Table 1 Regulatory options

Scenario	Standard	Vehicle Group	Date of Effect		Fuel Sulphur Levels	Description of Scenario
			New Models	All Models		
S1	Euro 5	All light vehicles	1/01/2012	1/01/2013	No Change	Earliest practical introduction for vehicle standards, allowing minimum 2 years lead time from gazettal, and minimum 1 year after introduction in Europe (except E6 all model LCV date only 3 months after Europe).
	Euro 6	All light vehicles	1/01/2016	1/01/2017		
S1A	Euro 5	Petrol & LPG vehicles	1/01/2013	1/01/2014	No Change	Delayed introduction date for E5 petrol and LPG models, 3 years from gazettal. Unchanged implementation dates for E5 standards reflects earlier introduction of E4 for diesels.
		Diesel vehicles	1/01/2012	1/01/2013		
	Euro 6	All light vehicles	1/01/2016	1/01/2017		

The main quantifiable benefit identified is the health cost avoided[86] due to lower levels of pollutants emitted as a result of higher vehicle emission standards. The identified cost mainly relates to additional vehicle expenses involved in meeting the new emission standards.

Due to data and time constraints, a simplified approach is used to assess the health impact of the reduced pollution due to the introduction of Euro 5 and 6 standards. The analysis relies heavily on a small sample of the most recent available studies (Coffey Geosciences

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[86] There are other costs associated with air pollution, such as reduced visibility and increased corrosion, that are difficult to quantify and are likely to be small.

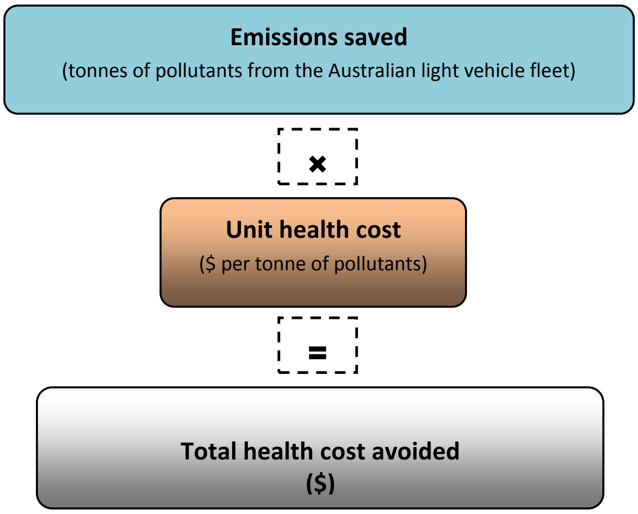
(2003), Watkiss (2002) and Beer (2002)) for deriving unit health cost values ($ per tonne of pollutants emitted).

The BCA results show that both regulatory options (S1 and S1A) are economically viable under the standard assumptions, unless a very low unit health cost value (–50%) is applied in calculating the health cost savings.

Methodology for estimating health benefits

The methodology employed to estimate the health benefits is described in Figure 1. The first step is to quantify the emissions of pollutants for the scenarios under investigation and estimate tonnes of emissions saved for each scenario of alternative vehicle emission standards (relative to the base case). The second step is to establish a value for an average health cost ($ per tonne of emissions) from existing studies. The final step is to calculate the total health benefit (or health cost avoided) by multiplying tonnes of emissions saved by unit value(s) for health costs.

Figure 1 The Study Approach



Emissions of air pollutants

The main pollutants of concern for air quality are HC, NO_x and PM_{10} (particulates).

Emissions of these pollutants from the Australian light vehicle fleet were modelled using a suite of BITRE fleet and projection models (including CARMOD, a model of the dynamics of the Australian car fleet; MVEm_Car, a detailed model of exhaust and evaporative emissions from Australian cars; and MVEm_LCV, a detailed model of exhaust and evaporative emissions from Australian light commercial vehicles).

These models are described in a variety of BITRE publications, such as BTRE (2002, 2003, and 2006). Note that the BITRE models allow for the effects of increasing traffic congestion levels within our urban areas, for example see BTRE (2007). Congestion imposes significant costs on society—with interruptions to urban traffic flow lengthening average journey times, making trip travel times more variable, and making vehicle engine operation less efficient. This leads not only to higher rates of fuel consumption, than would otherwise have occurred, but also to poorer urban air quality (with vehicles under congested conditions typically emitting far higher rates of air pollutants than under more freely flowing conditions).

Average Health Cost

Ideally, a bottom-up approach would be used to analyse the health impact of the proposed new fuel standards. Such an approach would follow the methodology recommended by Jalaludin, et al. (2009) and would comprise a series of steps to quantify and value air pollution in each major city, taking into account the effects of technology. However, this approach was not feasible for the current study due to data and time constraints.

The approach adopted for this study is to piggyback on the existing studies to derive plausible estimates of dollar-per-tonne health costs from air pollution. Disaggregation of the average costs by area has to rely on very limited information available from existing studies.

Table 2 presents estimates of dollar-per-tonne health costs obtained from a number of transport-related health impact studies for Australia. Two general observations can be made with respect to Table 2: first, unit cost estimates exhibit a considerable range of variation; second, more recent estimates tend to be much higher than those prior to the year 2000.

Table 2 Average capital city health cost ($/tonne of emissions)

Emission Type	CO	HC	NO_x	PM_{10}
Coffey Geosciences (2003)	13	2,200	59	232,000
Watkiss (2002)[a]	2	875	1,750	217,415
Beer (2002) – Ozone included				
Upper bound	9	72,500	900	221,100
Best estimate	3	19,331	870	147,429
Lower bond	2	11,700	280	108,300
Beer (2002) – Ozone excluded	3	18,719	11	147,429
BTRE (2005)	na	na	na	167,626[b]
Environment Australia (2000)	12	1,440	1,385	17,600
NSW EPA (1998)	na	na	68	310
NSW EPA (1997)	25	960	1,490	1,810

Note: [a] *Simple average for inner and outer areas of major capital cities (see Table 3 for detailed Watkiss (2002) results).*

[b] *Estimate for the year 2000, derived from results reported in BTRE (2005).*

Source: Coffey Geosciences (2003), Watkiss (2002) and BTRE (2005).

Coffey Geosciences (2003) is the first comprehensive benefit–cost analysis of the fuel quality and vehicle emissions standards in Australia. In estimating the health benefits of the new fuel quality and vehicle emissions standards, the study adopted a bottom-up approach that allowed explicit assumptions to be made in relation to a number of key parameters such as Relative Risk[87] and unit values of mortality and morbidity. For example, Coffey Geosciences (2003) assumed an exposure–response relationship value of 1.043 for long-term mortality in response to a change in $10ug/m^3$ concentration, which indicates that the number of deaths from all causes would rise to 1.043 times the current rate for a $10ug/m^3$ increase in average PM_{10} concentration. In terms of unit value for life, the study adopted a value of $5m, largely in line with those derived from the willingness-to-pay approach.

The average health cost from PM_{10} for the eight Australian capital cities estimated by Coffey Geosciences (2003) was the highest ($232,000 per tonne) among the studies reviewed.

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[87] An estimate of the magnitude of the association between exposure and disease that indicates the likelihood of developing the disease among persons who are exposed relative to those who are not.

Unfortunately, the study did not make any distinction in the average health cost between inner and outer areas of major capital cities nor between large and small capital cities. This gap in knowledge can be partially filled by relying on an earlier study undertaken by Watkiss (2002).

Watkiss (2002) estimated air pollution costs in Australia by transferring European health cost estimates from the ExternE study[88], adjusted for the demographic characteristics of Australian urban areas. Based on European data, Watkiss (2002) estimated the relationship between average emission costs and population density and provided separate unit health cost estimates that vary according to population density. For conservative pollutants, costs per tonne emitted are proportional to population density, and for ozone precursors, costs per tonne are equal throughout the metropolitan areas of the capital cities and zero elsewhere.

Table 3 presents the detailed results from Watkiss (2002) for average health costs from air pollutants by area. For particles, which are the dominant source of health impact, the unit health cost estimate for major cities is roughly of the same order of magnitude ($217,415=[$341,650+$93,180]/2) as some other Australian studies such as Coffey (2003) and Beer (2002), although it can vary significantly within the major capital cities.

Table 3 Average health cost ($/tonne of emissions) by area

Emission Type	Band 1	Band 2	Band 3	Band 4
	Inner areas of large capital cities (Melbourne, Sydney, Brisbane, Adelaide and Perth)	Outer areas of large capital cities	Other urban areas (Canberra, Hobart and Darwin)	Non-urban areas
Particles	341,650	93,180	93,180	1,240
CO	3.0	0.8	0.8	0.0
NO_x	1,750	1,750	260	0
THC	875	875	175	0
SO_2	11,380	4,380	2,800	5,205
Benzene	2,425	660	660	0
1,3-butadiene	90,730	24,745	24,745	0

Source: Watkiss (2002).

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[88] The ExternE project was jointly funded by the Research Directorate of the European Commission and the United States Department of Energy. The costs from air pollution were estimated for a large number of sites across Europe, (covering 12 countries and almost 50 individual locations).The ExternE study used the ‘Impact Pathway” methodology, in which dispersion models and exposure-response functions are employed to estimate health impact. Mortality cost of air pollution was based on Value of Statistical Life (A$6m) but adjusted to reflect years of life lost (VLYL).

The validity of Watkiss results is highly dependent on the tenability of the assumption made about the same rates of background incidence for Europe and Australia. Watkiss (2002) argues that there are likely to be differences in the Australian population, especially with respect to health status, age, life expectancy, mortality and morbidity rates, as well as other factors (incidence of smoking, affluence, etc), that will mean different background rates of health effects occur relative to Europe.

Beer's (2002) estimates of unit health costs were based on estimates of the annual short-term health costs of the four criteria pollutants[89] published in National Environment Protection Measure for Ambient Air Quality and estimates of the contribution of vehicles to concentration of criteria pollutants. The implied unit value of life used in the Beer's analysis was \$7.2m. While the central health cost estimate for PM_{10} was \$147,429 per tonne, the upper bound of the Beer's estimates (\$221,100 per tonne) coincided with the mean estimates of Coffey Geosciences (2003) and Watkiss (2002).

BTRE (2005) adopted the European approach (Impact Pathway[90]) to quantify the economic costs of the health effects of transport-related air pollution in Australia. The total costs of motor vehicle-related PM_{10} pollution for Australian capital cities were estimated to be \$2.33b for the year 2000. Total PM_{10} emissions were estimated to be 13.9 kilotonnes per year.[91] These led to a unit health cost value of \$167,626 per tonne of PM_{10} emitted. The unit value of life used in BTRE (2005) was derived from the human capital approach and was relatively low (\$1.3m). Had BTRE (2005) used a higher unit value of life (like those derived from the willingness-to-pay approach), the reported unit health cost would have been higher than those estimated by Coffey (2003) or Watkiss (2002).

Unit health costs vary from location to location and according to population and meteorological factors (Coffey Geosciences 2003). For analysing the impact of the proposed new fuel standards on emissions (in terms of tonnes of pollutants emitted), the best disaggregation of the location we can have – given the available data – is to split the total emissions into those for capital cities and the rest of Australia. In order to calculate the total health benefit, estimates of unit health costs are required for each of the two areas concerned.

The procedure that was employed to estimate unit health cost values include the following steps:

- Only the three most recent studies listed in Table 2 (excluding BTRE (2005)) were selected as input for estimation, namely, Coffey Geosciences (2003), Watkiss (2002) and Beer (2002);
- Unit values for capital cities were calculated by taking the simple average of the estimates from the three studies;

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[89] These were CO, NO_x, NMHC and PM_{10}.

[90] See footnote 73.

[91] There are large uncertainties in measuring PM_{10} emissions from motor vehicles due to data limitations. This would affect the reliability of the estimated unit health cost values.

- Unit values for the rest of Australia were based on the simple average of the estimates for Band 3 and Band 4 contained in Watkiss (2002);
- Given the uncertainties surrounding around the unit value estimates, an upper bound and a lower bound were established (an average +/- 50%) on the basis of observations made by Coffey Geosciences (2003); and
- Unit values presented in Table 2 were assumed to be in 2003 prices. These values were updated to 2009 prices using the CPI.

Table 4 presents the recommended unit values for calculating the health benefit and undertaking sensitivity analyses.

Table 4 Updated average health cost ($/tonne of emissions) by area (in 2009 prices)

	HC	NO_x	PM_{10}
Central			
Capital cities	8,832	1,056	235,261
Rest of Australia	103	154	55,827
Upper bound + 50%			
Capital cities	13,248	1,584	352,891
Rest of Australia	155	231	83,740
Lower bound -50 %			
Capital cities	4,416	528	117,630
Rest of Australia	52	77	27,913

Source: Derived from the results from Coffey Geosciences (2003), Watkiss (2002) and Beer (2002).

Benefit–cost analysis

For the purpose of benefit–cost analysis, the base and price year is set to 2009 with the evaluation period extending to 2040. Following the recommendations in the *Best Practice Regulation Handbook* (OBPR 2007), the discount rate used to estimate the net present value is 7%, with sensitivity tests at 3 and 11%.

The key indicators for economic viability are Net Present Value (NPV) and Benefit–Cost Ratio (BCR).

Scenarios

Two regulatory options are analysed against the business-as-usual (BAU) case. These two options differ slightly in the timing of introduction.

BAU case

The following assumptions are made for the base case scenario.

- Oil prices remain at current levels ($60-70 US per barrel).
- Population grows according to the mid-range ‘Series B’ scenario values of the latest ABS population projections.
- Income grows in line with Treasury’s latest Budget statements for short term and their Inter-generational report for longer term.
- Average fleet travel behaviour remains roughly the same as now (e.g. cars average about 15000 km per annum), but with overall per capita travel approaching saturation levels with respect to average income levels (in line with BITRE’s projection report provided to Treasury last year – *Modelling the Road Transport Sector*).
- There will be no change to current vehicle or fuel standards.
- Diesel vehicles continue to increase their market share in line with current growth trends, so that they will dominate LCV sales by 2040. They are a major component of SUV sales, but still account for only a small proportion of sedan sales. By 2040, diesel vehicles are forecast to achieve an overall market share of about 36% of annual light vehicle sales.
- Mid-range deterioration rates are assumed for the emissions-reducing technology. Deterioration is slow, such that most vehicles are still within the standards after about 10 years. A small proportion of the fleet, growing with vehicle age, will be grossly polluting, accounting for vehicles with poor service records or malfunctioning emission control.

The BAU case lacks some of the details of the full CARMOD model. For example, over the time-scale considered, the fleet is expected to include a significant number of plug-in hybrids. To have them in the BAU case would mean analysing electricity supply emissions, which is an unnecessary complication for the purpose at hand. Hence, the number of plug-ins is set to zero.

Scenario 1 (S1)

Scenario 1 is the same as the BAU case, except that the new standards are introduced according to the schedule in Table 1.

Scenario 1A (S1A)

Scenario 1A is the same as for Scenario 1, except for the delayed introduction of the new standards, as show in Table 1.

Health benefits

Tables 5 and 6 present modelling results for reductions in pollutants emitted (’000 tonnes) and health benefits ($ millions) for scenarios S1 and S1A compared with the BAU case. It can be seen that the health impacts of the two options are very similar.

Table 5 Changes in emissions from the light vehicle fleet ('000 tonnes)

	HC		NO_x		PM_{10}	
Year	S1	S1A	S1	S1A	S1	S1A
2009	0.00	0.00	0.00	0.00	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00	0.00
2011	0.00	0.00	0.00	0.00	0.00	0.00
2012	-0.07	-0.02	-0.20	-0.11	-0.07	-0.07
2013	-0.22	-0.07	-0.86	-0.59	-0.23	-0.22
2014	-0.40	-0.20	-1.78	-1.43	-0.38	-0.38
2015	-0.58	-0.40	-2.71	-2.38	-0.55	-0.55
2016	-0.78	-0.60	-4.29	-3.97	-0.73	-0.73
2017	-1.01	-0.84	-6.38	-6.06	-0.92	-0.92
2018	-1.26	-1.09	-8.32	-8.01	-1.12	-1.12
2019	-1.53	-1.36	-10.30	-10.00	-1.34	-1.33
2020	-1.81	-1.65	-12.27	-11.98	-1.56	-1.55
2021	-2.09	-1.94	-14.24	-13.96	-1.78	-1.78
2022	-2.37	-2.23	-16.15	-15.89	-2.00	-2.00
2023	-2.64	-2.50	-18.03	-17.78	-2.22	-2.22
2024	-2.91	-2.78	-19.93	-19.69	-2.45	-2.45
2025	-3.18	-3.06	-21.83	-21.61	-2.68	-2.68
2026	-3.45	-3.33	-23.72	-23.52	-2.91	-2.91
2027	-3.70	-3.59	-25.54	-25.35	-3.14	-3.14
2028	-3.93	-3.84	-27.29	-27.12	-3.35	-3.35
2029	-4.15	-4.07	-28.95	-28.80	-3.56	-3.56
2030	-4.36	-4.29	-30.52	-30.39	-3.75	-3.75
2031	-4.56	-4.50	-32.00	-31.88	-3.94	-3.94
2032	-4.75	-4.69	-33.39	-33.28	-4.12	-4.12
2033	-4.94	-4.89	-34.79	-34.69	-4.30	-4.30
2034	-5.08	-5.07	-35.95	-35.91	-4.45	-4.45
2035	-5.22	-5.20	-37.03	-37.00	-4.59	-4.59
2036	-5.36	-5.34	-38.10	-38.07	-4.74	-4.74
2037	-5.49	-5.47	-39.03	-39.00	-4.88	-4.88
2038	-5.60	-5.59	-39.87	-39.85	-5.00	-5.00
2039	-5.72	-5.71	-40.79	-40.76	-5.14	-5.14
2040	-5.83	-5.82	-41.61	-41.59	-5.26	-5.26

Note: *Reduction from the BAU scenario. Negative values imply reduction in emissions.*

Source: *BITRE estimates.*

Table 6 Health benefits ($ millions)

	HC		NO$_x$		PM$_{10}$		Total	
Year	S1	S1A	S1	S1A	S1	S1A	S1	S1A
2009	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0
2010	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0
2011	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0
2012	-0.44	-0.10	-0.15	-0.08	-12.11	-12.08	-12.7	-12.3
2013	-1.39	-0.41	-0.62	-0.42	-36.45	-36.40	-38.5	-37.2
2014	-2.48	-1.24	-1.29	-1.02	-62.43	-62.34	-66.2	-64.6
2015	-3.60	-2.45	-1.94	-1.70	-89.89	-89.77	-95.4	-93.9
2016	-4.84	-3.71	-3.05	-2.81	-119.40	-119.25	-127.3	-125.8
2017	-6.29	-5.18	-4.49	-4.25	-151.18	-151.01	-162.0	-160.4
2018	-7.84	-6.76	-5.81	-5.58	-185.29	-185.10	-198.9	-197.4
2019	-9.55	-8.49	-7.15	-6.93	-221.50	-221.29	-238.2	-236.7
2020	-11.33	-10.31	-8.47	-8.26	-258.92	-258.71	-278.7	-277.3
2021	-13.10	-12.12	-9.77	-9.57	-297.24	-297.03	-320.1	-318.7
2022	-14.81	-13.88	-11.01	-10.83	-334.24	-334.02	-360.1	-358.7
2023	-16.48	-15.59	-12.21	-12.03	-370.96	-370.74	-399.7	-398.4
2024	-18.24	-17.39	-13.43	-13.26	-410.89	-410.67	-442.6	-441.3
2025	-19.96	-19.16	-14.71	-14.55	-451.01	-450.80	-485.7	-484.5
2026	-21.63	-20.90	-16.01	-15.86	-490.82	-490.61	-528.5	-527.4
2027	-23.22	-22.54	-17.25	-17.11	-529.06	-528.87	-569.5	-568.5
2028	-24.71	-24.11	-18.44	-18.32	-565.97	-565.79	-609.1	-608.2
2029	-26.13	-25.60	-19.58	-19.47	-601.52	-601.36	-647.2	-646.4
2030	-27.45	-26.99	-20.66	-20.56	-635.34	-635.20	-683.4	-682.8
2031	-28.69	-28.29	-21.67	-21.59	-667.32	-667.19	-717.7	-717.1
2032	-29.88	-29.50	-22.62	-22.55	-697.52	-697.40	-750.0	-749.5
2033	-31.14	-30.79	-23.62	-23.54	-730.03	-729.88	-784.8	-784.2
2034	-32.06	-31.94	-24.41	-24.39	-755.89	-755.84	-812.4	-812.2
2035	-32.92	-32.81	-25.16	-25.14	-780.59	-780.54	-838.7	-838.5
2036	-33.82	-33.72	-25.92	-25.89	-806.74	-806.70	-866.5	-866.3
2037	-34.65	-34.56	-26.57	-26.55	-831.31	-831.27	-892.5	-892.4
2038	-35.36	-35.28	-27.16	-27.14	-852.21	-852.17	-914.7	-914.6
2039	-36.21	-36.14	-27.82	-27.81	-877.27	-877.24	-941.3	-941.2
2040	-36.92	-36.85	-28.41	-28.39	-898.42	-898.39	-963.7	-963.6

Note: Reduction from the BAU scenario. Negative values imply savings in health cost.

Source: BITRE estimates.

Implementation costs

The cost estimates for vehicle emission control technologies (Table 7) were sourced from European studies (CEC 2005 and EC 2006). These European estimates were converted to Australian-dollar estimates using the average exchange rate over the past few years.

Table 7 Incremental vehicle costs (Euro/vehicle)

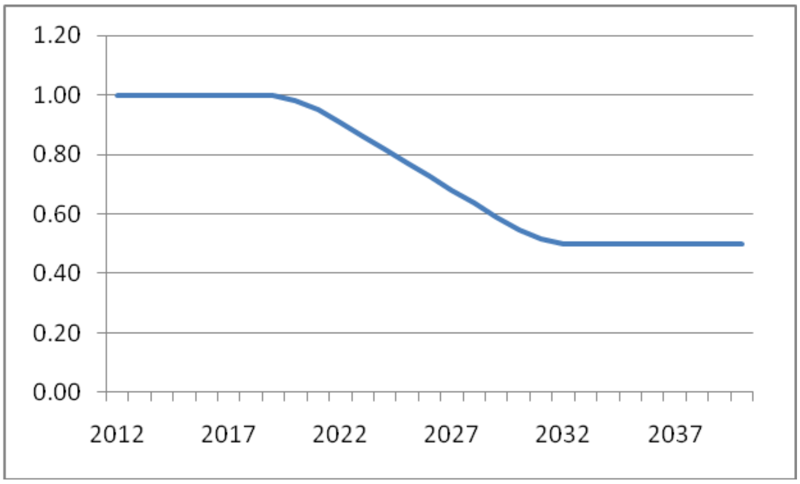
	Euro		A$		
	Euro 4 to Euro 5	Euro 5 to Euro 6	Euro 4 to Euro 5	Euro 5 to Euro 6	Euro 4 to Euro 6
Petrol vehicle	51	0	85	0	85
Diesel vehicle	377	213	628	355	983

Note: A$1=Euro0.60.

Source: CEC(2005) and EC (2006).

In estimating the additional unit vehicle cost over time, it was assumed that incremental vehicle technology costs (reported in Table 7) decline as the market expands for the new technology. The assumed cost adjustment process follows the path shown in Figure 2, that is, the additional unit vehicle costs are kept constant to 2020, then drop by half by 2030 and remain at that level after 2030. The adjusted additional per vehicle cost for petrol (P1) and diesel (D1) vehicles are shown in Figure 3.

Figure 2 Assumed cost adjustment path

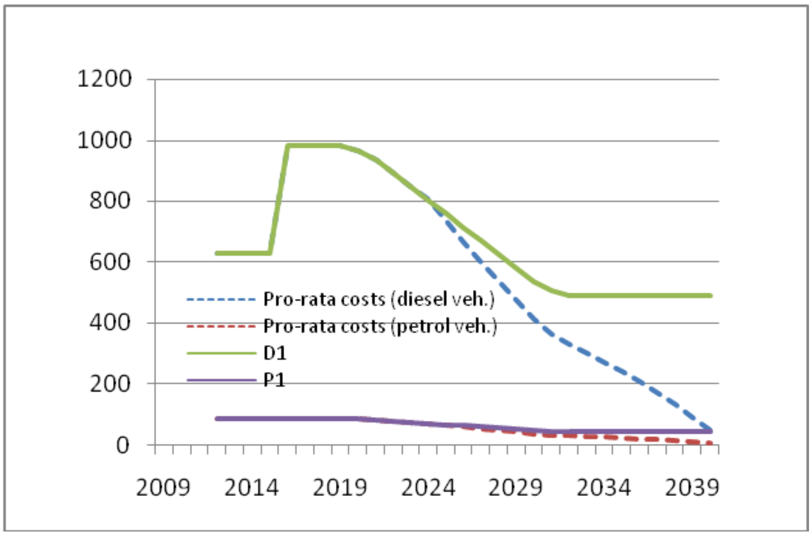


Emissions-reducing technology on vehicles purchased during the latter part of the evaluation period 2009 to 2040 will continue to generate benefits the end of the evaluation period in 2040. In benefit–cost analyses, where assets generate benefits beyond the evaluation period, the usual approach is to estimate the benefits from those assets over their entire lives and to include, as a 'residual value', the present value of benefits that accrue after the end of the evaluation period. For the present application, such an approach would entail a heavy calculation burden. Since the benefits from emission-reducing technology are fairly constant over the lives of the vehicles, a good approximation is obtained by prorating the cost of the technology over the lives of the vehicles, then only counting costs attributed to years before 2041.

The average vehicle life was assumed to be 17 years. For vehicles purchased during the last 16 years of the evaluation period, the cost of the emissions-reducing technology was annuitised over 17 years at the discount rate. The annual costs for years before 2041 were discounted to the present as implementation costs. Annual costs for years 2041 onward were omitted, consistent with the benefits for years 2041 onward being absent.

The 'pro-rata' curves in Figure 3 (P1 and D1) show the effects on costs per vehicle of excluding annualised costs after 2040 of emissions-reducing technology for vehicles purchased over the last the last 16 years of the evaluation period. The pro-rata curves approach zero by the end of the period, with vehicles purchased in 2040 having only one year of cost included.

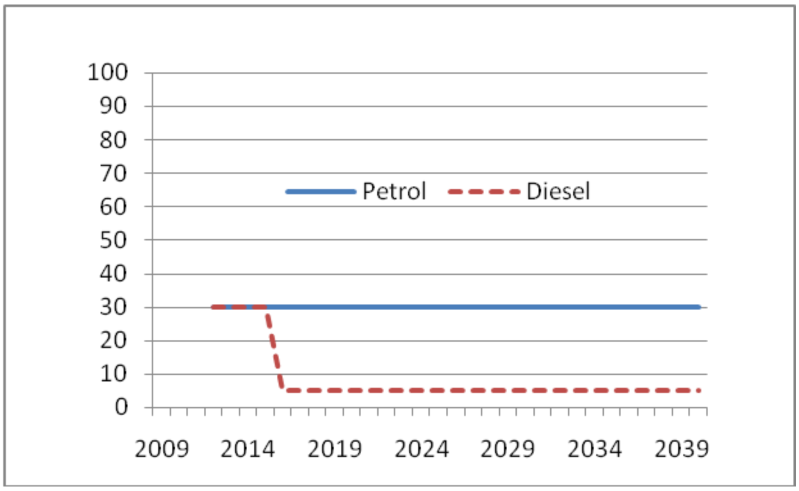
Figure 3 Additional Vehicle Cost Estimates (A$/vehicle)



In estimating the total implementation costs, two further assumptions were made. First, it was assumed that around half of the vehicles sold in the introduction year of each standard would meet the standard's requirements (i.e. either not from a 'new' model line, and therefore initially exempt, or a model already having emissions below the new standard), so only 50% of the new sales would attract an additional cost. Second, it was assumed for all other years that some proportion of new vehicles would have met the lower emission level even without the new standards implementation. For petrol vehicles, the proportion was set to 30% throughout the evaluation period. For diesel vehicles, the proportion was set to 30% when moving from Euro 4 to Euro 5 standards and to 5% from Euro 5 to Euro 6 standards (Figure 4).

The benefits from the lower emissions of these vehicles were not included in the benefits of introducing the new standards because these benefits accrue regardless.

Figure 4 **Proportion of new vehicles already complying with the new standards (%)**



Net economic benefits and BCR

Table 8 reports the BCA results for S1 and S1A. Both options are economically viable.

Table 8 Summary of costs and benefits (S1)

	Undiscounted Cash Flow ($m, in 2009 prices)			Discounting Factor	Discounted Cash Flow ($m) ($m, in 2009 prices)		
	Cost	Benefit	Net benefit	(7%)	Cost	Benefit	Net benefit
2009	0.0	0.0	0.0	1.0000	0.0	0.0	0.0
2010	0.0	0.0	0.0	0.9346	0.0	0.0	0.0
2011	0.0	0.0	0.0	0.8734	0.0	0.0	0.0
2012	-79.1	12.7	-66.4	0.8163	-64.6	10.4	-54.2
2013	-162.7	38.5	-124.2	0.7629	-124.1	29.3	-94.8
2014	-167.6	66.2	-101.4	0.7130	-119.5	47.2	-72.3
2015	-172.5	95.4	-77.1	0.6663	-114.9	63.6	-51.3
2016	-185.4	127.3	-58.1	0.6227	-115.5	79.3	-36.2
2017	-336.2	162.0	-174.3	0.5820	-195.7	94.3	-101.4
2018	-347.2	198.9	-148.3	0.5439	-188.9	108.2	-80.7
2019	-357.6	238.2	-119.4	0.5083	-181.8	121.1	-60.7
2020	-362.8	278.7	-84.1	0.4751	-172.4	132.4	-40.0
2021	-360.0	320.1	-39.9	0.4440	-159.8	142.1	-17.7
2022	-350.7	360.1	9.4	0.4150	-145.5	149.4	3.9
2023	-340.8	399.7	58.8	0.3878	-132.2	155.0	22.8
2024	-330.4	442.6	112.2	0.3624	-119.7	160.4	40.7
2025	-308.7	485.7	177.0	0.3387	-104.6	164.5	60.0
2026	-285.6	528.5	242.9	0.3166	-90.4	167.3	76.9
2027	-261.5	569.5	308.0	0.2959	-77.4	168.5	91.1
2028	-236.7	609.1	372.4	0.2765	-65.5	168.4	103.0
2029	-211.4	647.2	435.8	0.2584	-54.6	167.3	112.6
2030	-186.3	683.4	497.2	0.2415	-45.0	165.1	120.1
2031	-166.2	717.7	551.4	0.2257	-37.5	162.0	124.5
2032	-151.0	750.0	599.0	0.2109	-31.9	158.2	126.4
2033	-139.6	784.8	645.2	0.1971	-27.5	154.7	127.2
2034	-127.0	812.4	685.4	0.1842	-23.4	149.7	126.3
2035	-113.1	838.7	725.5	0.1722	-19.5	144.4	124.9
2036	-98.1	866.5	768.4	0.1609	-15.8	139.4	123.7
2037	-81.6	892.5	810.9	0.1504	-12.3	134.2	122.0
2038	-63.7	914.7	851.0	0.1406	-9.0	128.6	119.6
2039	-44.2	941.3	897.1	0.1314	-5.8	123.7	117.8
2040	-23.0	963.7	940.7	0.1228	-2.8	118.3	115.5
Total	**-6,050.9**	**14,746.1**	**8,695.2**		**-2,457.5**	**3,707.0**	**1,249.5**
Benefit–cost Ratio =			**1.51**	**NPV =**			**1,250**

(S1A)

	Undiscounted Cash Flow ($m, in 2009 prices)			Discounting Factor	Discounted Cash Flow ($m) ($m, in 2009 prices)		
	Cost	Benefit	Net benefit	(7%)	Cost	Benefit	Net benefit
2009	0.0	0.0	0.0	1.0000	0.0	0.0	0.0
2010	0.0	0.0	0.0	0.9346	0.0	0.0	0.0
2011	0.0	0.0	0.0	0.8734	0.0	0.0	0.0
2012	-56.4	12.3	-44.2	0.8163	-46.1	10.0	-36.1
2013	-140.0	37.2	-102.8	0.7629	-106.8	28.4	-78.4
2014	-167.6	64.6	-103.0	0.7130	-119.5	46.1	-73.5
2015	-172.5	93.9	-78.6	0.6663	-114.9	62.6	-52.4
2016	-185.4	125.8	-59.7	0.6227	-115.5	78.3	-37.2
2017	-336.2	160.4	-175.8	0.5820	-195.7	93.4	-102.3
2018	-347.2	197.4	-149.8	0.5439	-188.9	107.4	-81.5
2019	-357.6	236.7	-120.9	0.5083	-181.8	120.3	-61.5
2020	-362.8	277.3	-85.6	0.4751	-172.4	131.7	-40.6
2021	-360.0	318.7	-41.3	0.4440	-159.8	141.5	-18.3
2022	-350.7	358.7	8.0	0.4150	-145.5	148.9	3.3
2023	-340.8	398.4	57.5	0.3878	-132.2	154.5	22.3
2024	-330.4	441.3	111.0	0.3624	-119.7	160.0	40.2
2025	-308.7	484.5	175.9	0.3387	-104.6	164.1	59.6
2026	-285.6	527.4	241.8	0.3166	-90.4	167.0	76.5
2027	-261.5	568.5	307.0	0.2959	-77.4	168.2	90.8
2028	-236.7	608.2	371.5	0.2765	-65.5	168.2	102.7
2029	-211.4	646.4	435.0	0.2584	-54.6	167.0	112.4
2030	-186.3	682.8	496.5	0.2415	-45.0	164.9	119.9
2031	-166.2	717.1	550.8	0.2257	-37.5	161.9	124.3
2032	-151.0	749.5	598.5	0.2109	-31.9	158.1	126.2
2033	-139.6	784.2	644.6	0.1971	-27.5	154.6	127.1
2034	-127.0	812.2	685.2	0.1842	-23.4	149.6	126.3
2035	-113.1	838.5	725.4	0.1722	-19.5	144.4	124.9
2036	-98.1	866.3	768.3	0.1609	-15.8	139.4	123.6
2037	-81.6	892.4	810.8	0.1504	-12.3	134.2	121.9
2038	-63.7	914.6	850.9	0.1406	-9.0	128.6	119.6
2039	-44.2	941.2	897.0	0.1314	-5.8	123.6	117.8
2040	-23.0	963.6	940.6	0.1228	-2.8	118.3	115.5
Total	**-6,005.5**	**14,720.1**	**8,714.5**		**-2,421.7**	**3,695.1**	**1,273.5**
Benefit–cost Ratio =			**1.53**	**NPV =**			**1,274**

Sensitivity tests

Given that the S1 and S1A results are so similar (especially over the longer term), sensitivity testing was done only for S1.

Changes to the base case

The first set of sensitivity tests (ST1) is for diesel penetration. The ‘low’ case has new sales remaining roughly at their current proportion of total sales (and are thus only about 17% of 2040 sales) and the ‘high’ case has strong increases in diesel vehicles sales (with the result that about half of 2040 car sales, and most of LCV sales, are diesels).

The second set of sensitivity tests (ST2) is for durability of the emission-reducing technology. The ‘low’ case has the deterioration rates set to zero for all post-2010 models, and the ‘high’ case has the default parameter values doubled for all post-2010 models.

If the changed deterioration rates applied only to the Euro 5 and 6 technology, the zero deterioration assumption would lead to higher benefits (the ‘high’ case), and conversely for doubling the deterioration rate parameter (the ‘low’ case). However, the changes to the deteriorate rate parameter are applied to the BAU case as well as the ‘new standards’ case, and they affect the BAU results more than they affect the ‘new standards’ results. Consequently, the savings in emissions are lower for the sensitivity run with zero deterioration (making it the ‘low’ case) and greater for the run that doubles the deterioration rate (making it the ‘high’ case).[92]

The results of sensitivity tests for ST1 and ST2 are presented in Table 9. It appears that the results are more sensitive to the changes in the second set of assumptions.

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[92] When the changes to the deterioration rate parameters are applied to the ‘new standards’ case only, zero deterioration becomes the ‘high’ case with a BCR of 1.97, and double deterioration becomes the ‘low’ case with a BCR of 1.06.

Table 9 Changes to the base case

	Net Present Values ($m)	Benefit–cost Ratio
Main Base Case	1,250	1.51
ST1		
Low	857	1.47
High	1,331	1.52
ST2		
Low	476	1.19
High	2,037	1.83

Changes to unit health cost values

Under the unlikely scenario where mean unit health cost values have to be reduced by 50%, the NPV becomes negative.

Table 10 Changes to Unit Health Cost Values

	Net Present Values ($m)	Benefit–cost Ratio
Mean	1,250	1.51
Low (– 50%)	– 604	0.75
High (+ 50%)	3,103	2.26

Changes to implementation costs

There are uncertainties in the assumed cost adjustment process illustrated in Figure 2. An alternative assumption tested is to assume no downward cost adjustment over time. The result of the testing is presented in Table 11. As seen, even with this very conservative assumption, the NPV still remains positive.

Table 11 Changes to Implementation Costs

	Net Present Values ($m)	Benefit–cost Ratio
Mean	1,250	1.51
High Cost (no downward cost adjustment)	780	1.27

Changes to discount rates

The results of sensitivity testing in relation to the discount rates are shown in Table 12. With a discount rate of 3% (preferred by BITRE), BCR reaches a value of 2.0.

Table 12 Changes to Discount Rates

	Net Present Values ($m)	Benefit–cost Ratio
Mean (7%)	1,250	1.51
Low (3%)	3,964	2.02
High (11%)	300	1.18

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