Australian Government

Vehicle emissions standards for cleaner air

Draft Regulation Impact Statement

December 2016

Department of Infrastructure and Regional Development

Contents

Executive Summary

Noxious emissions from road vehicles–including oxides of nitrogen and sulfur (NOx and SOx), particulate matter (PM), hydrocarbons (HC), and carbon monoxide (CO)–impact on the quality of the air we breathe, leading to harmful health effects such as respiratory illness, cardiovascular disease and cancer.

Over the period 2005 to 2010, Australia is estimated to have experienced a 68 per cent increase in deaths attributable to air pollution to a total of 1,483 in 2010. In OECD countries, it is suggested that road transport accounts for approximately half of the cost of these preventable deaths[1].

The pattern and scale of urban development in Australian cities, and the associated increase in vehicle use, is placing increasing pressure on the challenge to maintain improvements in urban air quality. Vehicle emissions standards both in Australia and internationally have proven to be a cost-effective measure to reduce urban air pollution from the road transport sector.

This Early Assessment Regulation Impact Statement (RIS) examines the need for Australian Government action to improve urban air quality and reduce the adverse impacts of urban air pollution on human health by introducing more stringent noxious emissions standards for light and heavy road vehicles.

When considering the introduction of more stringent emissions standards, the Australian Government has a policy of harmonising the national standards for road vehicles–the Australian Design Rules (ADRs)–with international regulations adopted by the United Nations (UN) World Forum for the Harmonization of Vehicle Regulations (WP.29). The ADRs are legislative instruments under the *Motor Vehicle Standards Act 1989* (MVSA). Harmonisation with international standards facilitates trade and minimises compliance costs by providing a standardised system of vehicle certification. Keeping Australia's standards in line with international best practice also ensures a high level of safety and environmental performance. Furthermore, if local standards do not keep pace with international trends, Australia risks foregoing the benefits of technology available in other developed countries. The current UN regulations for noxious emissions for light and heavy vehicles are based on the 'Euro' standards adopted in the European Union (EU).

Light Vehicle Noxious Emissions Standards

For light vehicles, Australia has mandated Euro 5 emissions standards for newly approved models first manufactured from 1 November 2013, and for all light vehicles manufactured from 1 November 2016. The more stringent Euro 6 emissions standards for light vehicles commenced in the EU from September 2014 and equivalent standards are currently in force in most developed countries, including the US and Japan.

The key changes under Euro 6 are: a 55 per cent reduction in the emission limits for NOx for light diesel vehicles; a particle number limit to reduce fine particle emissions from direct injection petrol vehicles; and tighter thresholds and monitoring requirements for on-board diagnostic systems that monitor the performance of emission control systems. The next phase of the Euro 6 standards (initial 'Euro 6d'), commencing in the EU in September 2017, will introduce further changes to improve the integrity of the testing regime. The key change will be the replacement of the current drive cycle testing regime with the new Worldwide harmonised Light vehicle Test Procedure (WLTP) and the introduction of an on-road Real Driving Emissions (RDE) test. Consideration of Euro 6 for light vehicles in Australia will be based on the 2017 Euro 6 requirements, as this stage will have the greatest health benefits.

Heavy Vehicle Noxious Emissions Standards

For heavy vehicles, Australia mandated the Euro V emissions standards for all heavy vehicles manufactured from 1 January 2011. Euro VI emissions standards for heavy vehicles commenced in the EU from the end of 2012 and equivalent standards apply in most other developed countries.

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[1] OECD (2014), *The Cost of Air Pollution: Health Impacts of Road Transport*, OECD Publishing, Paris

The main changes under Euro VI compared with Euro V are an 80 per cent reduction in emission limits for NOx emissions, a reduction in emission limits for PM by up to 66 per cent, and the adoption of a more robust testing regime.

Options Explored

Within this RIS a total of six options, including both regulatory and non-regulatory, were explored:

- Option 1–Business as usual;
- Option 2–Fleet purchasing policies;
- Option 3–Voluntary standards;
- Option 4–Mandate Euro 6 for light vehicles under the *Motor Vehicle Standards Act 1989*;
- Option 5–Mandate Euro VI for heavy vehicles under the *Motor Vehicle Standards Act 1989*; and
- Option 6–Mandate both Euro 6 for light vehicles and Euro VI for heavy vehicles under the *Motor Vehicle Standards Act 1989*.

Following a qualitative assessment of the options, options 1, 4, 5 and 6 were considered viable.

Options 2 and 3 were not considered viable for a number of reasons. Option 2 proposed that the Australian Government require vehicles to meet Euro 6/VI or equivalent standards to be eligible to be purchased for use in its fleet. However, as the Australian Government fleet makes up less than one per cent of new vehicle sales, any benefits to the community from adopting requirements in this fleet alone would be insignificant. Option 3 proposed that the Australian Government establish voluntary noxious emissions standards through agreements with peak industry bodies. However, if voluntary standards were adopted, there could be no certainty of requirements being met. Further, if non-compliances are detected, unlike for mandatory standards (where mandatory recall provisions and fines for non-compliance apply under law), the Australian Government would be unable to force manufacturers to fix underperforming vehicles.

Cost-Benefit Analysis

Quantitative benefit-cost analyses were carried out for the viable options.

There are no benefits or costs associated with option 1 as this is the ‘do nothing’ approach.

The benefit-cost analysis of option 4–mandating Euro 6 for light vehicles–estimated a net benefit of $411 million over the period from 2016 to 2040. The analysis was based on an implementation period of 2019 for new light vehicle models and 2020 for all light vehicles. Costs of introducing Euro 6 were assessed on the basis of capital costs, and benefits on the basis of avoided health costs.

The benefit-cost analysis of option 5–mandating Euro VI standards for heavy vehicles–estimated a net benefit of $264 million over the period 2016 to 2040. The analysis was again based on an implementation period of 2019 for new heavy vehicle models and 2020 for all new heavy vehicles. Costs of introducing Euro VI were assessed on the basis of capital costs, fuel costs, urea/diesel exhaust fluid costs, productivity losses, and greenhouse gas emissions, and benefits were assessed on the basis of avoided health costs.

The benefit-cost analysis of option 6–mandating both Euro 6 and Euro VI for light and heavy vehicles–estimated a net benefit of $675 million over the period 2016 to 2040.

The benefit-cost analyses were undertaken by the Department of Infrastructure and Regional Development’s (the Department) Bureau of Infrastructure, Transport and Regional Economics (BITRE). The Department engaged an independent consultant specialising in economics to review the methodology and assumptions underpinning this work. The results of this review confirmed that the analyses aligned with the benefit-cost analysis guidelines established by the Office of Best Practice Regulation (OBPR).

Fuel Quality

A key issue that has been highlighted through stakeholder consultations is whether Australian petrol is of an appropriate quality–in terms of sulfur content–to support the implementation of Euro

6. Currently, the maximum level of sulfur permitted in petrol in Australia is 150 parts per million (ppm) for ‘regular’ unleaded petrol (ULP) and 50 ppm for ‘premium’ unleaded petrol (PULP). By comparison, the EU, Japan and US (which have implemented Euro 6 or equivalent standards) already have, or are planning to transition to, 10 ppm sulfur fuel.

Light vehicle manufacturers consider low sulfur petrol necessary to ensure the benefits of Euro 6 are realised on road. The Australian refining industry, through the Australian Institute of Petroleum (AIP), argues that the average sulfur content in Australian petrol is well below regulated levels and would be sufficient to support the implementation of Euro 6, citing 2014-15 average levels of 16 ppm for PULP and 28 ppm for ULP in Sydney, and 26ppm for PULP and 60 ppm for ULP in Melbourne. They further claim that mandating low sulfur petrol would threaten the economic viability of Australian refineries.

The Department engaged an independent consultant to undertake research to provide clarity on this issue. Results suggest that while 10 ppm sulfur or less is ideal, petrol with sulfur content of less than 30 ppm is unlikely to affect the ability of vehicles to meet Euro 6 requirements over the required durability period of 160,000 km. Results also suggest that there is lack of available and credible information internationally on the effects of sulfur between 30 and 50 ppm, but there is evidence that 50 ppm or higher will most likely be problematic for modern emissions control systems.

The benefit-cost analysis for Euro 6 made a number of assumptions about the level of sulfur in Australian petrol. Firstly, it assumed that there would be no change to current fuel standards. Secondly it assumed that current actual levels of sulfur in petrol (at a national average of about 30 ppm for PULP and 70 ppm for ULP) are in line with those advised by the AIP. Thirdly it assumed that over the analysis period there would be an increase in the proportion of vehicles using PULP (along with a gradual decrease in the level of sulfur in both ULP and PULP), leading to an average sulfur level of well below 30 ppm across all sales by 2040.

The modelling made allowances for some deterioration of the vehicle emissions control systems, in part because of the higher than 10 ppm sulfur levels in Australian petrol. BITRE has noted that if the sulfur content was limited to 10 ppm, under the current modelling formulation, projected emissions volumes (of vehicle pollutants controlled by catalytic converters, such as NOx, CO and HC) would reduce on average by around 5–10 per cent (which is likely to be a conservative estimate).

In parallel with this work, the Department of the Environment and Energy is currently undertaking a review of the individual fuel standards under the *Fuel Quality Standards Act 2000*, including consideration of reducing the maximum allowable sulfur content in Australian petrol. Any further noxious emissions reductions that might be obtained from introducing Euro 6 with mandated low sulfur fuel will be captured through this review.

In line with the principles for Australian Government policy makers, the regulatory costs imposed on business, the community and individuals associated with each viable option were quantified. These have been agreed by the OBPR.

Introduction

On 31 October 2015, the Australian Government established a Ministerial Forum to coordinate a whole-of-government approach to addressing emissions from motor vehicles.

The terms of reference for the Ministerial Forum cover:

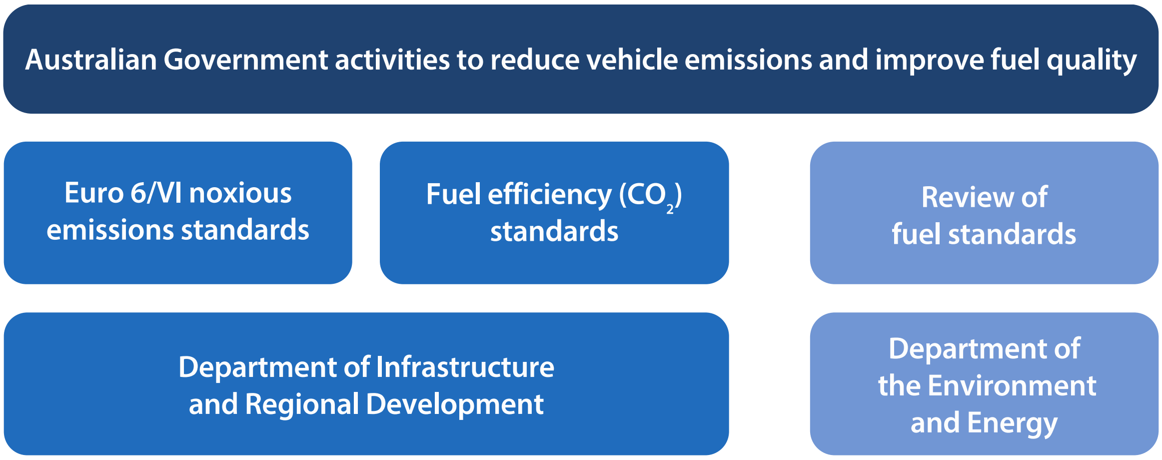
- implementation of Euro 6 or equivalent standards for new vehicles;
- fuel efficiency (CO_2) measures for new light vehicles;
- fuel quality standards;
- emissions testing arrangements for vehicles in conjunction with international regulatory agencies to ensure robust testing;
- Australian Government measures under the National Clean Air Agreement (NCAA);
- Emissions Reduction Fund and Safeguard Mechanism–transport measures;
- future infrastructure to support new vehicles, including funding available through the Clean Energy Finance Corporation and Australian Renewable Energy Agency; and
- National Energy Productivity Plan.

On 11 February 2016, the Ministerial Forum released a discussion paper seeking feedback on possible measures that could be adopted to reduce Australia's vehicle emissions. The paper closed for comment on 8 April 2016 and 80 submissions were received from a range of stakeholders, including vehicle manufacturers, fuel companies, consumer groups, health and environment groups, and private individuals.

The paper explored issues associated with the implementation of more stringent standards for noxious emissions (Euro 6 for light vehicles and Euro VI for heavy vehicles), and a standards regime for fuel efficiency for light vehicles to reduce carbon dioxide emissions. Also considered were complementary or stand-alone measures to address vehicle emissions. The paper specifically foreshadowed the development of this RIS.

This RIS forms part of a comprehensive package of activities currently being undertaken to deal with emissions from road vehicles. The Department of Infrastructure and Regional Development (the Department) is responsible for considering the proposed introduction of Euro 6/VI vehicle emission standards for light and heavy vehicles, and fuel efficiency standards for light vehicles. The Department of the Environment and Energy is leading a separate review of Australia's fuel quality standards.

Figure 1: Current vehicle emissions reduction activities



This RIS follows the Australian Government RIS requirements for an Early Assessment RIS, addressing fully the first four questions as set out in the Australian Government Guide to Regulation[2]:

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[2] Australian Government (2014) *The Australian Government Guide to Regulation*, available at: <https://www.cuttingredtape.gov.au/handbook/australian-government-guide-regulation>

1. What is the problem you are trying to solve?
2. Why is government action needed?
3. What policy options are you considering?
4. What is the likely net benefit of each option?

The consultation plan outlined in Section 5 addresses the fifth question:

5. Who will you consult and how will you consult them?

This RIS will be released for public comment to enable stakeholders to respond to the options presented. The final RIS will be prepared following consideration of this feedback and will address the last two questions:

6. What is the best option from those you have considered?
7. How will you implement and evaluate your chosen option?

Your Comments

Comments on this RIS are requested by 10 March 2017 and should be submitted by email as a separate word or pdf document to vemissions@infrastructure.gov.au, or posted to:

Vehicle Emissions Working Group
Department of Infrastructure and Regional Development
GPO Box 594
CANBERRA ACT 2601

All submissions received will be published on the Department's website unless a specific request for confidentiality is made. In this case, please indicate which parts of your submission you wish to keep confidential (including your identity, if you wish to remain anonymous). To protect the privacy of individuals making submissions, personal contact details will not be published.

1 What is the Problem?

1.1 Introduction

Air pollutants can have a significant impact on human health, especially on the cardio-respiratory system. Individuals with pre-existing respiratory conditions, such as asthma and allergies, are especially vulnerable to air pollutants. The effects on human health can include reduced lung function, heart disease, stroke, respiratory illnesses, and lung cancer[3].

In economic terms, health impacts are hard to quantify, but studies suggest they may be substantial[4]. Over the period between 2005 and 2010, Australia is estimated to have experienced a 68 per cent increase in deaths attributable to air pollution to a total of 1,483 in 2010. In OECD countries, it is suggested that road transport accounts for approximately half of the cost of these preventable deaths[5].

Air pollutants from motor vehicles are particularly harmful for human health as the general population has a higher level of exposure to motor vehicle exhaust emissions than most other pollutant sources[6]. The air pollutants of greatest concern produced by motor vehicle exhaust emissions are particulate matter (PM), especially fine and ultrafine particles. Oxides of nitrogen (NOx), and sulfur (SOx) and ground level ozone–an indicator of photochemical smog–are also detrimental to human health. Motor vehicles are a major contributor to these pollutants in urban airsheds, and their emissions are increasing as vehicle usage continues to rise as a result of economic and population growth.

Emissions of PM are of increasing concern amongst health researchers, with linkages between adverse health effects and particulate exposure being demonstrated at increasingly lower levels of particulates in the atmosphere. These associations are observed even when air pollutant concentrations are below national standards. Recent research suggests the risks of cardiovascular effects may be particularly great for exposure to fine (<2.5μm) and ultrafine (<0.1μm) exhaust particles[7]. A 2013 study into the public risk of exposure to air pollutants found that long term population exposure to particulate matter alone is attributable to nine per cent of all deaths due to ischemic heart disease in Australia's four largest cities[8].

The current consensus is that there is no safe level of exposure to particulates and that any reduction in particle concentrations would improve population health outcomes[9,10,11,12]. In

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3 International Agency for Research on Cancer, World Health Organisation (2013), *Air Pollution and Cancer*, editors, K. Straif, A. Cohen, J. Samet (IARC Scientific Publications; 161)

4 Air Pollution Economics. *Health Costs of Air Pollution in the Greater Sydney Metropolitan Region*, The NSW Department of Environment and Conservation 2005

5 OECD (2014), *The Cost of Air Pollution: Health Impacts of Road Transport (Summary)*, OECD Publishing, Paris

6 Department of the Environment, National Pollutant Inventory

7 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.

8 Golder Associates (2013) Exposure Assessment and Risk Characterisation to Inform Recommendations for Updating Ambient Air Quality Standards for PM2.5, PM10, O3, NO2 SO

9 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.

10 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*

June 2012, the International Agency for Research on Cancer, within the World Health Organisation, declared that diesel exhaust is a 'known carcinogen', with a special emphasis on particulates[13]. The same report also declared that PM itself is a carcinogenic substance. It should be noted that petrol engines also emit PM, but generally to a lesser extent.

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 adverse health effects, especially when some members of a population are sensitive even at very low concentrations[14].

There are also strong associations between levels of NOx and daily mortality, hospital admissions for asthma, chronic obstructive pulmonary disease and heart disease. NOx can also contribute to the formation of secondary particulate matter in the form of nitrates, which are also detrimental to human health.

1.2 Air Quality in Australia's Urban Environment

In a global context, Australia has comparatively clean air on average, but dense urban areas frequently experience periods of poor air quality. Some pollutants, including ground level ozone and PM–both products of vehicle emissions–exceed current air quality standards on occasion. This is especially the case in urban areas with high volumes of traffic. The levels of benzene near major roads, for example, have been shown to be high, particularly when traffic is congested[15]. Population growth, urbanisation and increasing demands for transport services all contribute to increasing levels of ambient air pollution in urban air sheds.

Almost 90 per cent of Australia's population live in an urban environment. In 1990, 14.5 million Australians lived in an urban area. By 2014 this number had increased to 21 million and continues to rise, exposing more Australians to the risks associated with ambient air pollution[16].

1.3 Contribution of Road Vehicles to Air Pollution

Motor vehicles are one of the major emitters of air pollutants in urban Australia, and are estimated to contribute 60-70 per cent of NOx emissions and up to 40 per cent of HC emissions[17]. Between 2010 and 2015, the vehicle fleet in Australia grew at an average annual rate of 2.4 per cent[18], making vehicles a growing source of air pollution.

Light diesel vehicles, while currently constituting 16 per cent of the vehicle fleet in Australia, tend to emit NOx at a higher rate per vehicle relative to petrol vehicles (and are permitted to do so under current standards).

Heavy vehicles (vehicles over 3.5 tonnes) constitute approximately four per cent of the vehicle fleet in Australia, but contribute approximately 25 per cent of transport related emissions. The heavy vehicle fleet performs about eight per cent of all vehicle kilometres travelled (VKT), and accounts

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particulate matter and mortality within the APHEA multicity project, Journal Environmental Health Perspectives, 113:88-95.

11 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.

12 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.

13 International Agency for Research on Cancer, World Health Organisation (2012), Press Release No. 213, 12 June 2012

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

15 Department of the Environment and Heritage (2005) Air Quality Fact Sheet – Air Toxics

16 Trading Economics (2014) Urban Population (% of Total) in Australia

17 Department of Infrastructure and Transport (2010) Final RIS for Review of Euro 5/6 Light Vehicle Emissions Standards

18 Australian Bureau of Statistics (2016) 9309.0 - Motor Vehicle Census*, Australia, 31 Jan 2016*

for around 25 per cent of all road transport fuel consumed in Australia. The heavy vehicle fleet in Australia is also dominated by diesel engines (which emit higher levels of NOx and particulates).

While road vehicles are not the only source of particulate emissions in most urban airsheds, fuel combustion sources such as motor vehicle engines can contribute up to 30 per cent of the overall particulate load in urban airsheds[19], particularly from diesel vehicles. Predictably, particulate levels tend to be highest near busy roads and dense urban areas.

1.4 Government Actions to Address the Problem

There have been significant efforts by governments and industry over a number of years to improve air quality in Australia by reducing noxious emissions from road vehicles.

This RIS examines whether there is a need for the Australian Government to do more to improve the noxious emissions performance of vehicles.

1.4.1 Current Noxious Emissions Standards

Australia has had noxious emissions standards for vehicles in place since the early 1970s. These have been progressively strengthened in response to:

- vehicle technology advances and availability of suitable fuels;
- increasing international concern over air pollution problems, as greater scientific knowledge has highlighted detrimental effects on human health; and
- increases in the size of and make up of vehicle fleets as well as vehicle usage patterns, particularly in urban areas.

Noxious emissions from vehicles are currently regulated through the Australian Design Rules (ADRs). The ADRs are the national standards for road vehicles under the *Motor Vehicle Standards Act 1989* (Cth) (MVSA). All new road vehicles in Australia, whether they are manufactured here or imported, are required to comply with the Australian Design Rules (ADRs) before they can be supplied to the market. The ADRs set minimum requirements for vehicle safety, environmental performance and anti-theft protection.

In developing the ADRs, the Australian Government has committed to adopting United Nations (UN) regulations where possible. In 2000, the Australian Government acceded to the UN 1958 Agreement[20], under which these regulations are developed. There are currently 50 Contracting Parties to the 1958 Agreement. The Agreement provides a mechanism for mutual recognition (acceptance) of approvals issued according to the UN regulations by other Contracting Parties.

The World Trade Organisation (WTO) identifies the UN regulations as the peak international vehicle regulations. Under the WTO's Agreement on Technical Barriers to Trade, Australia, and other WTO members, are strongly encouraged to adopt international regulations where they are available.

Harmonisation with the UN regulations facilitates international trade and minimises compliance costs, while ensuring a high level of safety and environmental performance. This is particularly relevant with the cessation of domestic light vehicle manufacturing from 2018. Globalisation of the motor vehicle industry and the relatively small size of the vehicle market in Australia make the development of unique Australian standards undesirable from both a consumer cost and regulatory perspective.

If the ADRs do not keep pace with international trends, Australia runs the risk of foregoing the benefits of technology available in other developed countries. Manufacturers may find it more cost effective to continue supplying older technology to the Australian market.

[19] Greenbaum, D.S. Chapter 5. Sources of Air Pollution: Gasoline and Diesel Engines, IARC Scientific Publication

[20] Full title of UN 1958 Agreement–*Agreement concerning the Adoption of Uniform Technical Prescriptions for Wheeled Vehicles, Equipment and Parts which can be fitted and/or used on Wheeled Vehicles and the Conditions for Reciprocal Recognition of Approvals Granted on the basis of these Prescriptions* of March 1958.

The current UN regulations for noxious emissions for light and heavy vehicles are based on the 'Euro' standards adopted in the European Union (EU).

For light vehicles, Australia has mandated Euro 5 noxious emissions standards (through ADR 79/04–Emission Control for Light Vehicles) for newly approved models first manufactured from 1 November 2013, and for all light vehicles manufactured from 1 November 2016. For heavy vehicles, Australia mandated the Euro V noxious emissions standards (through ADR 80/03–Emission Control for Heavy Vehicles) for all heavy vehicles manufactured from 1 January 2011.

These standards are less stringent than those in comparable countries. The more rigorous Euro 6 standards for light vehicles became mandatory in the EU from September 2014 and equivalent standards are now in force in most developed countries. Similarly, Euro VI standards for heavy vehicles commenced in the EU from the end of 2012 and equivalent standards are now in force in most other developed countries.

The key improvements under Euro 6 compared with Euro 5 are a 55 per cent reduction in the emission limits for NOx for light diesel vehicles; a particle number limit to reduce fine particle emissions from petrol direct injection (GDI) vehicles; and tighter thresholds and monitoring requirements for on-board diagnostic (OBD) systems that monitor the performance of emission control systems. The next phase of the Euro 6 standards, commencing in the EU in September 2017, will introduce further changes to improve the integrity of the testing regime. The key change will be the replacement of the current drive cycle testing regime with the new Worldwide harmonised Light vehicle Test Procedure (WLTP) and the introduction of an on-road Real Driving Emissions (RDE) test. Any consideration of Euro 6 for light vehicles in Australia will be based on the 2017 Euro 6 requirements, as this stage will have the greatest health benefits.

The key improvements under Euro VI compared with Euro V are an up to 80 per cent reduction in emission limits for NOx emissions, a reduction in emission limits for particulates by up to 66 per cent, and the adoption of more a robust testing regime.

The differences in emissions limits between Euro 5 and Euro 6, and Euro V and Euro VI are outlined in the tables below.

Table 1: Euro 5 and Euro 6 light passenger vehicle emissions limits

	Euro 5		**Euro 6**	
	Petrol/LPG	**Diesel**	**Petrol/LPG**	**Diesel**
Oxides of nitrogen	60 mg/km	180 mg/km	60 mg/km	80 mg/km
Particulate matter	4.5 mg/km (for direct injection)	4.5 mg/km	4.5 mg/km (for direct injection)	4.5 mg/km
Particle number limit	No limit	$6x10^{11}$/km	$6x10^{11}$/km (for direct injection)	$6x10^{11}$/km

Table 2: Euro 5 and Euro 6 light commercial vehicle emissions limits

	Euro 5		**Euro 6**	
	Petrol/LPG	**Diesel**	**Petrol/LPG**	**Diesel**
Oxides of nitrogen	82 mg/km	280 mg/km	82 mg/km	125 mg/km
Particulate matter	4.5 mg/km (for direct injection)	4.5 mg/km	4.5 mg/km (for direct injection)	4.5 mg/km
Particle number limit	No limit	$6x10^{11}$/km	$6x10^{11}$/km (for direct injection)	$6x10^{11}$/km

Table 3: Euro V and Euro VI emissions limits for heavy diesel vehicles

	Euro V	**Euro VI**

	Stationary Cycle	Transient Cycle	Stationary Cycle	Transient Cycle
Oxides of nitrogen	2,000 mg/kWh	2,000 mg/kWh	400 mg/kWh	460 mg/kWh
Particulate matter	20 mg/kWh	30 mg/kWh	10 mg/kWh	10 mg/kWh

This RIS examines whether there would be net benefits to the community if the Australian Government introduced these more stringent international standards.

In 2010, the Department completed a RIS to review Euro 5 and 6 for light vehicles in Australia[21]. The RIS recommended that Euro 5 be mandated for new light vehicles from 2013. It also recommended that Euro 6 be mandated from 2017, but only when available through the UN regulations (which was not the case at the time). This RIS builds on the analysis from the 2010 RIS.

1.4.2 Fuel Quality Standards

The composition of fuels can directly affect the level of noxious emissions (as well as greenhouse gas emissions) from road vehicles. It can also affect the range of technologies that can be adopted to improve vehicle emissions.

The Australian Government regulates fuel quality under the *Fuel Quality Standards Act 2000*, which is administered by the Department of the Environment and Energy. Fuel quality is regulated to reduce pollutants and emissions that can contribute to environmental and health issues, namely carbon monoxide (CO), NOx, SOx, VOCs and PM.

The principal fuel quality parameter that is regulated to control noxious vehicle emissions is sulfur content, which can affect the durability and operation of vehicle emissions control systems such as catalysts and particulate filters[22].

There is a key issue of whether the Australian petrol is of an appropriate quality–in terms of sulfur content–to support the implementation of Euro 6 standards for light vehicles. The current standard for petrol sets the maximum petrol sulfur limits at 150 parts per million (ppm) for ‘regular’ unleaded petrol (ULP) and 50 ppm for ‘premium’ unleaded petrol (PULP). By comparison, the EU, Japan and US (which have implemented Euro 6 or equivalent standards) already have, or are planning to transition to, 10 ppm sulfur. The current standard for automotive diesel in Australia has a sulfur limit of 10 ppm, in line with international best practice.

The car components that relate to this issue include:

- catalytic converters–which convert noxious emissions into less harmful substances. As noted, high sulfur levels in petrol can reduce the effectiveness of catalytic converters;
- OBD system–which is a computer-based system built into the vehicle that monitors the engine and emissions control equipment; and
- malfunction indicator lamp–if the OBD detects a fault with the emissions control equipment, the indicator lamp will be activated to alert the driver of the vehicle.

These three components are all interrelated. If the catalytic converter is not working effectively and emitting higher than the noxious emission limits, the OBD system will detect this fault, which will activate the indicator lamp on the dashboard of the car. Under Euro 6 the OBD thresholds for detecting noxious emission levels are reduced and the OBD is required to undertake more regular emissions monitoring.

A literature study by Orbital Australia in 2013[23] (commissioned by the then Department of the Environment) found that the lowering of OBD thresholds for Euro 6 is likely to result in malfunction indicator lamps being activated more often when petrol with 150 ppm sulfur is used, as NOx

[21] Department of Infrastructure and Transport (2010) Final RIS for Review of Euro 5/6 Light Vehicle Emissions Standards

[22] International Council for Clean Transportation (ICCT) (2015) Briefing Paper – Policies to Reduce Fuel Consumption and Air Pollution and Carbon Emissions from vehicles in G20 nations, May 2015

[23] Orbital Australia (2013) Review of sulfur limits in petrol

emission levels would exceed the threshold. The report also found that with petrol with 50 ppm sulfur content, the margin of error is reduced but not exceeded, meaning that it is not likely to cause the triggering of the indicator lamp, but is more likely to do so compared with 10 ppm petrol.

Euro 6 is also likely to require the introduction of particulate filters for GDI vehicles in order to meet the new particle number requirements. As noted, sulfur can affect the durability of particulate filters.

There remains some uncertainty on the degree to which current sulfur levels in Australian petrol would affect the implementation of Euro 6 for light vehicles. Light vehicle manufacturers insist that a lower sulfur limit of petrol is necessary to ensure the benefits of Euro 6 are realised on road. The Australian petroleum industry disagrees and claims the sulfur levels in petrol are already well below regulated levels and would be sufficient to support the introduction of Euro 6, citing 2014–15 average levels of 16 ppm for PULP and 28 ppm for ULP in Sydney, and 26 ppm for PULP and 60 ppm for ULP in Melbourne.

During a Ministerial Forum stakeholder engagement meeting in April 2016, the Minister for Urban Infrastructure, the Hon Paul Fletcher MP, got agreement from the Federal Chamber of Automotive Industries (FCAI) (representing light vehicles manufacturers) and the Australian Institute of Petroleum (AIP) to engage an independent consultant to provide clarity on this issue.

The Department of Infrastructure and Regional Development (the Department) subsequently engaged IHS Markit to undertake research to determine what level of sulfur in petrol–considering both the maximum and reported average levels in Australia–would affect Euro 6 compliance.

The results suggest that while 10 ppm sulfur or less is ideal, Australian petrol with a sulfur content of less than 30 ppm is unlikely to affect the ability of vehicles to meet Euro 6 requirements over the required durability period of 160,000 km. Results also suggest that there is lack of available and credible international information on the effects of sulfur between 30 and 50 ppm, but (similar to the results of the Orbital Australia study) there is evidence that 50 ppm or higher may be problematic for modern emissions control systems.

Following completion of an independent review of the *Fuel Quality Standards Act 2000*, the Australian Government announced on 8 May 2016 that the Act would be retained and amended and that the individual fuel standards under it would be reviewed. The Department of the Environment and Energy is currently undertaking this review, including consideration of reducing the maximum allowable sulfur content in Australian petrol. This would directly impact on any implementation of Euro 6, which is why it is important that these two bodies of work are considered together.

1.4.3 National Clean Air Agreement

In December 2015, Australia's Environment Ministers established the National Clean Air Agreement (NCAA) to ensure that Australians continue to enjoy clean air and to address the impacts of air pollution on human health and the environment. It sets out a framework to help governments identify and agree future actions to ensure Australia can respond to current and emerging air quality priorities.

The NCAA considers actions to reduce air pollution and improve air quality through cooperative action between industry and government at the national, state and local levels. The Agreement is designed to incorporate a range of existing, new and complementary measures to improve Australia's air quality.

The NCAA provides scope for a wide range of actions to be formulated over time across four strategic approaches, including reviewing and strengthening air quality monitoring and reporting standards, targeted measures to reduce emissions from key sources of air pollution, improving access to air quality information for communities, and fostering partnerships with industry.

One of the key initial actions under the Agreement was to strengthen the national ambient (outdoor) air quality reporting standards for particles in the National Environment Protection (Ambient Air Quality) Measure (NEPM)[24]. Reporting standards have been adopted for $PM_{2.5}$ particles for an annual average and 24 hour concentration of 8µg/m^3 and 25µg/m^3 respectively,

[24] Department of the Environment (2015) National Clean Air Agreement – Fact Sheet

aiming to move to 7µg/m^3 and 20µg/m^3 respectively by 2025. An annual average standard for PM_{10} particles of 25µg/m^3 has also been adopted. The PM_{10} standards will be reviewed in 2018.

The NEPM establishes a national framework to monitor and report against six criteria pollutants– PM, sulfur dioxide, nitrogen dioxide, ground-level ozone, CO and lead. States and territories are responsible for implementing the NEPM, and implement strategies towards meeting the standards.

Other key actions under the Agreement include introducing new emission standards for non-road spark ignition engines and equipment (such as gardening equipment and marine engines)[25] and jurisdictions adopting measures to reduce wood heater emissions[26]. These actions will also help to improve air quality in Australia, including in urban areas.

The NCAA and NEPM set upper limits for pollution, but do not reduce the amount of noxious emissions from road vehicles. More stringent vehicle standards (Euro 6/VI) would complement the actions under the NEPM and the NCAA in improving air quality.

[25] Reducing Emissions from Non-Road Spark Ignition Engines and Equipment–Decision Regulation Impact Statement (2015)

[26] National Environment Protection Council Service Corporation (2013) Consultation RIS for reducing emissions from wood heaters

2 Why is Government Action Needed?

Government action may be needed where the market fails to provide the most efficient and effective solution to a problem.

Australians should be able to expect clean air to breathe. Air pollution from road vehicles is a negative externality–the health costs are not borne directly by the vehicle manufacturers nor owners, but shared by the community. As such, this problem is not addressed effectively by the operation of market forces alone. When buying new vehicles, consumers are less likely to demand improved noxious emissions performance compared with other aspects that directly affect them, like safety or comfort features. Manufacturers therefore have no clear market incentive to supply vehicles with the latest noxious emissions technology.

Government actions to strengthen noxious emissions standards and improve fuel quality are internationally recognised 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 on reducing urban air pollution, 'the imposition and enforcement of [vehicle emissions] standards have proven a very effective environmental policy in many countries.'[27]

Australia has had increasingly more stringent noxious emissions standards in place for vehicles since the 1970s. This RIS examines whether further Australian Government action is required to improve the noxious emissions performance of light and heavy vehicles in order to reduce the health costs of these emissions to the community. It is important that any Australian Government actions are in accordance with Australia's international obligations.

2.1 Current Government Action May Not Remain Effective

While Australia's average air quality is currently considered good by international standards, there are still concerns about the health impacts of air pollution in Australian cities.

As outlined in Section 1, noxious vehicle emissions are a major contributor to urban air pollution. There is an increasing need to reduce these emissions, considering the rapid population growth[28] and growth in demand for transport services in our major urban centres. The issue is compounded by an ageing urban population that is more susceptible to the health impacts of air pollutants, with the proportion of the population aged over 65 expected to more than double over the next 40 years[29]. As the Australian population increases there will also be an increase in the number of vehicles on the road.

In addition to increasing vehicle numbers and usage, there has also been a recent shift towards diesel-powered light vehicles in Australia. A 2016 Australian Bureau of Statistics (ABS) Motor Vehicle census showed that the number of diesel vehicles registered in Australia had increased by more than double that of petrol vehicles since 2015. The increase in registrations of diesel vehicles was in passenger vehicles and light commercial vehicles, which together accounted for 95 per cent of the overall increase from 2015 to 2016.[30]

This shift puts further pressure on our ability to maintain our good air quality, as diesel engines tend to produce higher levels of oxides of nitrogen (NOx) than petrol engines and are permitted to do so under our current light vehicle noxious emissions standards (Euro 5). The implementation of more stringent international noxious emissions standards for light vehicles–Euro 6–would address this issue. Euro 6 requires a 55 per cent reduction in NOx emissions from diesel vehicles (compared with Euro 5), bringing the limit much closer to the limit for petrol vehicles.

There has also been a sizable increase in the uptake of light petrol direct injection (GDI) vehicles in Australia (and globally) over the past five years and this is expected to continue to grow[31]. GDI

27 World Bank (2004) Reducing Air Pollution from Urban Transport

28 Infrastructure Australia (2015) Australian Infrastructure Audit – Executive Summary

29 Commonwealth of Australia (2015) 2015 Intergenerational Report – Australia in 2055

30 Australian Bureau of Statistics (2016) Motor Vehicle Census, Australia, 31 Jan 2016

31 Robert Bosch (Australia) Submission to Vehicle Emissions Discussion Paper, February 2016

engines tend to emit more hazardous fine particles than traditional petrol engines[32]. The implementation of Euro 6 would also address this issue by introducing a particle number limit per kilometre for GDI vehicles of $6x10^{11}$. This limit already exists for light diesel vehicles under Euro 5.

Further, heavy vehicle usage is also steadily increasing, with total heavy vehicle travel predicted to grow by 62 per cent between 2010 and 2030[33]. The implementation of Euro VI would help to mitigate the impact of this growth on air pollution by requiring significant improvements in NOx and particulate matter (PM) emissions.

2.2 International Standards

Most developed countries have now adopted noxious emissions standards based on, or equivalent to, Euro 6 for light vehicles and Euro VI for heavy vehicles. It is important to recognise that this does not guarantee that all vehicles in other markets–such as Australia–will be manufactured to comply with these standards in the future.

The number of vehicles meeting a particular international standard can vary considerably from one market to another. This depends on the status of the international standard within each country's domestic regulations (whether it is mandated), as well as differences in non-regulatory approaches such as government and private sector fleet purchasing policies, and consumer preferences. Hence, vehicles from different markets that may otherwise appear identical are tailored by the manufacturer to the requirements of each market.

As an example of market variation in vehicle design, in 2013, the Global New Car Assessment Program (Global NCAP) undertook a research project on the passive safety performance of popular light vehicle models sold in India. One of the vehicles Global NCAP tested as part of this project, the Hyundai i10 (a small passenger car), is also sold in Europe and had previously been tested by the European New Car Assessment Program (Euro NCAP).

Global NCAP undertook a frontal impact test on the Hyundai i10. At the time, the vehicles sold to the Indian market were not required to meet United Nations (UN) frontal or side impact crash test regulations. The vehicle was not equipped with any frontal airbags and scored zero per cent for adult occupant protection[34,35].

In comparison, the Hyundai i10 tested by Euro NCAP was equipped with driver and passenger frontal airbags and scored 79 per cent for adult occupant protection for the same test[36]. In Europe, light passenger vehicles such as the Hyundai i10 are required to meet UN regulations for frontal and side impact protection.

The number of Euro 6 and Euro VI compliant vehicles supplied to the market in Australia is expected to increase, reflecting implementation of these standards in other markets. However, the example above highlights that, in the absence of domestic regulation, the Australian Government cannot guarantee that all vehicles supplied to the Australian market would eventually meet these standards.

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[32] SAE International (2014) Attacking GDI Engine Particulate Emissions

[33] Bureau of Infrastructure, Transport and Regional Economics (2013) unpublished

[34] Global NCAP (2014) Research Project: Safer car for India by Global NCAP, document no. WP.29-162-21

[35] United Nations Economic Commission for Europe (2014) Reports of the World Forum for Harmonization of Vehicle Regulations on its 162nd session, Geneva, 11-14 March 2014, document no. ECE/TRANS/WP.29/1108

[36] Euro NCAP (2014) Test Results – Hyundai i10

3 What Policy Options Are Being Considered?

3.1 Available Options

Available options for the Australian Government to reduce noxious emissions from new light and heavy vehicles are listed below.

3.1.1 Non-Regulatory Options

The Australian Government could consider the following non-regulatory options:

Option 1–Business as usual
Allow existing arrangements and market forces to provide a solution.

Option 2–Fleet purchasing policies
Influence vehicle purchasing decisions by adopting minimum noxious emissions performance requirements in new Australian Government fleet purchasing policies.

3.1.2 Regulatory Options

The Australian Government could consider the following regulatory options:

Option 3–Voluntary standards
Vehicle manufacturers, through peak industry groups, enter into an agreement with the Australian Government to meet minimum noxious emissions performance requirements.

Option 4–Mandatory standards for light vehicles
Mandate Euro 6 for light vehicles under the *Motor Vehicle Standards Act 1989* (MVSA).

Option 5–Mandatory standards for heavy vehicles
Mandate Euro VI for heavy vehicles under the MVSA.

Option 6–Mandatory standards for light and heavy vehicles
Mandate both Euro 6 for light vehicles and Euro VI for heavy vehicles under the MVSA.

3.2 Discussion of Options

3.2.1 Option 1–Business as Usual

The business as usual case relies on the current noxious emissions standards to continue to deliver lower emissions and improvements in air quality.

As outlined in Section 1.4.1, for petrol, diesel and gaseous fuelled light vehicles (up to 3.5 tonnes gross vehicle mass (GVM))[37], Australia has mandated Euro 5 noxious emissions standards (through Australian Design Rule (ADR) 79/03 and 79/04) for newly approved models first manufactured from 1 November 2013, and for all light vehicles manufactured from 1 November 2016.

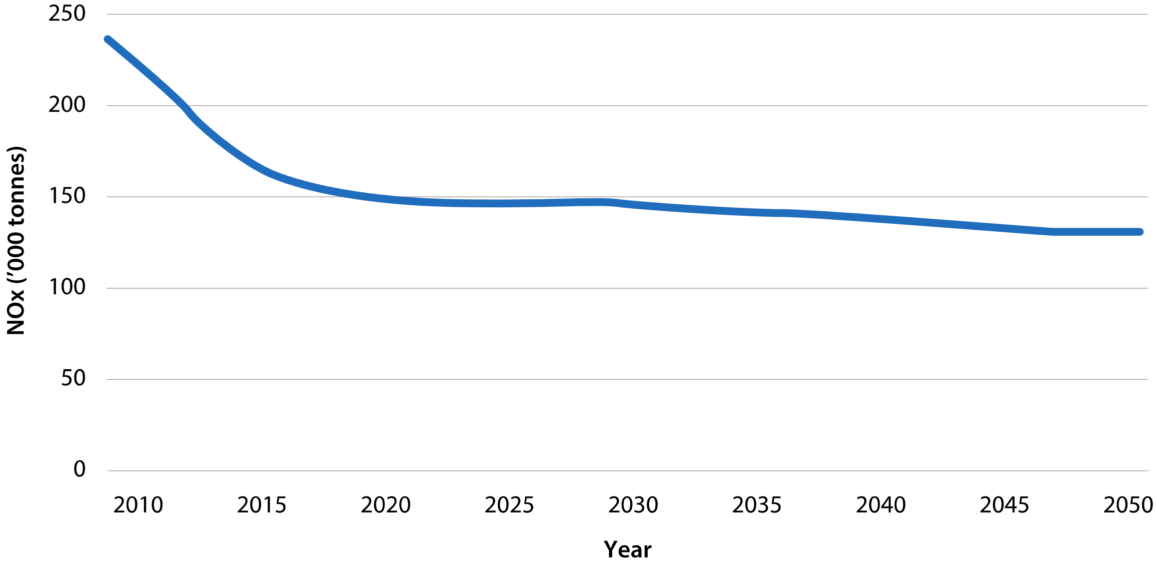
For diesel and gaseous fuelled heavy vehicles (GVM over 3.5 tonnes), Australia has mandated Euro V noxious emissions standards (through ADR 80/03) from 1 January 2011, with vehicles that comply with equivalent US and Japanese standards also accepted[38].

These standards have already delivered air quality benefits and will continue to do so as new vehicles meeting the more stringent requirements replace older vehicles. However, Bureau of Infrastructure, Transport and Regional Economics (BITRE) emissions projections undertaken for this RIS–Figure 2 to Figure 5 below–indicate that these standards are likely to be insufficient in the longer term in continuing to deliver reductions in oxides of nitrogen (NOx) and particulate matter (PM) emissions. This is largely attributable to increasing vehicle numbers and vehicle kilometres travelled, as well as a greater uptake of diesel and GDI technology in new light vehicles.

[37] Light vehicles (GVM up to 3.5t) include cars, sports utility vehicles, people movers, small buses, and light commercial vehicles such as vans and utes/light trucks, but do not include motorcycles.

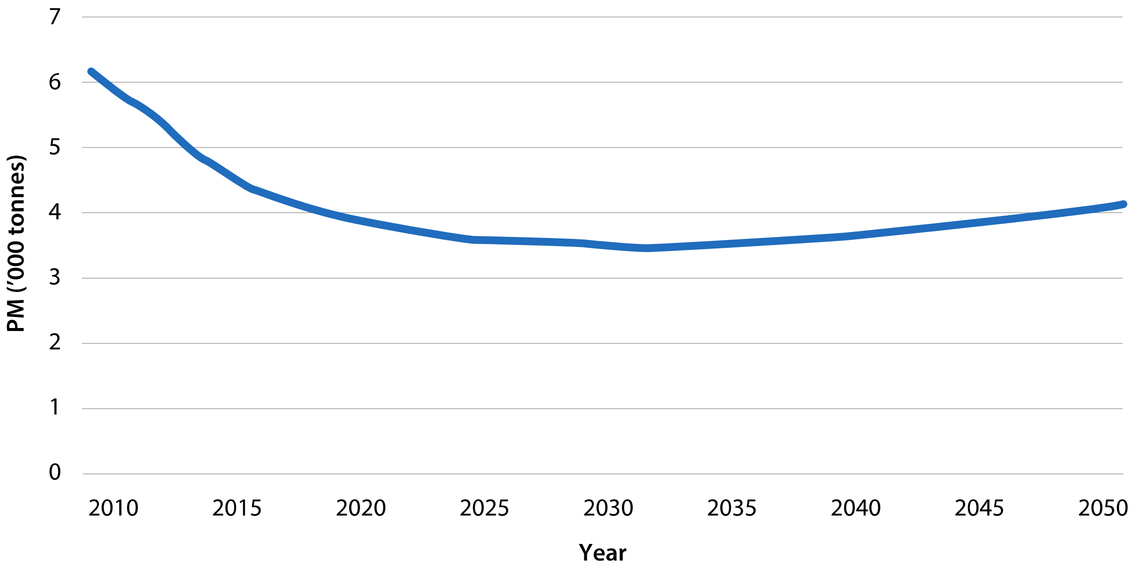
[38] Heavy vehicles (GVM over 3.5t) include the largest vans and utes/pickup trucks, as well as rigid trucks, buses and prime movers used in articulated vehicle combinations.

Figure 2: Projected impact of existing noxious emissions standards (Euro 5) on NOx emissions from the light vehicle fleet (2010–2050)



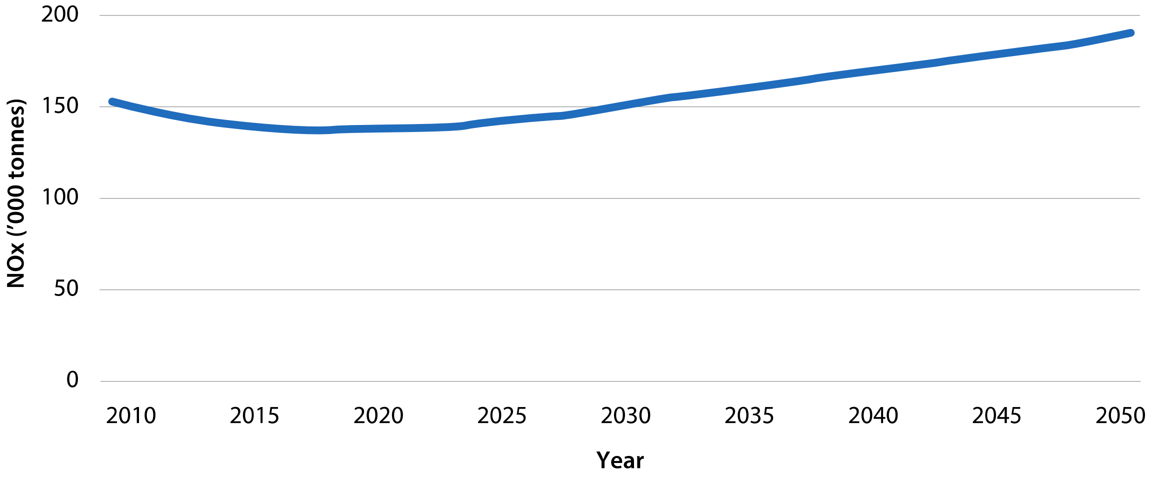
Source: BITRE projections, 2016

Figure 3: Projected impact of existing noxious emissions standards (Euro 5) on PM emissions from the light vehicle fleet (2010–2050)



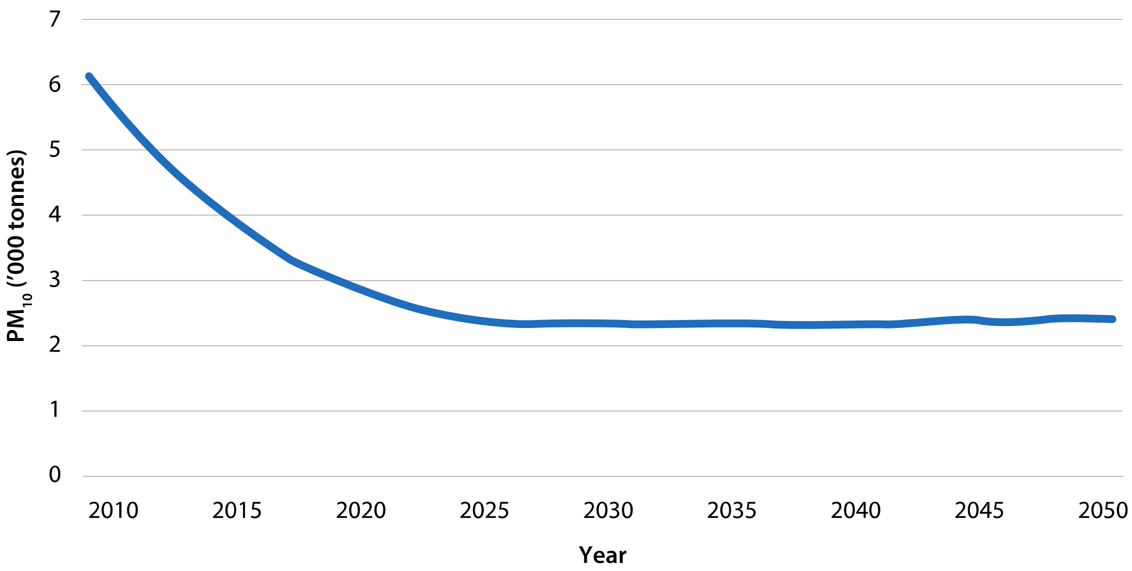
Source: BITRE projections, 2016

Figure 4: Projected impact of existing noxious emissions standards (Euro V) on NOx emissions from the heavy vehicle fleet (2010–2050)



Source: BITRE projections, 2016

Figure 5: Projected impact of existing noxious emissions standards (Euro V) on PM emissions from the heavy vehicle fleet (2010–2050)



Source: BITRE projections, 2016

Under the business as usual scenario, it is expected that a proportion of vehicles entering the Australian market will meet Euro 6 and Euro VI standards, reflecting implementation of these standards in overseas markets. There are a number of Euro 6 and Euro VI compliant vehicles available in Australia already[39,40].

However, in the absence of more stringent mandatory standards, some manufacturers will choose to continue supplying vehicles meeting current standards where it is cost effective to do so. This was outlined in Section 2.2. A further example is detailed in the Second National In-Service Emissions Study (NISE2) which examined vehicles manufactured between 1986 through 2007. The study found that many vehicles sold in Australia met only the minimum requirements

39 Australian Government Green Vehicle Guide

40 Truck Industry Council (2016) Submission to the Vehicle Emissions Discussion Paper, *April 2016*

applicable at the time despite the wide availability of more advanced technologies in other markets.[41]

This practice is particularly likely to occur in the case of standards for controlling urban air pollutant emissions. As discussed in Section 2, these emissions are not usually at the forefront of consumers' minds when purchasing a new vehicle, and so consumers are less likely to drive demand for vehicles meeting more stringent standards.

The Australian Government Guide to Regulation requires RISs to include analysis of the business as usual option as a benchmark. This option is therefore examined in Section 4.

3.2.2 Option 2–Fleet Purchasing Policies

In 2015, over 550,000 new light and heavy vehicles were purchased by government, business and rental fleets, representing approximately 46 per cent of new light vehicles and 96 per cent of new heavy vehicles sold in Australia[42]. As a result, purchasing/leasing decisions by fleet operators and businesses can influence the range of vehicles manufacturers choose to supply to the Australian market and the range of vehicles available to consumers in the second-hand vehicle market.

To encourage manufacturers to offer vehicles with improved noxious emissions performance, the Australian Government could play a leadership role by requiring vehicles to meet Euro 6/Euro VI or equivalent standards to be eligible to be purchased for use in its fleet. These requirements could set an example for other fleets to follow.

Advantages of targeting fleet purchasing are:

- ex-fleet vehicles are often sold after two to three years, giving the public the opportunity to buy a near new vehicle at a large discount; and
- fleet vehicles are on average driven twice as far annually as household vehicles, thus maximising the use of any technology benefits[43].

By setting minimum noxious emissions performance requirements for its fleet, the Australian Government would encourage manufacturers to supply a higher proportion of vehicles meeting these requirements.

However, as the Australian Government fleet is less than 0.3 per cent of new vehicle sales, the benefits to the community from adopting the requirements in this fleet alone would be minimal. The ability of this fleet purchasing policy to influence the noxious emissions performance of the broader vehicle fleet would be enhanced if other government and private fleets adopted similar policies.

The costs of adopting this option would be largely associated with the cost of developing a new fleet purchasing policy. There may, however, also be some lost opportunity for the fleet in foregoing a higher emitting vehicle that may be better placed to meet operational requirements.

As the costs and benefits of this policy are highly dependent on voluntary action by other government and private fleets, it is not possible to provide a reliable estimate of the costs and benefits of adopting this approach. Due to these reasons this option was not considered any further by the Department prior to public consultation.

3.2.3 Option 3–Voluntary Standards

To improve the noxious emissions performance of the new vehicle fleet, voluntary standards could be established through agreement between the Australian Government and peak industry bodies–specifically, the Federal Chamber of Automotive Industries (FCAI) and the Truck Industry Council (TIC). The FCAI represents 99 per cent of the manufacturers and importers involved with new light vehicles in Australia. TIC represents truck manufacturers and major component suppliers. These agreements could specify minimum noxious emissions performance requirements as well as monitoring and reporting arrangements.

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[41] Department of the Environment, Water, Heritage and the Arts (2009) The Second National In-Service Emissions Study

[42] Federal Chamber of Automotive Industries (2015), VFACTs

[43] Nesbit & Sperling (2001) *Fleet purchase behaviour: decision processes and implications for new vehicle technologies and fuels*. Transportation Research, Part C, Vol 9, pp. 297-318

For voluntary standards to work effectively, vehicle manufacturers would need to share a collective interest that aligns with the best interests of consumers and the general public, and there would need to be an incentive to meet standards that support social and environmental outcomes[44]. However, as discussed previously, there is limited incentive for manufacturers to improve the noxious emissions performance of vehicles, as these emissions do not have a high profile in the minds of new vehicle consumers (unlike safety).

If voluntary standards were adopted, there could be no certainty of requirements being met. In its consideration of the case for Euro 5 and 6 emissions standards, the European Commission (EC) stated that 'self-regulation would imply a significant departure from an approach that is well established all over the world and has proven its effectiveness in the past'. The EC 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 for mandatory standards, increasing costs and complexity.[45]

If non-compliances are detected, unlike for mandatory standards (where mandatory recall provisions and fines for non-compliance apply under law), the Australian Government would be unable to force manufacturers to fix underperforming vehicles. In the same way, a manufacturers' association would also struggle (including with potential conflicts of interest) in controlling any breaches among its members and certainly could not compel non-members, including any new suppliers which may enter the market in future, to adhere to a voluntary standard.

The issue of how to monitor compliance with voluntary standards and how to take action against non-compliances is not new. As long ago as 1961 in the US, it was reported that the Federal Government reached a voluntary agreement with the light vehicle industry to fit emission control devices to all cars. The agreement was made in order to avoid a threat to extend the then Californian and New York requirement for emission control devices to become a national requirement. However, it was subsequently reported that by 1964, one major manufacturer had ceased fitting the device due to 'operational and maintenance difficulties' in all states other than the two where it was regulated. It was notable that the government only became aware of this situation through a report on automotive pollution commissioned by the US Department of Health, rather than being informed by the manufacturer concerned.

More recently in Australia in 2004, the Department prepared a consultation RIS to examine the need for Australian Government intervention for the provision of intrusive seatbelt reminders in light passenger vehicles. At the time the RIS did not support a regulatory approach. The main reason was that seatbelt reminders were already fitted to 50 per cent of new vehicles and industry indicated that the fitment rate would increase to 95 per cent by 2007. The RIS proposed a voluntary approach, which included seatbelt reminders being a prerequisite to gaining a five-star vehicle rating under the Australasian New Car Assessment Program (ANCAP). There was also a recommendation to follow up on the effectiveness of this at a future date and to reconsider the case for regulation if a voluntary fitment rate of 95 per cent was not achieved.

A follow-up survey in 2010 indicated that the fitment rate had still only reached around 89 per cent. Therefore, in 2011, the Department commenced a second RIS process to consider the case for mandating seatbelt reminders for light passenger vehicles, with the result that seatbelt reminders were made mandatory in new light passenger vehicles from 2013.

The possibility of a double process like this becomes a consideration when looking at the use of voluntary standards. If voluntary standards are adopted and manufacturers fail to comply, it would not be possible to adopt mandatory standards without undertaking another full RIS process. This is likely to delay any Australian Government action by a number of years.

To improve the incentive for manufacturers to comply, the Australian Government (or state and territory governments) could provide financial incentives to encourage the purchase of vehicles that comply with the voluntary standards. For the incentive to be effective, this is likely to require a significant financial commitment from governments.

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[44] Marsden-Jacob Associates (2016) Review of the Fuel Quality Standards Act 2000

[45] Commission of the European Communities (2005) Impact Assessment of Euro 5 Proposal relating to emissions of atmospheric pollutants from motor vehicles

Due to these reasons this option was not considered any further by the Department prior to public consultation.

3.2.4 Option 4–Mandatory standards (Euro 6) for light vehicles

Under this option, the Australian Government would mandate improved noxious emissions performance for light vehicles only, by determining a new ADR under the MVSA.

There are 65 active ADRs. Vehicles are approved on a model (or vehicle type) basis known as type approval, whereby the Australian Government approves the design of a vehicle type based on test and other information supplied by the manufacturer. Compliance of vehicles built under that approval is ensured by the regular audit of the manufacturer's production processes.

The ADRs apply equally to new imported vehicles and new vehicles manufactured in Australia. No distinction is made on the basis of country of origin or manufacture and this has been the case since the introduction of the MVSA. Currently around 90-95 per cent of light vehicles sold in Australia are imported, which will increase to 100 per cent from 2018.

The new ADR (ADR 79/05) would mandate the Euro 6 noxious emissions standards that will commence in the European Union (EU) in September 2017.

The adoption of Euro 6 would deliver the following key benefits for the light vehicle fleet:

- for light diesel vehicles, a 55 per cent reduction in the emission limits for NOx;
- for petrol vehicles with direct injection fuelling systems, the introduction of a limit on the number of particles in order to control fine particle emissions;
- more stringent requirements for on-board diagnostic systems that monitor the emission control systems, including a reduction in the thresholds at which a malfunction warning is detected and an increased frequency of monitoring (in-use performance ratio);
- the adoption of the Worldwide harmonised Light vehicle Test Procedure (WLTP) as the basis for determining compliance with emission limits to improve the correlation between laboratory tested and on-road emission levels; and
- the introduction of an on-road Real Driving Emissions (RDE) test to improve the correlation between laboratory tested and on-road emission levels.

The changes in emissions limits from Euro 5 to Euro 6 are detailed in Table 1 and Table 2.

The costs and benefits of this option are examined further in Section 4.

3.2.5 Option 5–Mandatory standards (Euro VI) for heavy vehicles

Under this option, the Australian Government would mandate improved noxious emissions performance for heavy vehicles only, by determining a new ADR under the MVSA.

The new ADR (ADR 80/04) would mandate the Euro VI noxious emissions standards in the latest version of UN Regulation 49/06.

The adoption of Euro VI would deliver the following key benefits for the heavy vehicle fleet:

- an increase in the durability requirements for vehicle emission control systems;
- a 70 per cent reduction in emission limits for hydrocarbons (HC);
- a 77-80 per cent reduction in the emission limits for NOx;
- a 50-66 per cent reduction in the mass emission limits for particulates;
- the introduction of a limit on the number of particles in order to control fine particle emissions;
- the adoption of the Worldwide Harmonised Stationary and Transient Cycles (WHSC and WHTC) as the basis for determining compliance to improve correlation between tested and on-road emissions; and
- more stringent requirements for on-board diagnostic systems that monitor the emission control systems, including a reduction in the thresholds at which a malfunction warning is detected and an increased frequency of monitoring (in-use performance ratio).

The changes in emissions limits from Euro V to Euro VI are detailed in Table 3.

Similar to ADR 80/03, ADR 80/04 may also allow for equivalent US or Japanese standards as alternatives to Euro VI. Specific feedback on this will be sought from the heavy vehicle industry during public consultation.

The costs and benefits of this option are examined further in Section 4.

Given that Euro 6 and Euro VI are two different standards that apply separately to light and heavy vehicles, it was considered sensible to examine their feasibility in an Australian context separately. The next option considers options 4 and 5 as a package.

3.2.6 Option 6– Mandatory standards (Euro 6/VI) for light and heavy vehicles

Under this option, the Australian Government would mandate improved noxious emissions performance for both light and heavy vehicles by determining new ADRs under the MVSA (ADR 79/05 and ADR 80/04).

The new ADRs would mandate Euro 6 for light vehicles and Euro VI (or possibly equivalent standards) for heavy vehicles.

The costs and benefits of this option are examined further in Section 4.

Proposed Timing for Options 4, 5 and 6

If the case is made for mandating more stringent noxious emissions standards in Australia (options 4 through 6), a balance would need to be found between the earliest possible introduction, which would maximise air quality benefits, and a delayed introduction, which would allow vehicle manufacturers sufficient time to amortise their investment in achieving compliance with one standard before being required to upgrade to meet new standards.

For light vehicles, Australia will have fully implemented the Euro 5 standards at the end of 2016. For heavy vehicles, Australia fully implemented the Euro V standards (with equivalent US and Japanese standards as alternatives) from 1 January 2011.

In the EU, Euro 6 commenced in September 2014, with all OBD and test requirements (except the final RDE conformity factor) phased in by the end of 2019. Euro VI commenced at the end of 2012, with all OBD requirements phased in by the end of 2016.

Taking into account the international situation, the Department considers that if new ADRs were to be determined in 2017, a phase-in period of 2019-2020 would be the earliest practical timeframe without unduly disrupting business planning. By that time, manufacturers should have a clear understanding of the steps required to meet these standards and should largely be able to utilise technologies they have adopted to meet equivalent standards in other countries.

4 What are the Likely Net Benefits of Each Option?

The Department, through the Bureau of Infrastructure, Transport and Regional Economics (BITRE), undertook a detailed benefit-cost analysis of the viable options–1, 4, 5 and 6.

The analysis was reviewed by an independent consultant specialising in economics–ACIL Allen–to ensure the methodology and assumptions were appropriate. The results of the review confirmed the approach used is consistent with the Office of Best Practice Regulation (OBPR) Guidance Note on Benefit-Cost Analysis[46].

In benefit-cost analysis terms, the key indicators of the economic viability of a proposed option are its net benefits and benefit-cost ratio (BCR). A positive net benefit means that the returns on the option will outweigh the resources outlaid. The BCR is a measure of the efficiency of the option. If the net benefits are positive, the BCR will be greater than one. A higher BCR means that, for a given cost, the benefits are paid back a number of times over.

The results of the benefit-cost analysis are summarised below, with details contained in Appendix A–Euro 6 Benefit-Cost Analysis and Appendix B–Euro VI Benefit-Cost Analysis.

4.1 Option 1–Business as Usual

There are no benefits or costs associated with option 1 as this is the ‘do-nothing’ approach.

4.2 Option 4–Euro 6 for Light Vehicles

See Appendix A–Euro 6 Benefit-Cost Analysis for the full explanation of this analysis.

4.2.1 What Are the Quantitative Costs and Benefits?

The analysis of option 4 estimated the net benefits and BCR of implementing Euro 6 standards for new light vehicle models from 2019 and for all new light vehicles from 2020.

Costs and benefits were assessed on the basis of capital costs and avoided health costs. Results showed that, over the evaluation period of 2016 to 2040 at a discount rate of seven per cent, implementing Euro 6 standards for new light vehicles in Australia would result in net benefits of $411 million and a benefit-cost ratio of 1.28 (see Table 4).

Table 4: Benefit-cost analysis for the implementation of Euro 6 standards for new light vehicles in Australia

Year	Capital costs ($m)	Avoided health costs ($m)	Net benefit ($m)
2016	0.0	0.0	0.0
2017	0.0	0.0	0.0
2018	0.0	0.0	0.0
2019	110.4	7.6	-102.8
2020	193.4	23.2	-170.2
2021	171.8	40.7	-131.1
2022	151.8	55.6	-96.2
2023	133.6	67.9	-65.7
2024	117.2	78.0	-39.2
2025	99.1	86.3	-12.9
2026	83.2	92.9	9.7
2027	69.2	98.0	28.8

46 OBPR (2016) Cost-benefit analysis guidance note

Year	Capital costs ($m)	Avoided health costs ($m)	Net benefit ($m)
2028	56.9	103.7	46.7
2029	47.8	105.4	57.7
2030	41.0	106.4	65.4
2031	35.9	106.7	70.8
2032	31.1	106.3	75.2
2033	26.6	105.4	78.8
2034	22.4	104.1	81.7
2035	18.5	102.3	83.8
2036	14.8	100.2	85.4
2037	11.4	97.7	86.3
2038	8.3	94.8	86.5
2039	5.3	91.8	86.4
2040	2.6	88.5	86.0
Total	1,452.3	1,863.3	411.0

4.2.2 What Are the Main Assumptions?

The analysis assumed that the emissions-reduction technology on vehicles purchased during most years of the evaluation period would continue to generate benefits beyond the end of the evaluation period in 2040.

Since the benefits from this technology are fairly constant over the lives of the vehicles, an approximation to residual evaluation was obtained by prorating the cost of the technology over the lives of the vehicles, then only counting costs attributed to years before 2040.

The average vehicle life (median survival time) was assumed to be 17 years. For vehicles purchased during the later years of the evaluation period, the cost of the emissions-reducing technology was annuitised over 17 years. A standard discount rate of seven per cent was used, as required by the OBPR. Sensitivity testing was conducted on discount rates of three and 11 per cent (see Table 5), which showed that, even with a discount rate of 11 per cent, the BCR would remain above one.

The analysis assumed an increase in the proportion of new vehicle models employing petrol direction injection (GDI) technology, with GDI light vehicles possibly approaching half of new petrol-vehicle sales before 2025. It also assumed that oil prices would remain relatively close to current levels over the medium term and then gradually rise over ensuing decades.

Fuel Quality

As discussed in Section 1.4.2, a key issue highlighted through stakeholder consultations is whether Australian petrol is of an appropriate quality–specifically in terms of sulfur content–to enable the implementation of Euro 6 for light petrol vehicles.

The benefit-cost analysis for Euro 6 made a number of assumptions about the level of sulfur in Australian petrol. Firstly, it assumed that there would be no change to current fuel standards. Secondly it assumed that current actual levels of sulfur in petrol (at a national average of about 30 parts per million (ppm) for premium unleaded petrol (PULP) and 70 ppm for regular unleaded petrol (ULP)) are similar to those provided by the Australian Institute of Petroleum (AIP). Thirdly it assumed that over the analysis period there would be an increase in the proportion of vehicles using PULP (along with a gradual decrease in the level of sulfur in both ULP and PULP), leading to an average sulfur level of well below 30 ppm across all sales by 2040.

Given that results from IHS Markit suggest that sulfur at less than 30 ppm is unlikely to affect the ability of vehicles to meet Euro 6 requirements, and that the average sulfur content of Australian

PULP is already below 30 ppm (and the average across all petrol sales is expected to be below 30 ppm in the future), the analysis made an overall assumption that there would not be significant issues for most petrol vehicles in meeting Euro 6 in Australia.

However, to account for the use of higher than 10 ppm sulfur petrol, the modelling made allowances for some deterioration of the vehicle emissions control systems. If the sulfur content was limited to 10 ppm, under the current modelling formulation, projected emissions volumes (of vehicle pollutants controlled by catalytic converters, such as oxides of nitrogen (NOx), carbon monoxide (CO) and hydrocarbons (HC)) would reduce on average by around 5–10 per cent. This is likely to be a conservative estimate, and actual emission reductions from lower sulfur fuel could be significantly higher (depending on the exact vehicle operating conditions).

As noted, the Department of the Environment and Energy is currently undertaking a review of the individual fuel standards under the *Fuel Quality Standards Act 2000*, including consideration of reducing the maximum allowable sulfur content in Australian petrol. Any further noxious emissions reductions that might be obtained from introducing Euro 6 with mandated low sulfur fuel will be captured through that review.

4.2.3 What Costs and Benefits are Included?

Costs and benefits of introducing the Euro 6 standards for new light vehicles in Australia were assessed on the basis of increased capital costs and avoided health costs. The cost estimates for vehicle emission control technologies were informed by industry submissions to the Vehicle Emissions discussion paper. The avoided health costs were calculated by quantifying the emissions of pollutants and estimating the emissions saved relative to the business as usual case and by establishing a value for an average health cost from existing literature.

The cost total is slightly conservative as it does not include additional maintenance costs. It is anticipated that there would be some increase in the maintenance costs for diesel light vehicles, notably in relation to the exhaust after-treatment system. Over the long term, as the technology becomes more mature, maintenance costs would likely reduce.

Further, the additional fuel costs from meeting Euro 6 were not included. The fuel economy of Euro 6 compliant light vehicles depends on the emissions abatement technology used and cycles (the way in which the engine is going to be used and, in particular, how hot it is going to run). A sensible assumption would be that, in a competitive environment, engine/vehicle manufacturers would make every effort to minimise fuel consumption to the lowest possible levels subject to compliance with the Euro 6 standards. Based on this, possible additional fuel costs were assumed to be negligible.

The benefit total is also conservative as it did not include secondary particulates and black carbon emissions reductions which are difficult to quantify precisely. The reductions in exhaust emission volumes flowing from implementation of the stronger standards are likely to lead to subsequent reductions in secondary particulate matter formation. However, due to the complicated nature of their formation, with rates typically strongly dependent on local atmospheric conditions, the exact amount of such reductions cannot be readily calculated.

Further, changes in greenhouse gas emissions were not included. Increases in fuel consumption from either changes in the fuel mix or the technology used to meet the Euro 6 standards would increase greenhouse gas emissions. However, the greenhouse gas emissions would decrease from the reduction in black carbon emissions. The benefits from reduced black carbon emissions are difficult to quantify due to uncertainty around the black carbon warming impact.

4.2.4 What Sensitivity Tests Were Considered?

Given the inevitable uncertainties with some of the assumptions used, sensitivity tests were undertaken on assumptions around: vehicle maintenance costs; health costs; discount rates; capital costs; reductions in secondary air pollutants; fuel consumption; and greenhouse gas emissions. The results are summarised below (Table 5). On balance of these results–with net benefits ranging from -$521m to $1.1b, and most scenarios being positive–an estimated net benefit of $411m for option 4 appears realistic.

The biggest uncertainty in this analysis was around the actual health costs of various pollutants, most notably NOx, given the wide range of values in available literature.

In their review of the benefit-cost analysis, ACIL Allen referred to a recent UK Department for Environment, Food and Rural Affairs report[47], which provided estimated ‘damage’ costs per tonne for NOx that were significantly higher than those used for this analysis.

If these high health costs for NOx given in the UK report were found to be valid for Australian conditions, BITRE has advised that the BCR would be strongly affected (with the current value close to 1.0 increasing to around 8.0).

Given this, it is likely that the health costs used for this analysis were conservative estimates.

Table 5: Sensitivity test results for Euro 6 for light vehicles

Sensitivity test	**Benefit-cost ratio**	**Net benefits ($m)**
Core Euro 6 scenario	1.28	411
Increase in maintenance costs (based on additional urea costs only)	1.26	385
Increase in maintenance costs (based on additional urea costs multiplied by a factor of two)	1.24	359
Upper range values for unit health costs of air pollutants (50 per cent higher than core scenario)	2.27	1,847
Lower range values for unit health costs of air pollutants (50 per cent lower than core scenario)	0.64	-521
Low discount rate (three per cent)	1.72	1,410
High discount rate (11 per cent)	1.11	107
Upper range values for extra capital costs (higher values for initial implementation, though retain downwards adjustment for future economies of scale or from learning by doing)	0.79	-504
Higher values for extra capital costs (using core scenario values for initial implementation, but assuming no downward cost adjustment over time for future economies of scale or from learning by doing)	0.89	-219
Lower range values for extra capital costs (retain downwards adjustment for future economies of scale or from learning by doing)	2.32	1,059
Possible reduction in secondary particulates	1.45	652
Possible impacts on fuel consumption	1.16	254
Possible effects on greenhouse gas emissions	1.30	438

4.3 Option 5–Euro VI for Heavy Vehicles

See Appendix B–Euro VI Benefit-Cost Analysis for the full explanation of this analysis.

4.3.1 What Are the Quantitative Costs and Benefits?

The analysis of option 5 estimated the net benefits and BCR of implementing Euro VI standards for new heavy vehicle models from 2019 and for all new heavy vehicles from 2020.

Benefits were assessed on the basis of health costs avoided, costs were assessed on the basis of capital costs, fuel costs, diesel exhaust fluid costs, potential productivity losses (in the form of lost

47 UK Department for Environment, Food and Rural Affairs (2015) Valuing impacts on air quality: Updates in valuing changes in emissions of Oxides of Nitrogen (NOx) and concentrations of Nitrogen Dioxide (NO_2)

payload to remain within legal mass and dimension limits), and possible increases in greenhouse gas emissions.

Results showed that, over the period 2016 to 2040 at a discount rate of seven per cent, implementing Euro VI for new heavy vehicles in Australia would result in net benefits of $264 million and a BCR of 1.13 (Table 6).

Table 6: Benefit-cost analysis for the implementation of Euro VI standards for new heavy vehicles in Australia

Year	Capital cost ($m)	Fuel costs ($m)	Diesel Exhaust Fluid ($m)	Productivity loss ($m)	Greenhouse gas emissions ($m)	Total costs ($m)	Health costs avoided ($m)	Net benefits ($m)
2016	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2019	140.5	0.7	-0.7	4.1	0.1	144.6	6.6	-138.0
2020	218.5	2.5	-2.8	10.7	0.3	229.2	25.0	-204.2
2021	186.9	4.6	-5.3	16.4	0.6	203.3	46.5	-156.8
2022	154.1	6.5	-6.6	21.3	0.8	176.2	66.0	-110.1
2023	124.7	8.1	-7.3	25.5	1.0	152.0	82.6	-69.4
2024	98.7	9.4	-8.0	27.8	1.2	129.0	96.5	-32.5
2025	90.1	10.5	-8.6	28.6	1.3	122.0	108.3	-13.6
2026	82.0	11.4	-9.1	28.9	1.4	114.6	118.0	3.5
2027	74.0	12.2	-9.5	28.6	1.5	106.7	125.8	19.1
2028	66.5	12.7	-9.9	27.8	1.5	98.7	131.7	33.1
2029	59.4	13.1	-10.2	26.8	1.5	90.6	135.8	45.2
2030	52.7	13.4	-10.4	25.5	1.5	82.7	138.4	55.7
2031	46.4	13.5	-10.6	24.1	1.5	75.0	139.3	64.3
2032	40.5	13.5	-10.7	22.7	1.5	67.5	138.9	71.4
2033	34.9	13.3	-10.7	21.3	1.5	60.3	137.4	77.0
2034	29.6	13.1	-10.8	19.9	1.5	53.3	135.0	81.7
2035	24.6	12.9	-10.9	18.5	1.4	46.6	131.9	85.4
2036	19.9	12.6	-10.9	17.2	1.4	40.2	128.2	88.0
2037	15.5	12.2	-10.9	16.0	1.3	34.1	123.9	89.8
2038	11.3	11.8	-10.8	14.8	1.3	28.3	119.3	91.0
2039	7.3	11.4	-10.7	13.7	1.2	22.8	114.5	91.7
2040	3.6	10.9	-10.6	12.7	1.1	17.6	109.5	91.8
Total	1,581.5	230.2	-195.8	452.9	26.4	2,095.2	2,359.3	264.1

4.3.2 What Are the Main Assumptions?

The analysis assumed that emissions-reduction technology on vehicles purchased during most years of the evaluation period would continue to generate benefits beyond the end of the evaluation period in 2040.

Since the benefits from this technology are fairly constant over the lives of the vehicles, an approximation to residual evaluation was obtained by prorating the cost of the technology over the lives of the vehicles, then only counting costs attributed to years before 2040.

The average vehicle life (median survival time) was assumed to be 20 years. For vehicles purchased during the later years of the evaluation period, the cost of the emissions-reduction technology was annuitised over 20 years. A standard discount rate of seven per cent was used, as required by the OBPR. Sensitivity testing was conducted on discount rates of three and 11 per cent (see Table 7), which showed that, even with a discount rate of 11 per cent, the benefit-cost ratio would not fall far below one (at about 0.9).

The benefit-cost analysis assumed that that most manufacturers will have to use integrated Exhaust Gas Recirculation and Selective Catalytic Reduction systems with Diesel Particulate Filters to achieve low levels of emissions set out in the proposed Euro VI standards.

4.3.3 What Costs and Benefits Are Included?

The main analysis focussed on the costs and benefits that could be reliably quantified. Costs considered included capital costs, fuel costs, diesel exhaust fluid costs, productivity losses, and greenhouse gas emissions. Benefits included health costs avoided. Some of the possible costs were omitted from the core analysis (such as maintenance costs) due to limited information and/or methodology to reliably estimate them, as well as some likely benefits similar due to methodological limitations.

The cost estimates for vehicle emission control technologies were informed by industry submissions to the Vehicle Emissions discussion paper.

The fuel costs were calculated by assuming that the fuel consumption of a Euro VI heavy vehicle would be 0.5-1 per cent higher than an equivalent Euro V vehicle due to the heavier vehicle mass and the use of Exhaust Gas Recirculation systems which tend to be less fuel efficient.

The diesel exhaust fluid costs were calculated by assuming that a move to Euro VI would entail more vehicles using urea than the base case, but with reduced rates of urea consumption per vehicle.

The productivity loss was calculated by estimating the cost of the reduced payload or seating capacity directly, assuming no change in legal mass and dimensional limits.

The changes in greenhouse gas emissions allowed for increased carbon dioxide emissions from the increased fuel consumption.

The avoided health costs were calculated by quantifying the emissions of pollutants and estimating the emissions saved relative to the base case and by establishing a value for an average health cost from existing studies. As noted, the benefit total is conservative as it did not include secondary particulates and black carbon emissions reductions.

4.3.4 What Sensitivity Tests Were Considered?

Again, given the inevitable uncertainties with some of the assumptions used, sensitivity tests were undertaken on assumptions around: the unit health costs; impacts on fuel and urea consumption; discount rates; impacts on capital costs; impacts on productivity; impacts on maintenance costs; reductions in secondary air pollutants; and impacts on greenhouse gas emissions. The results are summarised below (Table 7). On balance of these results–with net benefits ranging from -$915m to $1.9b, and most scenarios being positive–an estimated net benefit of $264m for option 5 appears realistic.

Again, the biggest uncertainty in this analysis was around the actual health costs of various pollutants, most notably NOx, given the wide range of values in available literature.

If the high health costs for NOx given in the UK report provided by ACIL Allen were found to be valid for Australian conditions, BITRE has advised that the BCR would be strongly affected (with the current value close to 1.0 increasing to around 8.0).

Given this, it is likely that the health costs used for this analysis were conservative estimates.

Table 7: Sensitivity test results for Euro VI for heavy vehicles

Sensitivity test	Benefit-cost ratio	Net benefits ($m)
Core Euro VI scenario	1.13	264.1
Using unit health costs in core Euro VI scenario	1.13	264.1
Upper range values for unit health costs	1.91	1,910.8
Lower range values for unit health costs	0.56	-915.6
No change to baseline fuel consumption rates	1.29	528.3
Higher fuel consumption losses (one per cent over baseline)	1.00	0.1
Higher fuel consumption losses (two per cent over baseline) and reduction in urea use per kilometre	0.92	-205.6
Low discount rate (three per cent)	1.44	1,309.3
High discount rate (11 per cent)	0.90	-146.5
Upper range values for initial extra capital costs (higher values for initial implementation, retain downwards adjustment for future economies of scale or from learning by doing)	0.85	-413.7
Higher average values for extra capital costs (using core scenario values for initial implementation, but assuming no downward cost adjustment over time for future economies of scale or from learning by doing)	0.75	-777.6
Lower range values for extra capital costs (retain downwards adjustment for future economies of scale or from learning by doing)	1.66	941.9
High productivity losses (increase of 50 per cent)	1.02	37.7
Using maintenance costs roughly modelled	0.97	-77.7
High maintenance costs (double modelled costs)	0.85	-419.5
With reductions in secondary particulates included	1.34	710.2
With reductions black carbon emissions included	1.15	299.3

4.4 Option 6–Euro 6 for Light Vehicles and Euro VI for Heavy Vehicles

Under this option, Euro 6 would be mandated for light vehicles and Euro VI for heavy vehicles.

It was expected that there could be no sharing of the costs of meeting both standards, given the differences between the standards and the differences between light and heavy vehicle manufacturing processes.

Therefore, the benefits and costs of this option were assumed to be simply the sum of the benefits and costs of meeting option 4 and option 5.

Table 8: Summary of benefit-cost analysis for the implementation of Euro 6 for new light vehicles and Euro VI for new heavy vehicles in Australia

Total costs ($m)	Total benefits ($m)	Net benefits ($m)	Benefit-cost ratio
3,547	4,222	675	1.19

4.5 Summary of Benefit-Cost Analysis Results

Table 9 below summarises the benefit-cost analysis results for options 1, 4, 5 and 6.

Table 9: Summary of benefit-cost analysis results for options 1, 4, 5 and 6

	Total costs ($m)	Total benefits ($m)	Net benefits ($m)	Benefit-cost ratio
Option 1–Business as Usual	-	-	-	-
Option 4–Euro 6 for Light Vehicles	1,452	1,863	411	1.28
Option 5–Euro VI for Heavy Vehicles	2,095	2,359	264	1.13
Option 6–Euro 6 for Light Vehicles and Euro VI for Heavy Vehicles	3,547	4,222	675	1.19

Option 6 resulted in the highest net benefits of $675m over the period 2016–2040. According to the Australian Government Guide to Regulation, the policy option offering the greatest net benefit should always be the recommended option.

4.6 Qualitative Impact Analysis

This considers the magnitude and distribution of the calculated benefits and costs. It also considers the impacts of the options on affected parties.

4.6.1 Identification of Affected Parties

In the case of any increased stringency of vehicle emissions standards, the major parties affected by the options would be:

- business and consumers, including: vehicle manufacturers and importers; vehicle emissions systems component manufacturers; vehicle owners; and vehicle operators; and
- governments: Australian, state and territory and local governments along with their represented communities.

The business/consumer parties are represented by several interest groups. These include:

- Federal Chamber of Automotive Industries (FCAI)–representing light vehicle manufacturers and importers, and component manufacturers and importers;
- Australian Automobile Association (AAA)—representing vehicle owners and operators (passenger cars and derivatives) through the various automobile clubs around Australia;
- Truck Industry Council (TIC)–representing truck manufacturers and major component suppliers; and
- Australian Trucking Association (ATA)–representing major truck operators.

4.6.2 Impacts of Viable Options

Option 1: Business as Usual

Under this option the government does not intervene, with market forces instead providing a solution to the problem.

As this option is the business as usual case, there are no new benefits or costs allocated. Any remaining options are calculated relative to this business as usual option, so that what would have happened anyway in the marketplace is not attributed to any proposed intervention.

Options 4–6: Euro 6 and Euro VI for Light and Heavy Vehicles

These options mandate Euro 6 standards for light vehicles, Euro VI standards for heavy vehicles, or both Euro 6 and Euro VI standards for light and heavy vehicles.

There would be a direct benefit to the health and wellbeing of the Australian community under these options as a result of a reduction in air pollution. This would have an indirect benefit to governments in terms of reducing pressure on the public health system.

There would be a direct cost to light and heavy vehicle manufacturers as a result of the additional capital costs required to meet Euro 6/VI standards. Some or all of these costs could be passed on to consumers purchasing new vehicles.

To meet Euro VI, heavy vehicle manufacturers may be required to fit additional technology that adds weight and/or takes space. This may lead to a loss in productivity for heavy vehicle operators in the form of reduced payload for trucks or seating capacity for buses/coaches.

There may also be higher fuel costs for heavy vehicle operators, due to the increased weight for Euro VI technology, as well increased use of Exhaust Gas Recirculation systems, which tend to be less fuel efficient.

Heavy vehicle operators may pass these increased costs onto consumers through higher prices for transported goods.

There would be some costs to governments for developing, implementing and administering new regulations.

Under each option, the quantified benefits outweigh the costs, resulting in net benefits to the community ranging from $264 m to $675 m over the analysis period (2016-2040) (using a discount rate of seven per cent).

4.7 Regulatory Burden and Cost Offsets

The Australian Government has established a deregulation policy that aims to improve productivity growth and enhance competitiveness across the Australian economy. The Department is a key Commonwealth regulator and continuous improvement is at the core of the portfolio's regulatory vision. The portfolio is vigorously pursuing regulatory reforms, with a particular focus on achieving efficiencies through harmonising international and domestic regulatory requirements where possible. This will maintain our high standards for Australia's transport systems while reducing unnecessary regulatory burden.

The Australian Government Guide to Regulation requires that all new regulatory options are costed using the Regulatory Burden Measurement Framework (RBM). The RBM is a different measure to the full cost benefit analysis as it does not capture the benefits of avoided health issues for the wider community. The average annual regulatory costs were established by calculating the average undiscounted costs for each option over the period from 2019–2028 inclusive.

For option 4, the costs included were capital costs only. For option 5, the costs included were also capital costs, as well as fuel costs.

The average annual regulatory costs under the RBM calculated for the viable options, options 1, 4, 5 and 6, are set out in Table 10 to Table 13. There are no costs associated with option 1 as it is the business as usual case. The average annual regulatory costs associated with options 4, 5 and 6 are $195m, $225m, and $420m respectively.

To the extent that market forces allow, the costs to business in the tables below may be passed on to consumers.

Table 10: Regulatory burden and cost offsets estimate table–option 1 (business as usual)

Average annual regulatory costs (from business as usual)				
Change in costs ($ million)	Business	Community organisations	Individuals	Total change in costs
Total, by sector	-	-	-	-
Cost offset ($ million)	Business	Community organisations	Individuals	Total, by source
Agency	N/A	N/A	N/A	N/A

Average annual regulatory costs (from business as usual)
Are all new costs offset? N/A
Total (Change in costs – cost offset) ($ million) = N/A

Table 11: Regulatory burden and cost offsets estimate table–option 4 (Euro 6 for light vehicles)

Average annual regulatory costs (from business as usual)				
Change in costs ($ million)	Business	Community organisations	Individuals	Total change in costs
Total, by sector	195			195
Cost offset ($ million)	Business	Community organisations	Individuals	Total, by source
Agency				
Are all new costs offset? □ Yes, costs are offset ✓ No, costs are not offset □ Deregulatory–no offsets required				
Total (Change in costs – Cost offset) ($ million) = 189				

Table 12: Regulatory burden and cost offsets estimate table–option 5 (Euro VI for heavy vehicles)

Average annual regulatory costs (from business as usual)				
Change in costs ($ million)	Business	Community organisations	Individuals	Total change in costs
Total, by sector	225			225
Cost offset ($ million)	Business	Community organisations	Individuals	Total, by source
Agency				
Are all new costs offset? □ Yes, costs are offset ✓ No, costs are not offset □ Deregulatory–no offsets required				
Total (Change in costs – Cost offset) ($ million) = 210				

Table 13: Regulatory burden and cost offsets estimate table–option 6 (Euro 6 for light and Euro VI heavy vehicles)

Average annual regulatory costs (from business as usual)				
Change in costs ($ million)	Business	Community organisations	Individuals	Total change in costs
Total, by sector	420			420
Cost offset ($ million)	Business	Community organisations	Individuals	Total, by source
Agency				
Are all new costs offset? □ Yes, costs are offset ✓ No, costs are not offset □ Deregulatory–no offsets required				
Total (Change in costs – Cost offset) ($ million) = 399				

5 Consultation

5.1 Previous Consultation

This RIS has been prepared by the Department following the consideration of:

- feedback received at Ministerial Forum stakeholder engagement meetings on 7 December 2015 and 4 April 2016;
- submissions received in response to the Ministerial Forum discussion paper released on 11 February 2016, which sought input on a range of issues and options to address the impacts of emissions from road vehicles including standards and alternative measures. All public submissions to the paper (and the paper itself) are available on the Department's website;
- an independent analysis of the methodology and assumptions underpinning the cost-benefit analysis; and
- independent research on the impacts of sulfur levels in Australian petrol on Euro 6 compliance.

The proposal to mandate Euro 6 and Euro VI noxious emissions standards for light and heavy vehicles has been discussed a number of times at meetings of the peak vehicle standards consultative forum, the Strategic Vehicle Safety and Environment Group (SVSEG). SVSEG consists of senior representatives of government (Australian and state/territory), the manufacturing and operational arms of the industry (including organisations such as the Federal Chamber of Automotive Industries, Truck Industry Council and the Australian Trucking Association), and consumer and road user organisations (including the Australian Automobile Association).

5.2 Consultation Plan

This Early Assessment RIS has been released for full public consultation to elicit views from all interested parties on its key proposals. Feedback is specifically sought on the estimated benefits and costs of the proposals, as well as the implementation timing.

Comments on this RIS are requested by 10 March 2017 and should be submitted as a separate word or pdf document to vemissions@infrastructure.gov.au, or posted to:

Vehicle Emissions Working Group
Department of Infrastructure and Regional Development
GPO Box 594
CANBERRA ACT 2601

The feedback received in response to this RIS, and through further stakeholder discussions, will help inform the Department in finalising the RIS for consideration by the Ministerial Forum in 2017. A summary of the public comment will be included in the final RIS, which will be published once the Ministerial Forum announces its decision.

Appendix A–Euro 6 Benefit-Cost Analysis

Executive Summary

The Department, through the Bureau of Infrastructure, Transport and Regional Economics (BITRE), undertook a study to assess the benefits and costs associated with the introduction of Euro 6 noxious emissions standards into the Australian light vehicle fleet. The 'core' scenario analysed involved introducing Euro 6 from 2019 for newly approved models and from 2020 for all new light vehicles.

The main benefits identified were the health costs avoided due to lower emissions of noxious air pollutants as a result of stronger emissions standards. The identified costs mainly comprised additional capital costs.

The benefit-cost analysis results (Table 14) show that this Euro 6 scenario would have a net benefit of $411m over the period analysed, with a benefit-cost ratio of 1.28 (using a discount rate of seven per cent).

Table 14: Benefits, costs and benefit-cost ratio for mandating Euro 6 for new light vehicles

Present value of costs ($m)	Present value of benefits ($m)	Net benefits ($m)	Benefit-cost ratio
$1,452	$1,863	$411	1.28

The analysis focused on the benefits and costs that could be reliably quantified. Some possible benefits and costs were omitted from the analysis due to limited information and/or methodology to estimate them reliably. Assessments of these possible additional benefits and costs were conducted in sensitivity analyses.

Introduction

The core scenario analysed involved introducing Euro 6 through the ADRs from 2019 for newly approved models and 2020 for all new vehicles. Table 15 shows a more detailed description of this scenario.

Table 15: Details of the core scenario analysed

Standard	Vehicle group	Date of effect	Description of scenario
ADR 79/05 based on the Euro 6 requirements applicable in the EU from September 2017	All new light vehicles (< 3.5 tonnes GVM)	2019 for newly approved light vehicle models and 2020 for all new light vehicles	Euro 6 emission standards including only well-quantified benefit and cost categories

All cost/price values (unless otherwise specified) are given in terms of 2015–16 Australian dollars.

The main benefits identified were the health costs avoided due to lower emissions of pollutants as a result of stronger emissions standards. Other benefits such as increased visibility and reduced corrosion are difficult to quantify and likely to be minor. The identified costs mainly related to additional capital costs involved in meeting the new emissions standards. While there may be a utility cost associated with reduced supply/range of some vehicle types as a result of difficulties in meeting the emissions standards, this is difficult to quantify and was assumed to be stable.

Due to data constraints, a simplified methodology was used to assess the health impacts of the reduced pollution from the introduction of Euro 6 standards. It is akin to the approach used by BITRE (2010a) in its analysis of the health impacts of introducing Euro 5 and 6 standards into the

Australian light vehicle fleet. Unit health cost values were reviewed and, where necessary, updated.

The benefit-cost analysis results show that Euro 6 scenario analysed would yield a net present benefit of $411m over the analysis period (to 2040) and a benefit-cost ratio of 1.28 (using a discount rate of seven per cent).

Methodology for Estimating Health Benefits

The methodology employed to estimate the health benefits was largely the same as employed by BITRE (2010a) in its analysis of the health impacts of introducing Euro 5 and 6 standards into the Australian light vehicle fleet and is illustrated in Figure 6. The first step was to quantify the emissions of pollutants for the scenario under investigation and estimate tonnes of emissions saved (relative to the base case). The second step was to establish a value for an average health cost ($ per tonne of emissions) from existing studies. The final step was to calculate the total health benefits (i.e. health cost avoided) by multiplying tonnes of emissions saved by unit value(s) for health costs.

Figure 6: The study approach

Emissions of Air Pollutants

The main pollutants of concern for air quality emitted by motor vehicles are NOx, PM_{10} (PM finer than 10 microns) and HC (volatile hydrocarbons).

Since the Australian Government first regulated noxious emissions through the ADRs, successive ADRs have been introduced to reduce the allowable exhaust emissions from light vehicles. Since 2003, emission standards for light vehicles have followed the ‘Euro’ standards in terms of allowable levels of HC, NOx, CO and PM emitted by a vehicle. While the changes in allowable emission levels from Euro 5 to Euro 6 are relatively small, the Euro 6 standard also introduces changes to the certification test regime, which are expected to deliver further reductions in noxious emissions from the light vehicle fleet by improving correlation between ‘laboratory-tested’ and ‘on-road’ emission levels.

Emissions of these pollutants from the Australian light vehicle fleet were modelled using a range of BITRE fleet and projection models; in particular, the BITRE Motor Vehicle Emission suite (MVEm), which estimates a wide range of pollutant emissions by vehicle type, when fed utilisation data from other BITRE projection models (such as TranSaturate). The MVEm models also roughly estimate possible order-of-magnitude effects for future urban traffic congestion levels (raising both average urban fuel consumption and noxious emission rates) on a city-by-city basis. The models take separate account of the passenger (car and SUV) and commercial components of the light vehicle fleet.

Various input scenarios run on these models provide base case (or ‘business-as-usual’) projections of emissions from the Australian light vehicle fleet over the medium to longer term, and estimate the possible emission changes flowing from the implementation of tighter vehicle standards. These models are described in a variety of BITRE publications, such as BITRE Working Paper 73, *Greenhouse Gas Emissions from Australian Transport: Projections to 2020* (BITRE 2009), *Modelling the Road Transport Sector* (BITRE & CSIRO 2008), *Urban Pollutant Emissions from Motor Vehicles: Australian Trends to 2020* (BTRE 2003), BTRE Report 107, *Greenhouse Gas Emissions From Transport: Australian Trends To 2020* (BTRE 2002), *Long-term emission trends* *for Australian transport* (Cosgrove 2008) and *Long-term Projections of Australian Transport Emissions: Base Case 2010* (BITRE 2010).

Some further technical background material for emission projection scenario setting is discussed in Cosgrove, Gargett, Evans, Graham & Ritzinger 2012, *Greenhouse gas abatement potential of the Australian transport sector: Technical report from the Australian Low Carbon Transport Forum* (a joint BITRE, CSIRO and ARRB project) and BITRE Report 127 (2012), *Traffic Growth in Australia*.

The BITRE emissions projection modelling suite was updated and revised for this benefit-cost analysis, using:

- recent vehicle fleet composition data results from the the Australian Bureau of Statistics (ABS) *Survey of Motor Vehicle Use* (ABS 2015a) and *Motor Vehicle Census* (ABS 2015b)[48];
- recent vehicle sales values from ABS (2016) *Sales of New Motor Vehicles, Australia* and FCAI VFACTS data;
- trend data on fuel consumption from the *Australian Petroleum Statistics* (Office of the Chief Economist 2016), and on average consumption rates from the BITRE New Passenger Vehicle Database–described in BITRE Information Sheet 66 (2014b) *New Passenger Vehicle Fuel Consumption Trends, 1979 to 2013*–and National Transport Commission (NTC) 2016, *Carbon Dioxide Emissions Intensity for New Australian Light Vehicles 2015*;
- further data on new vehicle specifications or fuel characteristics (by make and model) from Glass's Guide (Glass's Research Data, GRD) and the Green Vehicle Guide (www.greenvehicleguide.gov.au, hosted by the Department of Infrastructure and Regional Development);
- vehicle activity forecasting trends discussed in BITRE Information Sheet 61 (2014), *Saturating Daily Travel*, and BITRE Information Sheet 74 (2015), *Traffic and congestion cost trends for Australian capital cities*;
- various reports dealing with fleet modelling parameters–such as NISE2 data (e.g. DEWHA 2009, *The Second National In-Service Emissions Study: Technical Summary*), the Advisory Committee on Tunnel Air Quality (submission on Australian Government Vehicle Emissions Discussion Paper), or Smit 2014 (*Australian Motor Vehicle Emission Inventory for the National Pollutant Inventory*) which uses comprehensive vehicle emissions data within the COPERT Australia software–or market conditions and fuel intensity forecasts–such as SMMT 2016 (*New Car CO_2 Report 2016*), KPMG International 2015 (*KPMG's Global Automotive Executive Survey*), FCAI (2015, 2016), IHS Consulting 2016 (*Global Automotive Regulatory Requirements: Regulatory Environment and Technology Roadmaps*), H-D Systems 2015 (*New Light-Duty Vehicle Technology and Impact on Fuel Efficiency*), Rare Consulting 2012 (*Light vehicle emission standards in Australia–The case for action*), by CSIRO (e.g. Reedman & Graham 2013a, *Transport Sector Greenhouse Gas Emissions Projections 2013–2050* and 2013b, *Sensitivity analysis of modelling of light vehicle emission standards in Australia*) or by ClimateWorks Australia (e.g. ClimateWorks Australia 2014, *Improving Australia's Light Vehicle Fuel Efficiency*; ClimateWorks Australia et al. 2014, *Pathways to Deep Decarbonisation in 2050*);
- improved information for on-road fuel intensity trends and on the typical disparities between test and actual on-road fuel consumption–such as provided by International Council on Clean Transportation (ICCT) 2012 (*Discrepancies between type approval and "real-world" fuel consumption and CO_2 values*), ICCT 2013 (*Measuring in-use fuel economy in Europe and the US: Summary of pilot studies*), ICCT 2014a (*Development of Test Cycle Conversion Factors among Worldwide Light-Duty Vehicle CO_2 Emission Standards*), ICCT 2014b (*From Laboratory to Road: A 2014 update of official and "real-world" fuel consumption and CO_2 values for passenger cars in Europe*), ICCT 2014c (*Gap between reported and actual fuel economy*

[48] Note that for these BITRE results, vehicle stock projections (for each vehicle category) relate to estimated numbers of vehicles actually used on-road; that is, will sometimes differ slightly from total 'vehicle registration' levels. The annual stock evaluations make use of ABS SMVU estimates around the proportion of the vehicle fleet that, while registered for road use, does not perform any kilometres during the corresponding year.

higher than ever before), ICCT 2014d (*The WLTP: How a new test procedure for cars will affect fuel consumption values in the EU*), ICCT 2014e (*EU CO_2 Emission Standards for Passenger Cars and Light-Commercial Vehicles*), ICCT 2015 (*From Laboratory to Road: A 2015 update of official and "real-world" fuel consumption and CO_2 values for passenger cars in Europe*), Mock and German 2015 (*The future of vehicle emissions testing and compliance: How to align regulatory requirements, customer expectations, and environmental performance in the European Union*), Mock et al. 2013 (*From Laboratory to Road–A comparison of official and "real-world" fuel consumption and CO_2 values for cars in Europe and the United States*), TNO 2012 (*Supporting Analysis regarding Test Procedure Flexibilities and Technology Deployment for Review of the Light Duty Vehicle CO_2 Regulations*), Transport and Environment 2013 (*Mind the Gap! Why official car fuel economy figures don't match up to reality*), Transport and Environment 2015 (*How clean are Europe's cars?*) and US EPA 2014 (*Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends*);

- new information on fleet emission performance from real-world testing, including Australian results–e.g. from Smit & Kingston 2015a (*A Brisbane Tunnel Study to Validate Australian Motor Vehicle Emission Models)* and *2015b (A tunnel study to validate Australian motor vehicle emission software*), Smit et al. 2015 (*A Brisbane Tunnel Study To Assess Motor Vehicle Emission*); and international results–e.g. from Smit, Ntziachristos and Boulter 2010 (*Validation of road vehicle and traffic emission models–a review and meta-analysis*), Transport for London 2015 (*In-service emissions performance of Euro 6/VI vehicles: A summary of testing using London drive cycles*), ICCT 2014f and Franco et al. 2014 (*Real-World Exhaust Emissions From Modern Diesel Cars*), CAFEE 2014 (*In-Use Emissions Testing of Light-Duty Diesel Vehicles in the United States*), ICCT 2015b (*Real-world fuel consumption of popular European passenger car models*).

Based on expected manufacturing trends, the proportion of new vehicle models employing petrol (gasoline) direct injection (GDI) was assumed to increase, with GDI light vehicles (including turbocharged GDI, but generally stoichiometric rather than lean-burn GDI) possibly approaching half of new petrol-vehicle sales before 2025. If annual GDI sales do increase substantially, the passage of Euro 6 standards for pollutant emissions from light vehicles would tend to become more crucial–to help prevent any worsening of the health impacts of vehicle emissions (i.e. due to rising particulate emissions levels from GDI vehicles compliant only with Euro 5).

The emission modelling and health costings were further informed by the many submissions to the Ministerial Forum on Vehicle Emissions 2016 Discussion Paper and a range of studies looking into the details of vehicular PM emissions (both in mass terms and in particle number terms, especially with regards to output by GDI engines), on-road performance of modern emission control technology (including typical exceedance rates, above the relevant Euro standards, for PM and NO_x emissions from recent model vehicles) and/or the health impacts of pollutant emissions–including: ICCT 2015c (*NOx control technologies for Euro 6 Diesel passenger cars*), ICCT 2014g (*Real-World Emissions from Modern Diesel Cars*), Ulrich et al. 2012 (*Particle and metal emissions of diesel and gasoline engines–Are particle filters appropriate measures?*), Köhler 2013 (*Testing of particulate emissions from positive ignition vehicles with direct fuel injection system*), Kirchner et al. 2011 *(Investigation of Euro-5/6 Level Particle Number Emissions of European Diesel Light Duty Vehicles*), Mamakos et al. 2012a, 2012b and 2013 (*Cost effectiveness of particulate filter installation on Direct Injection Gasoline vehicles*), HEI 2010 (*Traffic Related Air Pollution: A critical review of the literature on emissions, exposure, and health effects*), Hime et al. 2015 *(Review of the health impacts of emission sources, types and levels of particulate matter air pollution in ambient air in NSW*), Howard 2015 (*Up in the Air–How to Solve London's Air Quality Crisis*), Transport and Environment 2013b, *Particle emissions from petrol cars*), DEFRA 2011, Boulter et al. 2012 (*The Evolution and Control of NO_x Emissions from Road Transport in Europe*), Giechaskiel et al. 2012, US EPA 2014b, AIRUSE 2015, Borken-Kleefeld & Chen 2014 (*New emission deterioration rates for gasoline cars–Results from long-term measurements*), and Ntziachristos & Samaras 2014.

Average Health Costs

Unit health cost values were sourced from BITRE's input into the Euro 5/6 light vehicle Regulation Impact Statement (RIS) (2010), updated to 2015-16 prices using the Consumer Price Index, and a literature review of relevant pollution costing studies (including those mentioned in the previous section). These estimates are presented in Table 16. For a detailed description of the earlier BITRE derivation methodology, refer to BITRE (2010a).

Table 16: Updated average health costs by area in 2015-16 prices

Area	CO ($/tonne)	HC/VOCs ($/tonne)	NOx ($/tonne)	PM_{10} ($/tonne)	Particle number ($/$10^{18}$ particles)
Values used in core analysis					
Capital cities	5	2,000	3,500	250,000	150
Rest of Australia	0.5	200	1,167	56,000	34
Upper bound					
Capital cities	8	6,000	5,250	500,000	300
Rest of Australia	1	300	1,750	84,000	50
Lower bound					
Capital cities	3	1,000	1,750	125,000	75
Rest of Australia	0.3	100	583	28,000	17

Source: BITRE estimates based on results from PAE Holmes (2013), Marsden Jacob Associates (2013), Mamakos et al. (2013), DEFRA (2011), Coffey Geosciences (2003), Watkiss (2002), Beer (2002) and Victoria Transport Policy Institute (2015)

The chosen unit health costs are very approximate, and have been averaged across a wide range of health impact studies, making use of (for PM mass values) detailed city-by-city (updated) values from the PAE Holmes 2013 report, *Methodology for valuing the health impacts of changes in particle emissions*.

In estimating such health benefits resulting from reductions in emissions, a wide range of damage cost values were used for sensitivity testing, reflecting significant uncertainty as to the actual health cost effects. This uncertainty was addressed via sensitivity tests at the upper and lower bound levels given in Table 16; with these high and low levels reflecting a typical spread in literature values where applicable, and simply set to ± 50 per cent from the chosen core values when such valuation limits/boundaries were less clear-cut.

Benefit-Cost Analysis

For the purpose of the benefit-cost analysis, the base and price year was set to 2016. The evaluation period goes out to 2040 to allow for 20-year analysis period after the proposed new ADR is introduced for all vehicle models in 2020, with a median light vehicle lifespan of 17 years. Following the recommendations in the Australian Government Guide to Regulation, the discount rate used to estimate the net benefits was seven per cent (with sensitivity tests set at ± 4 per cent, i.e. at low and high discount rates of three and 11 per cent). The key indicators for economic viability used in this benefit-cost analysis were net benefit and benefit-cost ratio. The core Euro 6 scenario was analysed against the business as usual case.

Business as Usual

The 'base case' or reference scenario emission projections used herein were estimated using primarily business as usual assumptions for the coming years. It was based on current trends in major economic and demographic indicators (with continuing growth in national population and average income levels, and only gradually increasing fuel prices) and likely future movements in vehicle technology. The following assumptions were made for the base case scenario:

- Proportion of new vehicle models employing petrol (gasoline) direct injection (GDI) assumed to increase, with GDI light vehicles (primarily stoichiometric) approaching half of new petrol-vehicle sales by 2025.
- Oil prices assumed to remain relatively close to current levels over the medium term and then gradually rise over ensuing decades–with the result that the resource cost of standard unleaded petrol (ULP) is set to increase around one per cent per annum, from current levels of about 70c/litre, over the projection period.
- Income grows in line with Treasury's latest Budget statements for the short term and their Intergenerational Report for the long term (Treasury 2015).
- Vehicle usage projections are based primarily on national population projections released by the ABS, using values to 2050 from their mid-range Population Projections trend–'Series B' (ABS 2013).
- Average fleet travel behaviour remains roughly the same as now with no major changes in the proportional activity of passenger and light commercial vehicles (though with projected growth in aggregate light commercial vehicle use, averaging around 2.3 per cent per annum, remaining marginally above that of passenger vehicles, at around 1.7 per cent per annum). Vehicle fleet fuel choice is also expected to remain fairly stable over the medium term (though allowance is made in the calculations for growing biofuel consumption, the continuing market share growth of premium gasoline blends[49], the current popularity of diesel light vehicles–especially in the Sports Utility Vehicle (SUV) and light commercial vehicle markets–and the niche use of alternatives such as natural gas and electricity).
- No change to current vehicle or fuel standards, with the new vehicle fleet generally meeting Euro 5 standards on-road with some NOx exceedances and Australia gaining some benefits from a sub-set of imported vehicles meeting stricter overseas pollution or efficiency standards.
- An increasing proportion of vehicles will use premium unleaded petrol (PULP) (95 or higher Research Octane Number (RON)), with extra demand for such fuels met by the existing fuel supply market
- Mid-range deterioration rates are assumed for fuel saving technology. Deterioration (or gradual degradation of vehicle emission systems over time) is likely to be slow, such that most vehicles would still have similar efficiency after about 10-15 years. A small proportion of the fleet, growing with vehicle age, will be less efficient, accounting for vehicles with poor service records or malfunctioning technology.

Euro 6 for Light Vehicles

Health Benefits

Table 17 and Table 18 present the modelling results for reductions in pollutants emitted ('000 tonnes) and health benefits ($m) for this scenario compared with the business as usual case.

The benefit totals provided in Tables 4 and 5 are conservative, in that they refer solely to changes in *primary* particulate volumes (i.e. those released directly from the vehicle exhausts), and do not include any additional reductions in *secondary* particulates, which are formed in the atmosphere from chemical processes involving vehicle exhaust emissions. The reductions in exhaust emission volumes flowing from implementation of the tighter standards are likely to lead to subsequent reductions in secondary particulate formation. However, due to the complicated nature of their formation, with rates typically strongly dependent on local atmospheric conditions, the exact amount of such reductions cannot be readily calculated. Given that eventual production of secondary particulate volumes from light vehicle emissions can be of a similar magnitude to the primary particulate output from those vehicle exhausts, and that the new standards are likely to reduce secondary nitrate aerosols as a result of a reduction in NOx light diesel vehicles (accompanied with some reduction in secondary sulfate aerosols as the petrol fleet moves further

[49] Which serves to lower the average sulphur content for overall gasoline consumption over time, but also leads to some increases in the average price paid (per litre) across the Australian gasoline market.

toward low sulfur blends), the health benefits provided are likely to underestimate actual particulate savings (probably by at least the order of 10-20 based on some rough modelling results)[50].

Table 17: Changes in emissions from the light vehicle fleet ('000 tonnes)

Year	HC	NOx	CO	PM	Number of Particles ($x10^{21}$)
2016	0.00	0.00	0.00	0.00	0
2017	0.00	0.00	0.00	0.00	0
2018	0.00	0.00	0.00	0.00	0
2019	-0.02	-1.89	0.00	-0.01	-69
2020	-0.09	-6.58	-0.42	-0.02	-197
2021	-0.22	-12.25	-1.60	-0.05	-355
2022	-0.37	-17.48	-3.13	-0.09	-499
2023	-0.53	-22.33	-4.83	-0.14	-636
2024	-0.69	-26.74	-6.70	-0.20	-772
2025	-0.86	-30.75	-8.76	-0.26	-908
2026	-1.04	-34.34	-10.97	-0.33	-1,046
2027	-1.22	-37.56	-13.32	-0.40	-1,184
2028	-1.41	-40.41	-15.78	-0.48	-1,400
2029	-1.60	-42.91	-18.35	-0.56	-1,504
2030	-1.80	-45.11	-21.03	-0.64	-1,610
2031	-2.00	-47.04	-23.79	-0.72	-1,721
2032	-2.20	-48.70	-26.59	-0.81	-1,832
2033	-2.40	-50.12	-29.41	-0.90	-1,950
2034	-2.60	-51.30	-32.20	-0.98	-2,071
2035	-2.79	-52.28	-34.93	-1.07	-2,190
2036	-2.97	-53.04	-37.60	-1.15	-2,312
2037	-3.15	-53.54	-40.18	-1.24	-2,433
2038	-3.31	-53.80	-42.60	-1.32	-2,549
2039	-3.48	-53.92	-45.07	-1.40	-2,668
2040	-3.62	-54.02	-47.29	-1.47	-2,779
Total	-38.4	-836.1	-464.6	-14.2	-32,685

Source: BITRE estimates (2016). Note that negative values imply a reduction in emissions.

Table 18: Health benefits ($m)

Year	HC	NOx	CO	PM	Number of Particles ($x10^{21}$)
2016	0.00	0.00	0.00	0.00	0.00
2017	0.00	0.00	0.00	0.00	0.00

50 A sensitivity test (provided in a later section) based on this rough modelling of possible impacts on secondary particulate formation yields an estimated net benefit result over 50 per cent higher than for the core scenario (only primary PM reductions) results.

Year	HC	NOx	CO	PM	Number of Particles (x10^{21})
2018	0.00	0.00	0.00	0.00	0.00
2019	0.02	5.06	0.00	1.10	7.44
2020	0.13	17.60	0.00	4.11	21.30
2021	0.33	32.75	0.01	9.48	38.63
2022	0.55	46.67	0.01	17.59	54.71
2023	0.78	59.54	0.02	27.24	70.06
2024	1.02	71.20	0.03	38.05	85.47
2025	1.28	81.75	0.03	50.02	101.05
2026	1.54	91.13	0.04	62.96	116.94
2027	1.82	99.53	0.05	76.76	132.92
2028	2.10	106.91	0.06	91.34	157.43
2029	2.39	113.33	0.07	106.59	170.01
2030	2.69	118.91	0.08	122.48	182.78
2031	2.99	123.78	0.09	138.85	196.13
2032	3.30	127.90	0.10	155.43	209.51
2033	3.60	131.36	0.11	172.29	223.54
2034	3.90	134.23	0.12	189.19	237.96
2035	4.19	136.56	0.13	206.02	252.25
2036	4.47	138.30	0.14	222.69	266.85
2037	4.74	139.38	0.15	238.98	281.32
2038	5.00	139.82	0.16	254.51	295.15
2039	5.25	139.95	0.17	270.00	309.22
2040	5.47	140.12	0.18	284.32	322.46
Total	57.5	2195.8	1.8	2,740.0	3,733.1

Source: BITRE estimates (2016).

Implementation Costs

To meet more stringent standards, continuous efforts will need to be made in improving and integrating existing known emission control technologies. These improvements are likely to incur additional costs. The available emission control technologies that may be adopted to meet the Euro 6 requirements are likely to include:

For all vehicles:

- Exhaust Gas Recirculation;
- OBD equipment.

For diesel vehicles:

- Diesel Particulate Filters / Diesel Oxidation Catalyst;
- Selective Catalytic Reduction using a Diesel Exhaust Fluid (a urea solution, also known as AdBlue);
- Lean NOx traps.

For petrol vehicles:

- Three way catalytic converters (for port fuel injected vehicles);
- Gasoline Particulate Filters/four-way catalysts (for direct injection vehicles);

- Lean NOx Traps (for lean burn direct injection vehicles).

Additional Capital Costs

Obtaining reliable cost estimates for emission control technologies and subsequent vehicle on-costs to users proved to be problematic due to the sensitive nature of cost information and difficulty in apportioning costs.

For this study, the cost estimates for vehicle emission control technologies were informed by estimates provided by the Federal Chamber of Automotive Industries (FCAI) to the Vehicle Emissions discussion paper, which estimated that the typical additional cost of supplying a Euro 6 compliant vehicle over a Euro 5 compliant vehicle ranges from $300 to $800 per vehicle (and up to $1,800 for some models).

Using the FCAI's submission (and a range of studies giving component costs for the above-mentioned control technologies), for petrol vehicles, the benefit-cost analysis employed a weighted fleet average, with extra costs ranging from $30 to $1,000 per vehicle depending on the technology used, and assumed most commonly to be in the $150 to $300 range. For diesel vehicles, the benefit-cost analysis used a weighted fleet average with extra costs ranging from $300 to $1,800 per vehicle depending on the technology used, and assumed most commonly to be in the $500 to $800 range.

This resulted in an estimated average capital cost required to meet the new standards of $160 per petrol vehicle and $550 per diesel vehicle, as outlined in Table 19.

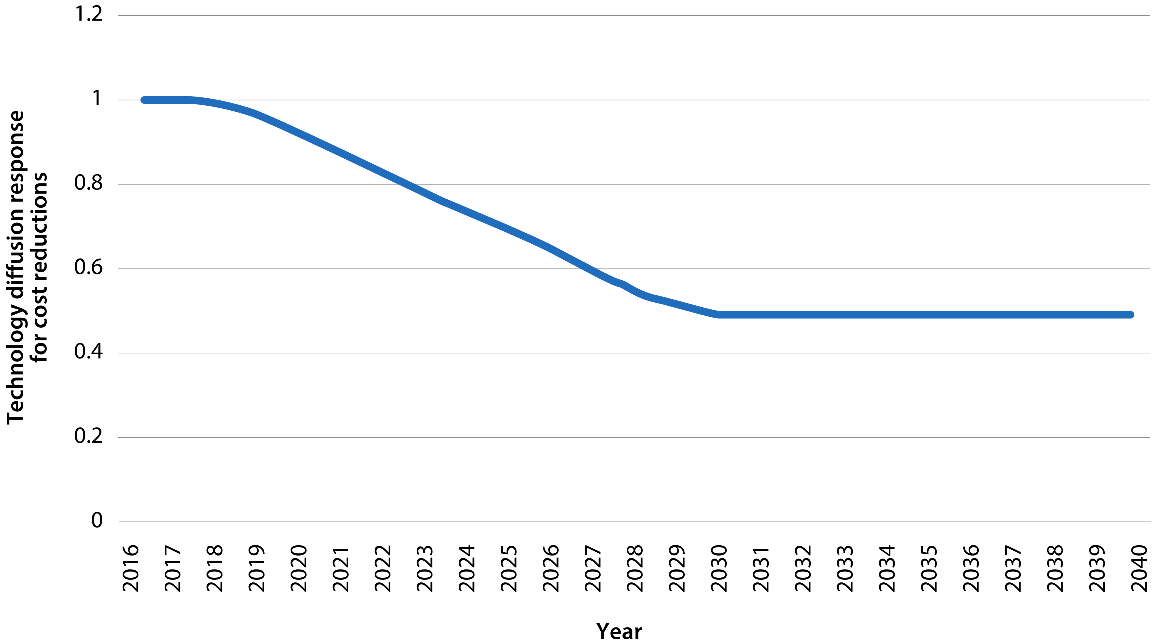
Table 19: Incremental vehicle costs ($A per vehicle, in 2016 prices)

Vehicle fuel type	Low	High	Weighted average
Petrol	$30	$1,000	$160
Diesel	$300	$1,800	$550

In estimating the additional unit vehicle cost for the Euro 6 scenario over time, it was assumed that incremental vehicle technology costs decline in response to the expected introduction of the new emission standards and with expansion of the market for the new technology overseas.

The assumed cost adjustment process follows the path shown in Figure 7, that is, the additional unit vehicle costs are kept constant to 2017, then drop in a fairly linear fashion by 50 per cent by 2030. As a result, by 2020 when Euro 6 is introduced for all vehicle models, the assumed additional capital cost is $500 per diesel vehicle and $145 per petrol vehicle (Figure 8). Economies of scale and learning processes are assumed to lead to further gradual reductions, to average per vehicle levels of $211 and $61 (across the diesel and petrol fleets respectively in 2030 when the assumed cost adjustment factor is at 50 per cent). These cost assumptions are tested by sensitivity scenarios in following sections.

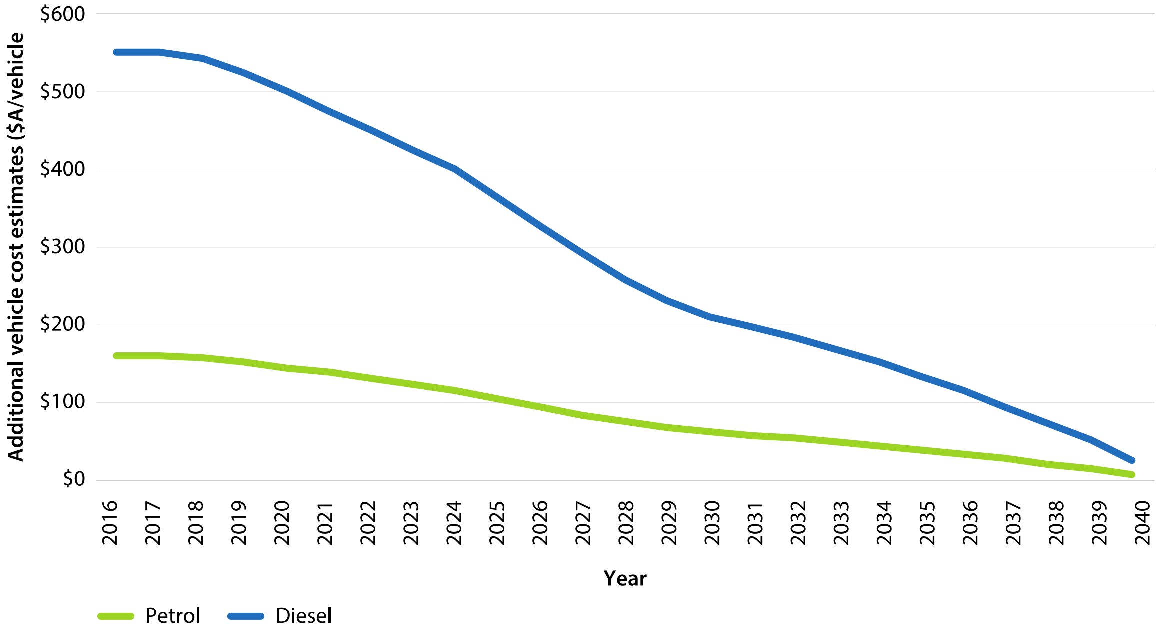
Figure 7: Assumed cost adjustment path



Emissions-reducing technology on vehicles purchased during most years of the evaluation period 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 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 fuel/emission-reducing technology are constant over the lives of the vehicles, an approximation to residual evaluation is obtained by prorating the cost of the technology over the lives of the vehicles, then only counting costs attributed to years before 2040.

The average vehicle life (median survival time) was assumed to be 17 years. For vehicles purchased during the later years of the evaluation period, the cost of the emissions-reducing technology was annuitised over 17 years at the standard discount rate of seven per cent. Annual costs for years after 2040 were omitted, consistent with the benefits for years 2040 onward being absent from the evaluation. Resulting pro-rata cost curves approach zero by the end of the evaluation period (e.g. with vehicles purchased in 2039 having only one year of cost included, since only one year of their fuel saving benefit is captured by the fleet assessments).

Figure 8: Additional pro rata vehicle cost estimates ($A per vehicle)

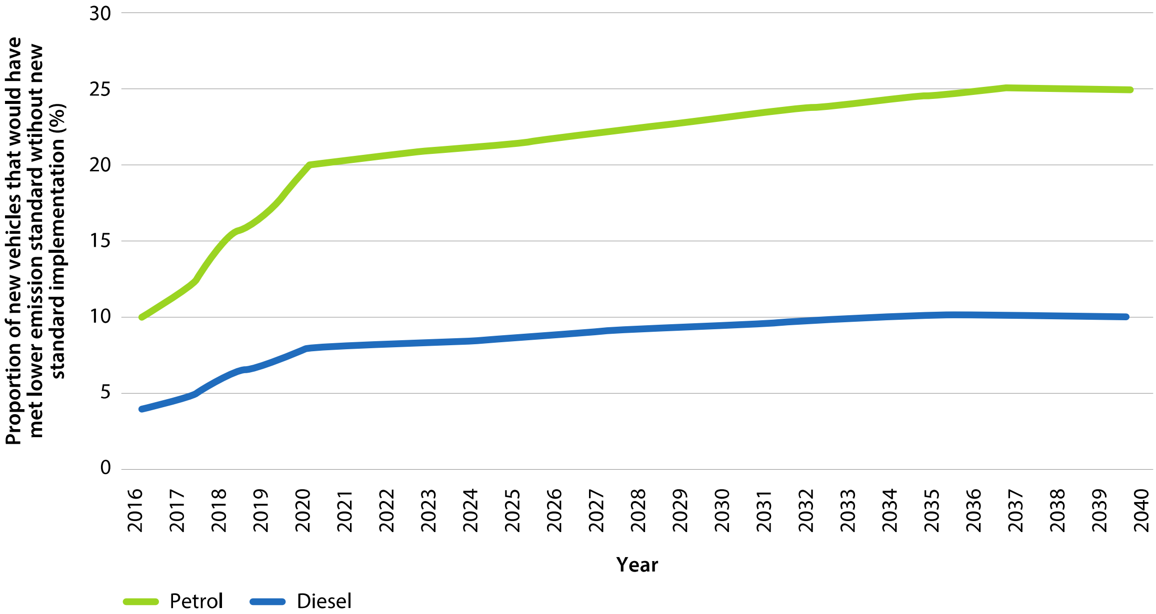


In estimating the total implementation costs, two further assumptions were made. Firstly, it was assumed that around 50 per cent of the vehicles sold in the introduction year would meet the standard's requirements (i.e. either not from a 'new' model line, and therefore initially exempt, or a model already having emissions below the new standard), so only 50 per cent of the new sales would attract an additional cost.

Secondly, 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, as shown in 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.

Though these future likely proportions are difficult to predict, their uncertain nature does not greatly affect the benefit-cost analysis results (since the estimated benefit-cost ratio values will not alter appreciably even if these assumed proportion values are set significantly higher or lower).

Figure 9: Assumed proportion of new vehicles that would have met the lower emission standard without new standards implementation



Net Economics Benefits and Benefit-Cost Ratio

Table 20 reports the benefit-cost analysis results for the Euro 6 scenario. On the cost side, there are net costs relating to the vehicle capital costs. On the benefits side, there are savings from the avoided health costs. Overall, benefits are higher than costs resulting in an overall discounted net benefit of $411 million (using a discount rate of seven per cent). The benefit-cost ratio is estimated to be 1.28.

It should be noted that this analysis omits some less quantifiable costs (such as maintenance costs) and benefits (such a reduction in secondary air pollutants) that may affect the benefit-cost ratio. The results are also fairly sensitive to the actual fleet technology mix (around engine/fuel types) that might result over the coming decades–where even greater than baseline levels of GDI and diesel vehicle use, as could be encouraged by manufacturers having to meet fuel/CO_2 intensity standards in the absence of upgraded pollution standards (such as Euro 6), could lead to significantly higher health damage costs. For example, an adjusted scenario that assumes petrol vehicle sales to be predominantly GDI variants by 2025 would probably have ‘health costs avoided’ totals (relative to Euro 5 compliant vehicles) around 30 per cent higher than those given in Table 20.

Table 20: Summary of costs and benefits under the Euro 6 scenario–undiscounted and discounted

Undiscounted cash flow

Financial year	Capital costs	Maintenance costs	Utility loss	Total costs	Fuel saving	GHG gas emissions avoided	Health costs avoided	Total benefits	Net benefit
2016	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2019	135.3	0.0	0.0	135.3	0.0	0.0	9.4	9.4	-125.9
2020	253.5	0.0	0.0	253.5	0.0	0.0	30.4	30.4	-223.1

Financial year	Capital costs	Maintenance costs	Utility loss	Total costs	Fuel saving	GHG gas emissions avoided	Health costs avoided	Total benefits	Net benefit
2021	241.0	0.0	0.0	241.0	0.0	0.0	57.1	57.1	-183.8
2022	227.8	0.0	0.0	227.8	0.0	0.0	83.4	83.4	-144.4
2023	214.5	0.0	0.0	214.5	0.0	0.0	109.0	109.0	-105.6
2024	201.4	0.0	0.0	201.4	0.0	0.0	134.0	134.0	-67.4
2025	182.3	0.0	0.0	182.3	0.0	0.0	158.6	158.6	-23.7
2026	163.7	0.0	0.0	163.7	0.0	0.0	182.7	182.7	19.0
2027	145.6	0.0	0.0	145.6	0.0	0.0	206.2	206.2	60.6
2028	128.2	0.0	0.0	128.2	0.0	0.0	233.5	233.5	105.2
2029	115.1	0.0	0.0	115.1	0.0	0.0	254.1	254.1	139.0
2030	105.8	0.0	0.0	105.8	0.0	0.0	274.3	274.3	168.5
2031	99.0	0.0	0.0	99.0	0.0	0.0	294.3	294.3	195.3
2032	91.8	0.0	0.0	91.8	0.0	0.0	313.8	313.8	222.0
2033	84.1	0.0	0.0	84.1	0.0	0.0	333.0	333.0	248.9
2034	75.7	0.0	0.0	75.7	0.0	0.0	351.8	351.8	276.1
2035	66.9	0.0	0.0	66.9	0.0	0.0	370.0	370.0	303.1
2036	57.3	0.0	0.0	57.3	0.0	0.0	387.7	387.7	330.4
2037	47.2	0.0	0.0	47.2	0.0	0.0	404.4	404.4	357.2
2038	36.6	0.0	0.0	36.6	0.0	0.0	419.8	419.8	383.3
2039	25.2	0.0	0.0	25.2	0.0	0.0	435.0	435.0	409.8
2040	13.0	0.0	0.0	13.0	0.0	0.0	449.2	449.2	436.2
Total	2,710.9	0.0	0.0	2,710.9	0.0	0.0	5,491.6	5,491.6	2,780.7

Discounted cash flow at 7 per cent

Financial year	Capital cost	Maintenance Cost	Utility loss	Total Costs	Fuel saving	GHG emissions avoided	Health costs avoided	Total benefits	Net benefit
2016	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2019	110.4	0.0	0.0	110.4	0.0	0.0	7.6	7.6	-102.8
2020	193.4	0.0	0.0	193.4	0.0	0.0	23.2	23.2	-170.2
2021	171.8	0.0	0.0	171.8	0.0	0.0	40.7	40.7	-131.1
2022	151.8	0.0	0.0	151.8	0.0	0.0	55.6	55.6	-96.2
2023	133.6	0.0	0.0	133.6	0.0	0.0	67.9	67.9	-65.7
2024	117.2	0.0	0.0	117.2	0.0	0.0	78.0	78.0	-39.2
2025	99.1	0.0	0.0	99.1	0.0	0.0	86.3	86.3	-12.9
2026	83.2	0.0	0.0	83.2	0.0	0.0	92.9	92.9	9.7
2027	69.2	0.0	0.0	69.2	0.0	0.0	98.0	98.0	28.8

Financial year	Capital cost	Maintenance Cost	Utility loss	Total Costs	Fuel saving	GHG emissions avoided	Health costs avoided	Total benefits	Net benefit
2028	56.9	0.0	0.0	56.9	0.0	0.0	103.7	103.7	46.7
2029	47.8	0.0	0.0	47.8	0.0	0.0	105.4	105.4	57.7
2030	41.0	0.0	0.0	41.0	0.0	0.0	106.4	106.4	65.4
2031	35.9	0.0	0.0	35.9	0.0	0.0	106.7	106.7	70.8
2032	31.1	0.0	0.0	31.1	0.0	0.0	106.3	106.3	75.2
2033	26.6	0.0	0.0	26.6	0.0	0.0	105.4	105.4	78.8
2034	22.4	0.0	0.0	22.4	0.0	0.0	104.1	104.1	81.7
2035	18.5	0.0	0.0	18.5	0.0	0.0	102.3	102.3	83.8
2036	14.8	0.0	0.0	14.8	0.0	0.0	100.2	100.2	85.4
2037	11.4	0.0	0.0	11.4	0.0	0.0	97.7	97.7	86.3
2038	8.3	0.0	0.0	8.3	0.0	0.0	94.8	94.8	86.5
2039	5.3	0.0	0.0	5.3	0.0	0.0	91.8	91.8	86.4
2040	2.6	0.0	0.0	2.6	0.0	0.0	88.5	88.5	86.0
Total	1,452.3	0.0	0.0	1,452.3	0.0	0.0	1,863.3	1,863.3	411.0

Sensitivity Tests on Euro 6 for Light Vehicles

Given the inevitable uncertainties with some of the assumptions used in the Euro 6 scenario, sensitivity tests were undertaken on the assumptions for:

- vehicle maintenance costs;
- health costs;
- discount rates;
- capital costs;
- reductions in secondary air pollutants;
- fuel consumption; and
- effects on greenhouse gas emissions.

Vehicle Maintenance Costs

It is anticipated that there will be some increase in maintenance costs, in particular for light diesel vehicles using selective catalytic reduction to meet Euro 6 requirements, as this technology requires motorists to use a consumable reagent to meet Euro 6 requirements. Due to limited information, additional maintenance costs were not included in the total costs of the core Euro 6 scenario, which will lead to a slight underestimation of the implementation costs.

To account for a possible increase in maintenance costs, a sensitivity test was applied to the Euro 6 scenario to roughly account for possible additional urea provision costs incurred for diesel vehicles meeting Euro 6 requirements. It was otherwise assumed that service schedules would remain roughly stable.

To roughly account for other possible maintenance costs, an additional sensitivity test was undertaken, to provide an estimate of the change to the derived benefit-cost ratio if total fleet service costs increased by the estimated cost of urea supply (required to meet the Euro 6 standards) multiplied by a factor of two. The inclusion of these additional maintenance costs led to a small change in the overall net benefit (Table 21).

Table 21: Changes to maintenance costs

Sensitivity test	Benefit-cost ratio	Net benefits ($m)
Core Euro 6 scenario	1.28	411
With an increase in maintenance costs based on additional urea costs only	1.26	385
With an increase in maintenance costs based on additional urea costs multiplied by a factor of 2	1.24	359

Health Costs

As discussed above, the unit health costs used in the core analysis of the Euro 6 scenario were substantially based on the unit health costs in the final RIS for Euro 5 and 6 (prepared by the Department of Infrastructure and Transport in November 2010, adjusted to 2015-16 prices); supplemented by results from a range of recent studies on the likely health costs associated with air pollution.

Sensitivity tests were undertaken for higher and lower estimates unit health costs. Under the rather unlikely scenario (given the levels most typically quoted in literature) where mean unit health cost values are reduced by 50 per cent, the introduction of the new standards for light vehicles would become economically unviable, with a benefit-cost ratio of 0.64 (Table 22).

Table 22: Changes to health costs

Sensitivity test	Benefit-cost ratio	Net benefits ($m)
Core Euro 6 scenario	1.28	411
Upper range values for unit health costs of air pollutants (50 per cent higher than core scenario)	2.27	1,847
Lower range values for unit health costs of air pollutants (50 per cent lower than core scenario)	0.64	-521

In their review of the benefit-cost analysis, ACIL Allen referred to a recent UK Department for Environment, Food and Rural Affairs report, which provided estimated ‘damage’ costs per tonne for NOx that were significantly higher than those used for this analysis.

If these high health costs for NOx given in the UK report were found to be valid for Australian conditions, BITRE has advised that the BCR would be strongly affected (with the current value close to 1.0 increasing to around 8.0).

Discount Rates

The core analysis of the Euro 6 scenario used the seven per cent discount preferred by the OBPR. The results of sensitivity testing in relation to the discount rates are shown in Table 23. With a discount rate of three per cent, the benefit-cost ratio reaches a value of 1.72. The results show that even with a high discount rate of 11 per cent, the benefit-cost ratio remains above one (1.11).

Table 23: Changes to discount rates

Sensitivity test	Benefit-cost ratio	Net benefits ($m)
Core Euro 6 scenario (7 per cent)	1.28	411
Low discount rate (3 per cent)	1.72	1,410
High discount rate (11 per cent)	1.11	107

Capital Costs

Due to difficulties in obtaining average capital cost estimates that could be independently verified, a sensitivity test was undertaken for the additional capital costs used in the core analysis of the

Euro 6 scenario (Table 24). If higher capital cost assumptions are used in the analysis, based on applying FCAI (2014) estimates (for the standard additional capital costs of supplying a fully Euro 6 compliant vehicle over one only compliant with Euro 5, for petrol and diesel) to the entire new vehicle fleet, as the input for average initial implementation costs, while retaining the downwards adjustment proportions for future economies of scale or from learning by doing, the benefit-cost ratio decreases to 0.79.

If the assumed average capital cost inputs are increased somewhat less appreciably, using the main scenario values for initial implementation but assuming no downwards adjustment proportions for future economies of scale or from learning by doing, the derived benefit-cost ratio also becomes less than 1, but decreases less (to 0.89).

Alternatively, if the capital cost inputs are decreased, towards lower range values from the literature, the benefit-cost ratio increases to 2.32.

Table 24: Changes to capital costs

Sensitivity test	Benefit-cost ratio	Net benefits ($m)
Core Euro 6 scenario	1.28	411
Upper range values for extra capital costs (higher values for initial implementation, though retain downwards adjustment for future economies of scale or from learning by doing)	0.79	-504
Higher values for extra capital costs (using Scenario 1 values for initial implementation, but assuming no downward cost adjustment over time for future economies of scale or from learning by doing)	0.89	-219
Lower range values for extra capital costs (retain downwards adjustment for future economies of scale or from learning by doing)	2.32	1,059

Reductions in Secondary Particulates

The health benefits estimated for the Euro 6 scenario in Table 17 and Table 18 are conservative, in that they do not include secondary particulates which are difficult to quantify precisely. The emission reductions in core Euro 6 scenario refer solely to changes in primary particulate volumes (i.e. those released directly from the vehicle exhausts), and do not include any reductions in secondary particulates (formed in the atmosphere from chemical processes involving vehicle exhaust emissions). The reductions in exhaust emission volumes flowing from implementation of the stronger standards are likely to lead to subsequent reductions in secondary particulate formation. However, due to the complicated nature of their formation, with rates typically strongly dependent on local atmospheric conditions, the exact amount of such reductions cannot be readily calculated. Table 25 shows the results of a sensitivity test conducted to estimate possible additional benefits associated with a reduction in secondary particulates, based on rough order-of-magnitude modelling of likely sulfate and nitrate formation changes.

Table 25: Changes to emissions inclusions

Sensitivity test	Benefit-cost ratio	Net benefits ($m)
Core Euro 6 scenario	1.28	411
Including a possible reduction in secondary particulates	1.45	652

Possible Effects on Fuel Consumption

The fuel economy of Euro 6 compliant light vehicles may be affected by the emission abatement technology used and duty cycles (the way in which the engine is going to be used and, in particular, how hot it is going to run). A sensible assumption would be that, in a competitive environment and regulatory pressure to reduce fuel consumption and CO_2 emissions in vehicle markets comprising 80 per cent of global vehicle sales, engine/vehicle manufacturers will make every effort to minimise fuel consumption to the lowest possible levels subject to the compliance with the Euro 6 standards. Based on this, possible additional fuel costs are assumed to be negligible in the Euro 6 scenario, and not included in the core results. This may lead to a slight underestimation of the implementation costs.

Table 26 shows the results of a rough sensitivity test conducted to account for a possible impact on fuel consumption[51].

Table 26: Possible higher fuel consumption

Sensitivity test	Benefit-cost ratio	Net benefits ($m)
Core Euro 6 scenario	1.28	411
Including possible impacts on fuel consumption	1.16	254

The fleet projections allow for an increasing proportion of future vehicle sales to use premium, lower sulfur gasoline–PULP (95 RON and 98 or higher RON). In the main scenario, this extra demand for such (generally lower sulfur) fuels is assumed able to be met by the existing fuel supply market–so no extra costs for further domestic petroleum desulfurisation are included in the core scenario results (though allowance is made for the higher average prices of premium blends, and thus the increased fleet fuel costs from their greater demand/consumption).

If the introduction of Euro 6 serves to further accelerate the take-up of premium blend (lower sulphur) gasolines, or if the increased demand for such fuels leads to a slight increase in the average supply cost (per litre sold, across all gasoline product types) for the retail petrol market, the benefit-cost ratio will be reduced further than in Table 13 scenario–with some further rough scenario modelling, of possible fuel mix impacts, deriving benefit-cost ratio values in the vicinity of one.

Possible Effects on Greenhouse Gas Emissions

If the technology required to meet Euro 6 led to a slight increase in fuel consumption, there would be increase in CO_2 emissions. However, total greenhouse gas emission impacts may possibly decrease due to Euro 6 effects on fleet particulate emissions, as a result of a reduction in black carbon emissions. The black carbon warming impact is often assessed as between 100 to 2000 times that of CO_2 (e.g. see discussions in BITRE 2010b and Mamakos et al. 2013), with a conservative value of 500 assumed in a sensitivity benefit-cost analysis.

For this sensitivity test, a value for future climate damages of $35 per tonne of CO_2 equivalent was used to estimate possible greenhouse benefits from a reduction in black carbon emissions. This unit value is based on appraisals conducted for the US Government on the social cost of carbon

[51] Note that the Table 26 estimates only include the extra fuel expenditure flowing from this scenario, and not possible greenhouse impacts. If the BCA results were calculated to also include an estimated cost for the consequent increase in CO_2 emissions (from this scenario's slightly higher fuel consumption), then the BCR would show a slight further reduction. E.g. using a value for the social cost of carbon at $35 per tonne of CO_2 emitted would reduce the estimated net benefit in Table 26 to about $239 million (at a BCR of about 1.15), and using the average price of abatement from the first three auctions of the Emissions Reduction Fund of around $12 per tonne would reduce the estimated net benefit to about $249 million. See next section about the 'cost' of carbon.

(SCC) and used by US federal agencies (such as the US EPA) to estimate the possible climate benefits of legislation.

Values for the social cost of carbon refer to a rough estimate of the present value of future economic damages (typically over the long-term) associated with an increase in CO_2 emissions of one tonne in a given year. Such dollar values, derived from this long-term cost discounting, are then taken to represent the value of damages avoided for a given emission reduction/abatement (i.e. an assigned benefit for a reduction in current CO_2-equivalent emissions).

Such modelled average ‘social cost of carbon’ values will typically differ from current costs expended on emission abatement measures, especially since such costs will vary significantly from measure to measure. Note that if the average price of abatement from the first three auctions of the Emissions Reduction Fund (ERF) of $12.10 per tonne was used in the Table 27 calculations for CO_2 equivalent black carbon impacts, then the estimated net benefit rise would be less; giving a rough value of about $421 million (at a benefit-cost ratio of about 1.29).

Table 27: Possible greenhouse gas emissions impacts

Sensitivity test	Benefit-cost ratio	Net benefits ($m)
Core Euro 6 scenario	1.28	411
Including possible effects on greenhouse gas emissions	1.30	438

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Appendix B–Euro VI Benefit-Cost Analysis

Executive Summary

The Department, through the Bureau of Infrastructure Transport and Regional Economics (BITRE), undertook a study to assess the benefits and costs associated with the introduction of Euro VI noxious emissions standards into the Australian heavy vehicle fleet. The core scenario analysed involved introducing Euro VI from 2019 for newly approved models and from 2020 for all new vehicles.

The main benefits identified were the health costs avoided due to lower emissions of noxious air pollutants as a result of stronger emissions standards. The identified costs mainly comprised additional capital, fuel and AdBlue/Diesel Exhaust Fluid costs, as well as potential losses in productivity (in the form of lost payload to remain within legal mass and dimension limits).

The benefit-cost analysis results (Table 28) show that this Euro VI scenario would have a net benefit of $264m over the period analysed, with a benefit-cost ratio of 1.13 (using a discount rate of seven per cent).

Table 28: Benefits, costs and benefit-cost ratio for mandating Euro VI for new heavy vehicles

Present value of costs ($m)	Present value of benefits ($m)	Net benefits ($m)	Benefit-cost ratio
2,095	2,359	264	1.13

All cost/price values (unless otherwise specified) are given in terms of 2015-16 Australian dollars.

The analysis focused on the benefits and costs that could be reliably quantified. Some possible costs were omitted from the analysis (such as maintenance costs) due to limited information and/or methodology to reliably estimate them, as well as some likely benefits (such as a reduction in secondary particulates and black carbon emissions) also being omitted due to methodological limitations. Some assessments of these possible additional costs and benefits were conducted in sensitivity analyses.

Introduction

The core scenario analysed involved introducing Euro VI through the ADRs from 2019 for newly approved models and 2020 for all new vehicles. Table 29 shows a more detailed description of this scenario.

Table 29: Details of the core scenario analysed

Standard	Vehicle group	Date of effect	Description of scenario
ADR 80/04 based on the final Euro VI requirements in UN regulation 49/06	All new heavy vehicles (over 3.5 tonnes)	2019 for newly approved light vehicle models and 2020 for all new heavy vehicles	Euro VI emission standards including only well-quantified benefit and cost categories

The main benefits identified were the health costs avoided due to lower emissions of pollutants as a result of stronger emissions standards. Other benefits such as increased visibility and reduced corrosion are difficult to quantify and likely to be minor. The identified costs mainly related to additional capital costs, fuel/urea expenses involved in meeting the new emission standards as well as a possible loss in productivity as a result of an increase in tare mass and consequential reduction in payload or seating capacity to stay within current mass and dimension requirements.

Due to data constraints, a simplified methodology was used to assess the health impacts of the reduced pollution from the introduction of Euro VI standards. It is akin to the approach used by

BITRE (2010a) in its analysis of the health impacts of introducing Euro 5 and 6 standards into the Australian light vehicle fleet. Unit health cost values were reviewed and, where necessary, updated.

The benefit-cost analysis results show that Euro 6 scenario analysed would yield a net present benefit of $264m over the analysis period (to 2040) and a benefit-cost ratio of 1.13 (using a discount rate of seven per cent).

Methodology for Estimating Health Benefits

The methodology employed to estimate the health benefits was largely the same as employed by BITRE (2010a) in its analysis of the health impacts of introducing Euro 5 and 6 standards into the Australian light vehicle fleet and is illustrated in Figure 10. The first step was to quantify the emissions of pollutants for the scenario under investigation and estimate tonnes of emissions saved (relative to the base case). The second step was to establish a value for an average health cost ($ per tonne of emissions) from existing studies. The final step was to calculate the total health benefits (i.e. health cost avoided) by multiplying tonnes of emissions saved by unit value(s) for health costs.

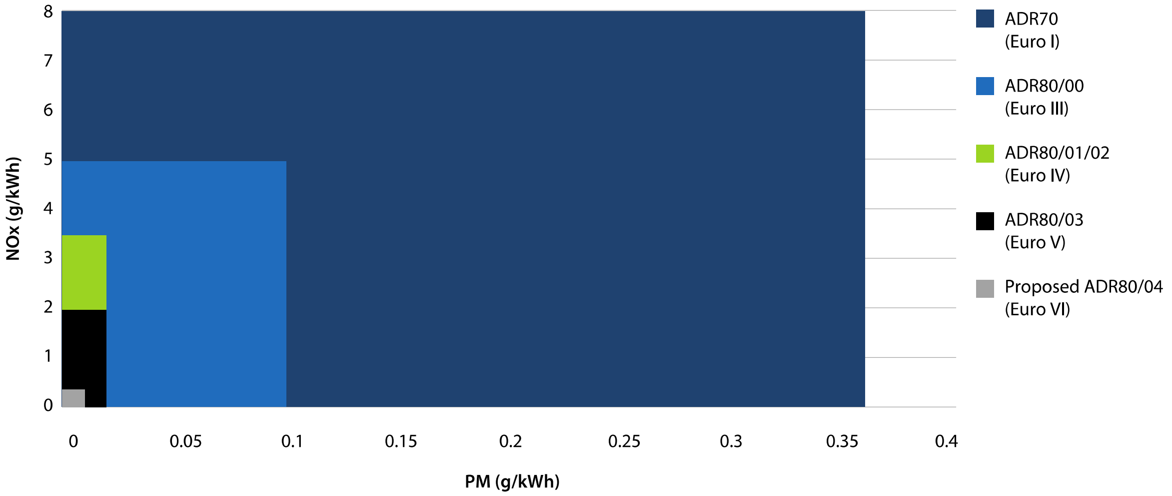
Figure 10: The study approach

Emissions of Air Pollutants

The main pollutants of concern for air quality emitted by motor vehicles are NOx (oxides of nitrogen), PM_{10} (particulate matter finer than 10 microns) and HC (volatile hydrocarbons).

Since the Australian Government first regulated noxious emissions through the ADRs, successive ADRs have been introduced to reduce the allowable exhaust emissions from heavy vehicles. The emission standards have generally followed the Euro standards (Euro I-VI) in terms of hydrocarbons, particulates and NOx emitted by a vehicle. Emissions are measured in grams per kilowatt hour (g/kWh). Figure 11 shows PM and NOx emission limits under the various ADRs for heavy vehicles. While the reduction in emission limits has been quite significant in percentage terms, the absolute amount of emissions reduced has become smaller for each successive ADR.

Figure 11: Historical heavy vehicle ADR emissions limits



Emissions of these pollutants from the Australian heavy vehicle fleet were modelled using a range of BITRE fleet and projection models; in particular, the BITRE MVEm suite, which estimates a wide range of pollutant emissions by vehicle type, when fed utilisation data from other BITRE projection models (such as TranSaturate). The MVEm models also roughly estimate possible order-of-magnitude effects for future urban traffic congestion levels (raising both average urban fuel consumption and noxious emission rates) on a city-by-city basis. The models take separate account of the articulated truck, rigid truck and commercial bus components of the heavy vehicle fleet.

Various input scenarios run on these models provide base case (business-as-usual) projections of emissions from the Australian heavy vehicle fleet over the medium to longer term, and estimate the possible emission changes flowing from the implementation of tighter vehicle standards. These models are described in a variety of BITRE publications, such as such as BITRE Working Paper 73, *Greenhouse Gas Emissions from Australian Transport: Projections to 2020* (BITRE 2009), *Modelling the Road Transport Sector* (BITRE & CSIRO 2008), *Urban Pollutant Emissions from Motor Vehicles: Australian Trends to 2020* (BTRE 2003), *Long-term Projections of Australian Transport Emissions: Base Case 2010* (BITRE 2010b).

Some further technical background material for emission projection scenario setting is discussed in Cosgrove, Gargett, Evans, Graham & Ritzinger 2012, *Greenhouse gas abatement potential of the Australian transport sector: Technical report from the Australian Low Carbon Transport Forum* (a joint BITRE, CSIRO and ARRB project) and BITRE Report 127 (2012), *Traffic Growth in Australia*.

The BITRE emissions projection modelling suite was updated and revised for this benefit-cost analysis using a wide range of studies/information, including:

- recent vehicle fleet composition data results from the Australian Bureau of Statistics (ABS) *Survey of Motor Vehicle Use* (ABS 2015a) and *Motor Vehicle Census* (ABS 2015b)[52];
- recent vehicle sales values from ABS (2016) *Sales of New Motor Vehicles, Australia* and FCAI VFACTS data;
- trend data on fuel consumption from the *Australian Petroleum Statistics* (Office of the Chief Economist 2016);
- vehicle activity forecasting trends discussed in BITRE Information Sheet 74 (2015), *Traffic and congestion cost trends for Australian capital cities*;

[52] Note that for these BITRE results, vehicle stock projections (for each vehicle category) relate to estimated numbers of vehicles actually used on-road; that is, will sometimes differ slightly from total ‘vehicle registration’ levels. The annual stock evaluations make use of ABS SMVU estimates around the proportion of the vehicle fleet that, while registered for road use, does not perform any kilometres during the corresponding year.

- various reports dealing with fleet modelling parameters–such as the Advisory Committee on Tunnel Air Quality (submission on Australian Government Vehicle Emissions Discussion Paper), or Smit 2014 (*Australian Motor Vehicle Emission Inventory for the National Pollutant Inventory*) which uses comprehensive vehicle emissions data within the COPERT Australia software–or market conditions and fuel intensity forecasts–such as KPMG International 2015 (*KPMG's Global Automotive Executive Survey*), FCAI (2015, 2016), IHS Consulting 2016 (*Global Automotive Regulatory Requirements: Regulatory Environment and Technology Roadmaps*), H-D Systems 2015 (*Heavy Duty Truck Fuel and Technology*), by CSIRO (e.g. Reedman & Graham 2013a, *Transport Sector Greenhouse Gas Emissions Projections 2013–2050*) or by ClimateWorks Australia (e.g. ClimateWorks Australia et al. 2014, *Pathways to Deep Decarbonisation in 2050*);
- improved information for on-road fuel intensity trends and on the typical disparities between test and actual on-road fuel consumption–such as provided by International Council on Clean Transportation (ICCT) 2012 (*Discrepancies between type approval and "real-world" fuel consumption and CO_2 values*), ICCT 2013b (*Measuring in-use fuel economy in Europe and the US: Summary of pilot studies*), ICCT 2014a (*Development of Test Cycle Conversion Factors among Worldwide Light-Duty Vehicle CO_2 Emission Standards*), ICCT 2014b (*From Laboratory to Road: A 2014 update of official and "real-world" fuel consumption and CO_2 values for passenger cars in Europe*), ICCT 2014d (*The WLTP: How a new test procedure for cars will affect fuel consumption values in the EU*), ICCT 2015 (*From Laboratory to Road: A 2015 update of official and "real-world" fuel consumption and CO_2 values for passenger cars in Europe*), Mock & German 2015 (*The future of vehicle emissions testing and compliance: How to align regulatory requirements, customer expectations, and environmental performance in the European Union*), Mock et al. 2013 (*From Laboratory to Road – A comparison of official and "real-world" fuel consumption and CO_2 values for cars in Europe and the United States*);
- new information on fleet emission performance from real-world testing, including Australian results–e.g. from Smit & Kingston 2015a (*A Brisbane Tunnel Study to Validate Australian Motor Vehicle Emission Models*) and 2015b (*A tunnel study to validate Australian motor vehicle emission software*), Smit et al. 2015 (*A Brisbane Tunnel Study To Assess Motor Vehicle Emission*); and international results–e.g. from Smit, Ntziachristos and Boulter 2010 (*Validation of road vehicle and traffic emission models–a review and meta-analysis*), Transport for London 2015 (*In-service emissions performance of Euro 6/VI vehicles: A summary of testing using London drive cycles*), ICCT 2014f and Franco et al. 2014 (*Real-World Exhaust Emissions from Modern Diesel Cars*), CAFEE 2014 (*In-Use Emissions Testing of Light-Duty Diesel Vehicles in the United States*), ICCT 2015b (*Real-world fuel consumption of popular European passenger car models*).

The emission modelling updates (which require information on characteristics of the entire fleet–both for light vehicles and heavy vehicles) and health costings for the benefit-cost analysis were further informed by submissions to the Ministerial Forum on Vehicle Emissions' 2016 discussion paper[53] and a range of studies looking into the details of vehicular emissions (especially with regards to heavy vehicle performance and for PM emissions in particle number terms), on-road performance of modern emission control technology (including typical exceedance rates, above the relevant Euro standards, for PM and NO_x emissions) and/or the health impacts of pollutant emissions–including: ICCT 2013, ICCT 2015c (*NO_X control technologies for Euro 6 Diesel passenger cars*), ICCT 2014g (*Real-World Emissions from Modern Diesel Cars*), ICCT 2015d (*Accelerating progress from Euro 4/IV to Euro 6/VI vehicle emissions standards*),TIC 2013 and 2013b, BIC 2012, Ulrich et al. 2012 (*Particle and metal emissions of diesel and gasoline engines–Are particle filters appropriate measures?*), Kirchner et al. 2011 (*Investigation of Euro-5/6 Level Particle Number Emissions of European Diesel Light Duty Vehicles*), Mamakos et al. 2013, Jamriska et al. 2004 (*Diesel Bus Emissions Measured in a Tunnel Study*), US EPA 2008 (*Average In-Use Emissions from Heavy-Duty Trucks*), HEI 2010 (*Traffic Related Air Pollution: A critical review of the literature on emissions, exposure, and health effects*), Hime et al. 2015 (*Review of*

[53] E.g. ATA submission – *Australian Government Vehicle Emissions Discussion Paper, Australian Trucking Association Response, 8 April 2016*

the health impacts of emission sources, types and levels of particulate matter air pollution in ambient air in NSW), Howard 2015 (*Up in the Air–How to Solve London's Air Quality Crisis*), DEFRA 2011, Boulter et al. 2012 (*The Evolution and Control of NO_x Emissions from Road Transport in Europe*), Giechaskiel et al. 2012, AIRUSE 2015, Borken-Kleefeld & Chen 2014, Ntziachristos & Samaras 2014, Mercedes-Benz 2013, DEKRA 2014, Clean Fleets 2014 (*Clean Buses–Experiences with Fuel and Technology Options*) and Posada et al. 2016 (*Costs of Emission Reduction Technologies for Heavy-Duty Diesel Vehicles*).

Average Health Costs

Unit health cost values were sourced from BITRE's input into the Euro 5/6 light vehicle Regulation Impact Statement (RIS) (2010), updated to 2015-16 prices using the Consumer Price Index, and a literature review of relevant pollution costing studies (including those mentioned in the previous section). These estimates are presented in Table 30. For a detailed description of the earlier BITRE derivation methodology, refer to BITRE (2010a).

Table 30: Updated average health costs by area in 2015–16 prices

Area	CO ($/tonne)	HC/VOCs ($/tonne)	NOx ($/tonne)	PM10 ($/tonne)	Particle number ($/$10^{18}$ particles)
Core Euro VI scenario values					
Capital cities	5	2,000	3,500	250,000	150
Rest of Australia	0.5	200	1,167	56,000	34
Upper bound					
Capital cities	8	6,000	5,250	500,000	300
Rest of Australia	1	300	1,750	84,000	50
Lower bound					
Capital cities	3	1,000	1,750	125,000	75
Rest of Australia	0.3	100	583	28,000	17

Source: BITRE estimates based on results from PAE Holmes (2013), Marsden Jacob Associates (2013), Mamakos et al. (2013), DEFRA (2011), Coffey Geosciences (2003), Watkiss (2002), Beer (2002) and Victoria Transport Policy Institute (2015)

The chosen unit health costs are very approximate, and have been averaged across a wide range of health impact studies, making use of (for PM mass values) detailed city-by-city (updated) values from the PAE Holmes 2013 report, *Methodology for valuing the health impacts of changes in particle emissions*.

In estimating such health benefits resulting from reductions in emissions, a wide range of damage cost values were used for sensitivity testing, reflecting significant uncertainty as to the actual health cost effects. This uncertainty was addressed via sensitivity tests at the upper and lower bound levels given in Table 16; with these high and low levels reflecting a typical spread in literature values where applicable, and simply set to ± 50 per cent from the chosen core values when such valuation limits/boundaries were less clear-cut.

Benefit-Cost Analysis

For the purpose of the benefit-cost analysis, the base and price year was set to 2016. The evaluation period goes out to 2040 to allow for 20-year analysis period after the proposed new ADR is introduced for all vehicle models in 2020. This is consistent with the median survival period of a heavy vehicle of 20 years.

Following the recommendations in the Australian Government Guide to Regulation, the discount rate used to estimate the net benefits was seven per cent (with sensitivity tests conducted at three and 11 per cent). The key indicators for economic viability used in this benefit-cost analysis were net benefit and benefit-cost ratio. The core Euro VI scenario was analysed against the business as usual case.

Business as Usual

The 'base case' or reference scenario emission projections used herein were estimated using primarily business as usual assumptions for the coming years. It was based on current trends in major economic and demographic indicators (with continuing growth in national population and average income levels, and only gradually increasing fuel prices) and likely future movements in freight sector performance and vehicle technology. The following assumptions were made for the base case scenario:

- Oil prices remain relatively close to current levels over the medium term then gradually rise over ensuing decades–with the result that the resource cost of automotive diesel (ADO) is set to increase around one per cent per annum, from current levels of about 70c/litre, over the projection period.
- Income grows in line with Treasury's latest Budget statements for the short term and their Intergenerational Report for the long term (Treasury 2015).
- Heavy vehicle usage projections are in line with the Treasury economic growth projections (Treasury 2015); national population projections released by the Australian Bureau of Statistics (ABS), using values to 2050 from their mid-range Population Projections trend–'Series B' (ABS 2013); and major commodity projections released by the Office of the Chief Economist (e.g. OCE 2016, *Resource and Energy Quarterly*).
- Average fleet travel behaviour remains roughly the same as now (with no major changes to freight modal shares, and growth in aggregate freight demand linked to GDP growth). Vehicle fleet fuel choice is also assumed to remain basically stable over the medium term–i.e. for diesel to continue as the dominant fuel type for Australian heavy vehicles (though allowance is made in the calculations for growing biodiesel consumption and the niche use of alternatives such as natural gas and electricity).
- No change to current vehicle or fuel standards, with the new heavy vehicle fleet generally meeting Euro V standards on road (though with some NOx exceedances) and Australia gaining some benefits from a sub-set of imported engines/vehicles meeting stricter overseas pollution standards.
- Mid-range deterioration rates were assumed for the emissions-reducing technology. Deterioration (or gradual degradation of vehicle emission systems over time) is likely to be slow, such that most vehicles would still be within the relevant emissions standards after about 10–15 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 equipment.

Euro VI for Heavy Vehicles

Health Benefits

Table 31 and Table 32 present the modelling results for reductions in pollutants emitted ('000 tonnes) and health benefits ($m) for this scenario compared with the business as usual case.

The benefit totals provided below are conservative, in that they refer solely to changes in *primary* particulate volumes (i.e. those released directly from the vehicle exhausts), and do not include any additional reductions in *secondary* particulates, which are formed in the atmosphere from chemical processes involving vehicle exhaust emissions. The reductions in exhaust emission volumes flowing from implementation of the tighter standards are likely to lead to subsequent reductions in secondary particulate formation. However, due to the complicated nature of their formation, with rates typically strongly dependent on local atmospheric conditions, the exact amount of such reductions cannot be readily calculated. Given that secondary particulate volumes from vehicle exhausts can be of a similar magnitude to the primary particulate output, and that the new standards are likely to reduce secondary nitrate aerosols as a result of strong reductions in NOx (particularly from diesel vehicles), the health benefits provided are likely to underestimate actual

particulate savings, perhaps by the order of
20 per cent (based on some rough modelling results).

Table 31: Changes in emissions from the heavy vehicle fleet ('000 tonnes)

Year	HC	NOx	CO	PM	Number of Particles (x10^{21})
2016	0.00	0.00	0.00	0.00	0.00
2017	0.00	0.00	0.00	0.00	0.00
2018	0.00	0.00	0.00	0.00	0.00
2019	-0.02	-1.47	0.00	-0.01	-93.29
2020	-0.10	-6.32	-0.07	-0.06	-352.56
2021	-0.23	-13.96	-0.20	-0.12	-615.66
2022	-0.36	-22.40	-0.33	-0.19	-854.11
2023	-0.50	-30.76	-0.48	-0.27	-1,070.22
2024	-0.64	-39.04	-0.62	-0.35	-1,266.89
2025	-0.79	-47.24	-0.78	-0.43	-1,455.41
2026	-0.94	-55.27	-0.93	-0.51	-1,631.68
2027	-1.09	-63.11	-1.09	-0.60	-1,798.59
2028	-1.25	-70.72	-1.25	-0.69	-1,956.51
2029	-1.40	-78.04	-1.40	-0.78	-2,102.28
2030	-1.55	-85.10	-1.55	-0.86	-2,234.23
2031	-1.70	-91.61	-1.70	-0.95	-2,351.32
2032	-1.84	-97.71	-1.84	-1.03	-2,452.14
2033	-1.97	-103.39	-1.97	-1.11	-2,541.02
2034	-2.11	-108.75	-2.09	-1.19	-2,620.79
2035	-2.23	-113.75	-2.21	-1.26	-2,688.13
2036	-2.35	-118.27	-2.32	-1.32	-2,748.66
2037	-2.45	-122.30	-2.41	-1.38	-2,800.82
2038	-2.55	-125.97	-2.50	-1.44	-2,846.36
2039	-2.65	-129.47	-2.59	-1.49	-2,886.28
2040	-2.74	-132.54	-2.67	-1.54	-2,918.45
Total	-31.5	-1657.2	-31.0	-17.6	-42,285

Source: BITRE estimates (2016). Note that negative values imply a reduction in emissions.

Table 32: Health benefits ($m)

Year	HC	NOx	CO	PM	Number of Particles (x10^{21})
2016	0.00	0.00	0.00	0.00	0.00
2017	0.00	0.00	0.00	0.00	0.00
2018	0.00	0.00	0.00	0.00	0.00
2019	0.02	3.04	0.00	1.98	8.11
2020	0.10	13.22	0.00	8.07	30.87

Year	HC	NOx	CO	PM	Number of Particles (x10^{21})
2021	0.22	29.38	0.00	17.01	54.17
2022	0.36	47.46	0.00	27.07	75.51
2023	0.50	65.62	0.00	37.89	95.12
2024	0.66	83.83	0.00	49.50	113.22
2025	0.82	102.08	0.00	61.84	130.75
2026	0.98	120.14	0.00	74.76	147.38
2027	1.16	137.96	0.00	88.12	163.22
2028	1.33	155.36	0.00	101.75	178.25
2029	1.50	172.14	0.00	115.31	191.98
2030	1.68	188.46	0.00	128.96	204.54
2031	1.85	203.45	0.00	142.39	215.75
2032	2.01	217.57	0.01	155.43	225.50
2033	2.17	230.77	0.01	167.91	234.00
2034	2.33	243.25	0.01	179.95	241.65
2035	2.48	254.91	0.01	191.34	248.16
2036	2.62	265.50	0.01	201.82	254.07
2037	2.75	274.96	0.01	211.32	259.18
2038	2.86	283.58	0.01	220.17	263.65
2039	2.99	291.80	0.01	228.53	267.56
2040	3.10	299.01	0.01	235.76	270.73
Total	34.5	3,683.5	0.1	2,646.9	3,873.4

Source: BITRE estimates (2016).

Implementation Costs

The available emission control technologies for diesel engines include, among other measures,

- Exhaust Gas Recirculation;
- Diesel Particulate Filters / Diesel Oxidation Catalyst;
- Selective Catalytic Reduction using a Diesel Exhaust Fluid (a urea solution, also known as AdBlue); and
- OBD equipment.

For the current ADR 80/03 standards, most duty vehicles use either Exhaust Gas Recirculation and Diesel Particulate Filters or Selective Catalytic Reduction technology. To meet the more stringent ADR 80/04 standards, continuous efforts would need to be made in improving and integrating existing known emission control and diagnostic technologies. It has become apparent that most manufacturers will have to use integrated Exhaust Gas Recirculation and Selective Catalytic Reduction systems with Diesel Particulate Filters to achieve extremely low levels of emissions set out in the proposed ADR80/04 standards (Commercial Vehicle Engineer 2012). These improvements are likely to incur additional costs as well as adding mass to the vehicle.

The technologies available for natural gas vehicles (mostly buses) to reduce their emissions include both stoichiometric and lean burn engines. According to TNO (2006), all of the possible scenarios for Euro VI may potentially be met by stoichiometric engines with technologies that are more or less available today. The lean burn technology, while having higher fuel efficiency, suffers from relatively high NOx emissions. Like diesel vehicles, selective catalytic reduction can be installed to reduce the NOx emissions to acceptable levels.

For adequate NOx control, the base case assumption is that most heavy vehicle manufacturers will opt for Selective Catalytic Reduction on their Euro V-compliant vehicles (with the business as usual scenario input being that 85 per cent of new heavy diesel vehicles will use Selective Catalytic Reduction over the longer term).

Under the Euro VI scenario, it was assumed that heavy vehicle manufacturers will end up fitting both Exhaust Gas Recirculation and Selective Catalytic Reduction to nearly all vehicles in order to meet the low NOx levels required by Euro VI (with the input for regulated scenarios being 98 per cent of new heavy diesel vehicles using Selective Catalytic Reduction over the longer term).

Additional Capital Costs

Obtaining reliable cost estimates for emission control technologies and subsequent heavy vehicle on-costs to users has proved to be problematic due to the sensitive nature of cost information and difficulty in apportioning costs. There have been some attempts in this regard (for example, TNO (2006) on which the EU's RIS was based), but the study was undertaken many years before Euro VI vehicles were actually introduced and is therefore outdated. However, it still contains useful information for comparison purposes. For the present study, the cost estimates for vehicle emission control technologies: were informed by submissions by the Truck Industry Council, NC2 Global Australia and the Bus Industry Confederation to the Department of Infrastructure and Transport's 2012 Review of Emission Standards (Euro VI) for heavy vehicles discussion paper and reference estimates from more recent European studies, such as the ICCT report *Costs of Emission Reduction Technologies for Heavy-Duty Diesel Vehicles* (Posada et al. 2016); and make use of the additional cost range estimates provided by the ATA submission to the 2016 Vehicle Emissions discussion paper.

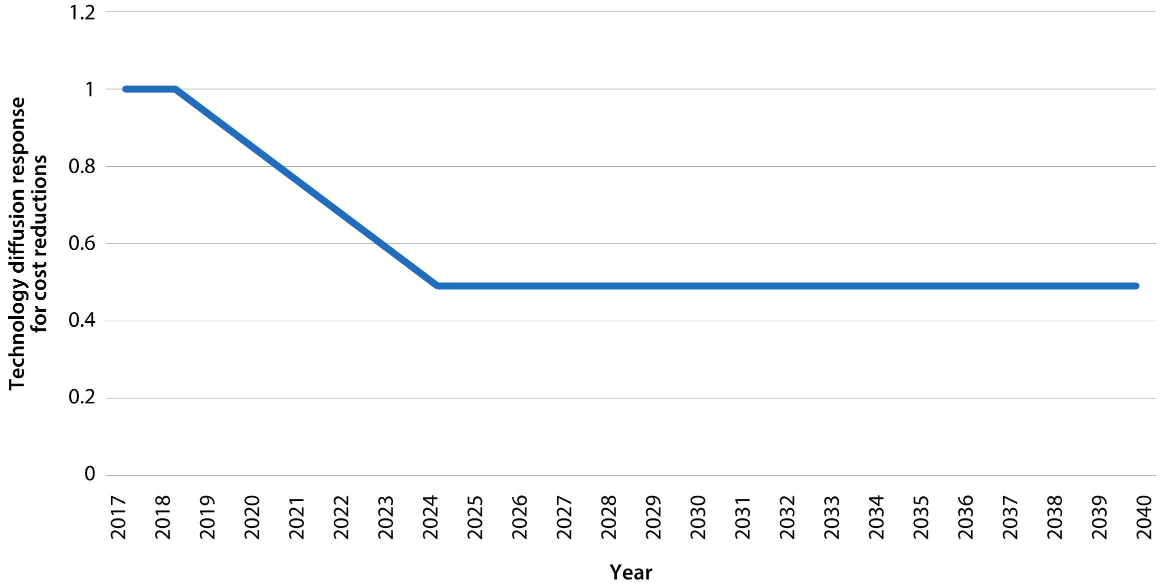
Based on these submissions, three scenarios (namely low, high and average cost) were used to cover the likely range of additional Euro VI costs for heavy vehicles (Table 33). The average capital cost required to meet the new standards is roughly estimated to be $10,500 per vehicle.

Table 33: Incremental vehicle costs ($A per vehicle, in 2016 prices)

	Low	Average	High
Heavy vehicle additional cost	$6,000	$10,500	$15,000

In estimating the additional unit vehicle cost for each scenario over time, it was assumed that incremental vehicle technology costs (reported in Table 33) decline in response to the expected introduction of the new emission standards and with expansion of the market for the new technology overseas. The assumed cost adjustment process follows the path shown in Figure 12. That is, the additional unit vehicle costs are kept constant to 2019, then drop in a linear fashion by 50 per cent by 2024. As a result, by 2020, when Euro VI standards are introduced for all vehicle models, the assumed additional capital cost is $8,750 (Figure 13). This will go down further to $5,250 in 2024 when the assumed cost adjustment factor is at 50 per cent. These adjusted estimates are roughly in line with the values suggested in TNO (2006) and ICCT (2013).

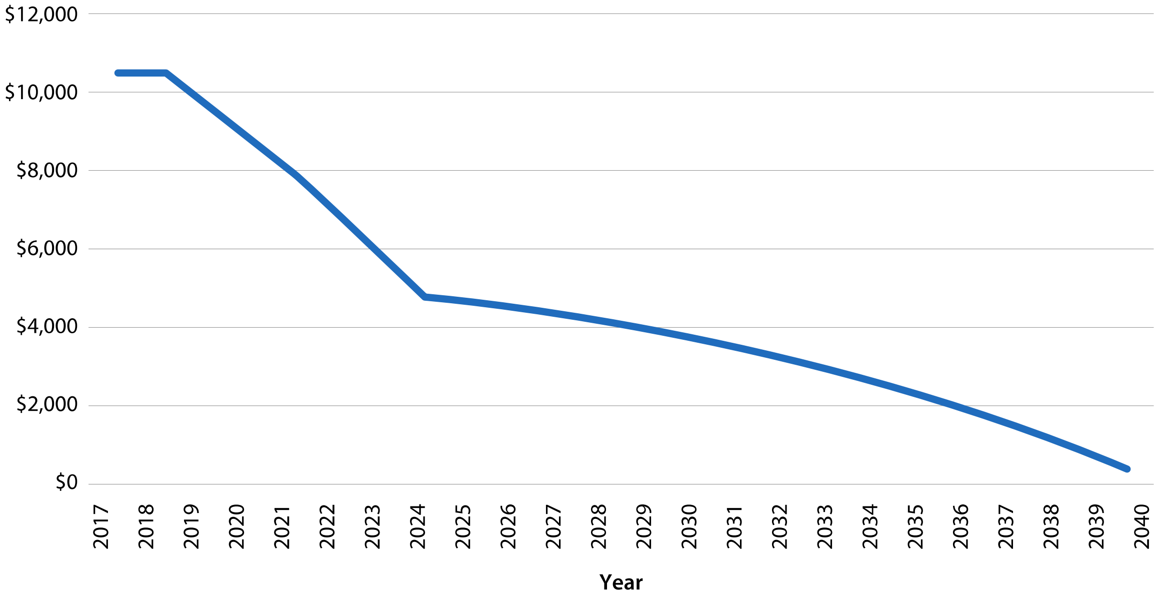
Figure 12: Assumed cost adjustment path



Emissions-reducing technology on vehicles purchased during most years of the evaluation period 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 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 fuel/emission-reducing technology are fairly constant over the lives of the vehicles, an approximation to residual evaluation was obtained by prorating the cost of the technology over the lives of the vehicles, then only counting costs attributed to years before 2040.

The average vehicle life (median survival time) was assumed to be 20 years. For vehicles purchased during the later years of the evaluation period, the cost of the emissions-reducing technology was annuitised over 20 years at the standard discount rate of seven per cent. Annual costs for years after 2040 were omitted, consistent with the benefits for years 2040 onward being absent from the evaluation. Resulting pro-rata cost curves approach zero by the end of the evaluation period (e.g. with vehicles purchased in 2039 having only one year of cost included, since only one year of their emission saving benefit is captured by the fleet assessments).

Figure 13: Additional vehicle cost estimates ($A per vehicle, pro rata)



In estimating the total implementation costs, two further assumptions were made. Firstly, it was assumed that around 50 per cent of the vehicles sold in the introduction year 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 per cent of the new sales would attract an additional cost.

Secondly, 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, this was set to 10 per cent. 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.

Additional Maintenance Costs

It is anticipated that there will be some increase in the maintenance costs for heavy vehicles, notably in relation to the exhaust after-treatment system. Over the longer run, as the technology becomes more mature, maintenance costs may reduce. Due to limited information, additional maintenance costs are not included in the core Euro VI scenario. This will lead to a slight under-estimation of the total implementation costs. The possible effects of an increase in maintenance costs are, however, considered as a sensitivity test.

Additional Fuel Costs

Fuel economy of Euro VI compliant heavy vehicles depends on the emission abatement technology used and duty cycles (the way in which engine is going to be used and, in particular, how hot it is going to run) (Commercial Vehicle Engineer 2012). A sensible assumption would be that, in a competitive environment, engine/vehicle manufacturers would make every effort to minimise fuel consumption to the lowest possible levels subject to the compliance with the Euro VI standards.

In the scenario analysed, average fuel consumption of Euro VI compliant heavy vehicles was assumed to be typically around 0.5-1 per cent higher than if they did not have to meet the tighter emission standard (i.e. relative to equivalent Euro V counterparts) due to heavier vehicle mass and more use of Exhaust Gas Recirculation systems which tend to be less fuel efficient. As a rule of thumb, fuel consumption will generally increase by around one per cent for every tonne of mass added. This means that adding 300 kg of fitments (Table 35) would typically lead to around a 0.3 per cent increase in average fuel consumption for Euro VI compliant heavy vehicles. It is implicitly assumed for the remaining 0.2-0.7 per cent increase in average fleet fuel consumption to be mainly due to higher adoption of Exhaust Gas Recirculation technology.

Fuel penalty effects caused by emission control measures may be neutralised to some extent by heavy vehicle manufacturers through developing better engine/vehicle technology, although this would lead to higher initial capital costs. Sensitivity tests were undertaken to gauge the impact of alternative fuel consumption scenarios on the outcome of the economic evaluation.

Costs Associated with the Use of Urea

Adoption of the Selective Catalytic Reduction technology will involve use of urea (Diesel Exhaust Fluid or AdBlue), where the typical use of urea solution is equivalent to between about 2–5 per cent of total diesel consumption, depending upon the particular technology implementation. The price of urea is similar to that of diesel, although it has been subject to more fluctuation (ICCT 2013).

The available evidence suggests that Euro VI heavy vehicles will generally have lower urea consumption than Euro V heavy vehicles. To meet the tighter standards most manufacturers will have to use both Selective Catalytic Reduction and Exhaust Gas Recirculation (whereas to meet Euro V they tend to only need one of these technologies, with most opting for Selective Catalytic Reduction) (Table 34). The addition of Exhaust Gas Recirculation to a Selective Catalytic Reduction-fitted vehicle tends to reduce the amount of NO_x emissions that the Selective Catalytic Reduction system has to cope with, thus substantially reducing the rate of urea use per km (compared to a SCR-only vehicle), with this effect likely to be more advantageous during stable than transient operation.

The base case thus has most heavy diesel vehicles eventually using urea (to comply with Euro V standards), and the Euro VI scenario has practically all heavy diesel vehicles eventually using urea. The predicted result is that a move to Euro VI will entail some more vehicles using urea than the base case, but with often reduced rates of urea consumption per vehicle, the overall use of urea (under the Euro VI scenario assumptions/inputs) may even fall. The extent of this possible fall is uncertain (and may depend on how much heavy vehicle travel is under steady state rather than transient operation) and sensitivity tests are carried out to assess the impact of alternative assumptions.

Table 34: Characterisation of technologies

Technology	NOx	PM_{10}	Fuel	Urea
Exhaust Gas Recirculation and Diesel Particulate Filters	Decrease	Decrease	Increase	N/A
Selective Catalytic Reduction and Diesel Oxidation Catalyst (Most common for Base case –Euro V standards)	Decrease	Decrease	Decrease	Increase
Typical Combination of the above (Euro VI standards)	Decrease	Decrease	Slight Increase (over Euro V)	Slight Decrease (over Euro V)

Productivity Loss

The new emissions control technologies may require further addition of fitments to heavy vehicles that add to weight and/or take space. For example, Selective Catalytic Reduction requires a tank to be fitted to the truck to carry urea that is used in the reduction process, which will in turn add to the weight on the steer axle.

More efficient and larger cooling systems may also be required for Exhaust Gas Recirculation (TIC 2013). It is considered that, on average, an extra 300 kg will be added to the weight of a typical heavy vehicle as a result of the introduction of the Euro VI standards (Table 35). Some reductions in average driving range may also eventuate.

Table 35: Typical net increase in heavy vehicle weight (kg), for Euro VI over Euro V

	Minimum	Average	Maximum

	Minimum	Average	Maximum
NC2 Global Australia (2013)	250	275	300
TIC (2013)	250	350	450
BIC (2013)	300	325	350
Average	267	317	367
Modelled scenarios	250	300	350

The general industry view is that the Euro VI technology and equipment will lead to a loss in productivity in the form of reduced payload for trucks or seating capacity for buses/coaches unless legal mass and dimensional limits are relaxed.

There are a number of ways of estimating the impact of new emission control technologies on productivity, depending on the type of legislation that the government may enact, such as:

1. Estimating the cost of the reduced payload or seating capacity directly, assuming no change in legal mass and dimensional limits;
2. Estimating the road damage cost caused by higher front steer axle mass, assuming relaxation of mass and dimensional limits, and hence no change in productivity; or
3. Estimating the road damage control costs, assuming an additional regulatory impost requiring wider profile steer tyres to be used to mitigate the road damage costs from relaxation of mass and dimensional limits.

Ideally, all the three of the above points should be evaluated and the one that generates the least cost should be selected for inclusion into the benefit-cost analysis. However, due to data limitations, only points 1 and 2 were assessed for this study.

Loss of payload

In estimating the productivity loss, the focus is on the reduced payload for trucks assuming the mass limit is unchanged. Trucks account for around 87.5 per cent of the total forecast new heavy vehicle sales, so they would account for the majority of loss in productivity for heavy vehicles. Explicit estimation of the costs associated with the loss in seating capacity for buses/coaches was not undertaken in the absence of any unambiguous supporting evidence[54] and due to a lack of a clear workable framework and data[55], and it was simply assumed that a portion of the new bus fleet would incur annual productivity losses of a similar magnitude to an equivalently sized truck.

One method for evaluating the possible impost of the extra vehicle weight is to estimate the lost revenue associated with the reduction in payload; another is to estimate the extra trucking cost to move the freight left behind from existing (otherwise overloaded) vehicles. The methodology used in this study is based on the former approach, with outcomes heavily dependent on the assumptions made on a number of key factors.

In estimating the lost revenue per truck per year the following assumptions are made:

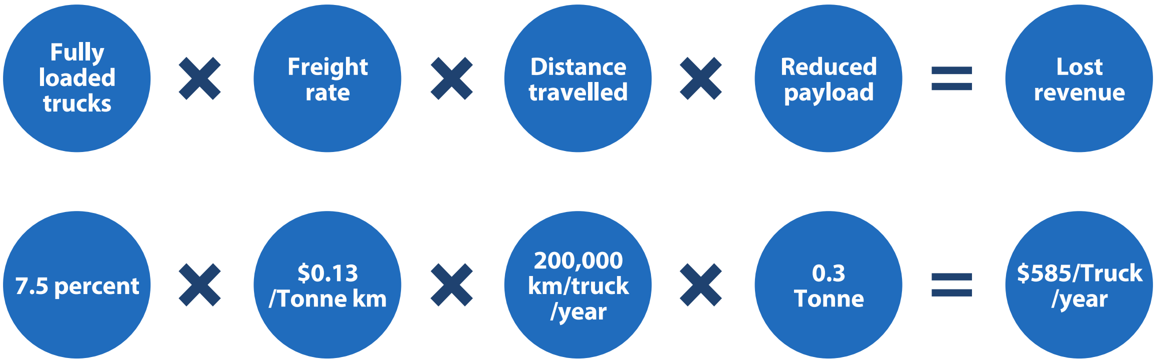
[54] It appears that there is a lack of sufficient evidence to support the claim that introduction of Euro VI standards will necessarily lead to a loss in seating capacity. For example, ACTION recently ordered from Scania 77 rigid buses which meet the strict Euro VI emissions standard. Scania tendered the same seating capacity for Euro VI as for Euro V in its tender response for rigid buses, that is, for ACTION there would be no loss of seating capacity. The number of standees tendered by Scania was also within ACTION’s tender requirements.

[55] If there were a reduction in seating capacity or the number of standees, costs would only occur when buses are full during peak hours. Detailed data would therefore be required if accurate estimates were to be made.

- For a mass-limited carrier, loss of payload will occur only when the vehicle is close to fully laden. According to ARTSA (2012), approximately 5-10 per cent of heavy vehicles that are intercepted are found to be overweight; and it is thus assumed that the mid-point of this range (about 7.5 per cent of heavy vehicles) is fully impacted by the standards-induced weight increase (i.e. will lose the full 300kg in payload), with a further 50 per cent of new sales assumed to be partially affected;
- A typical new articulated truck or B-double is assumed to have a full intensity lifespan of five years, travelling on average about 200,000 km per year during this period. After five years, the truck is likely to do a much less demanding job in terms of both weight and distance, so the loss in payload after the first 5 years is assumed to reduce markedly over time (and be mostly negligible after about 10 years).
- The lost revenues are calculated on the basis of the trucking costs, rather than the cartage rate paid by the end user, as the latter includes freight forwarding or logistic costs as well. Based on BITRE's latest unpublished research, the average road freight rate is assumed to be 13 cents per tonne-kilometre.
- Each new Euro VI compliant truck will lose an average payload capability of 300 kg (or equivalent proportion of volumetric capacity, for volume-constrained carriers).

Based on the above assumptions, the typical lost revenue per truck per year (averaged over all new sales, from the portion of total losses for trucks incurring the full weight penalty) can be initially calculated as shown in Figure 14.

Figure 14: Calculation of lost revenue per truck per year, initial estimate for new fleet average

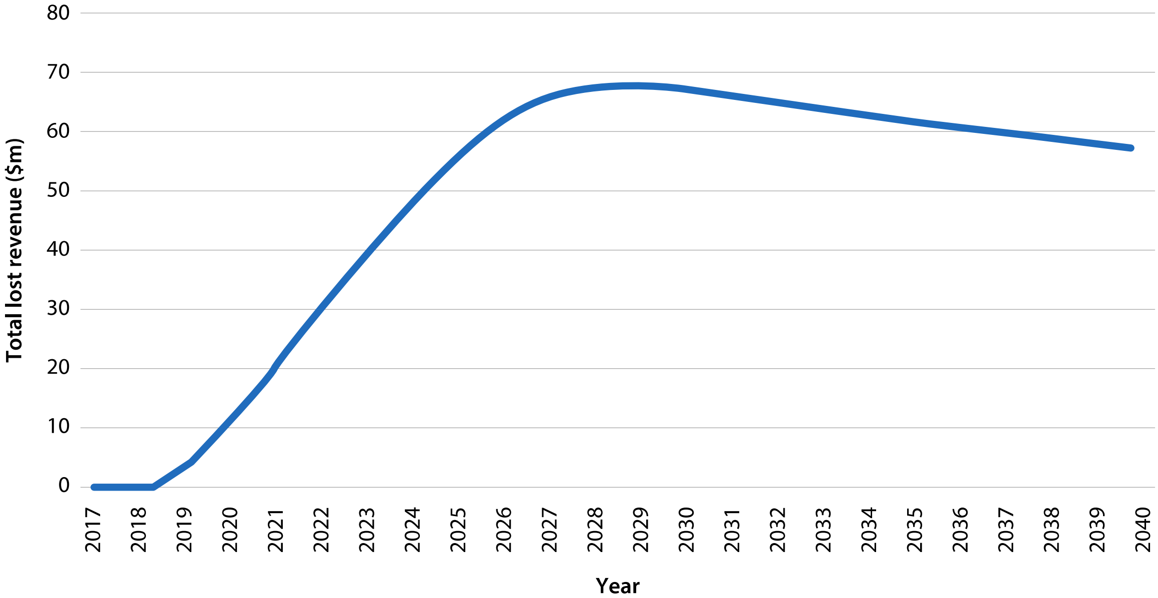


In estimating the total lost revenues, a further assumption is made, that is, the full 300kg loss of payload will only apply to heavier freight vehicles–taken here to be those with a gross vehicle mass greater than 15 tonnes.

Based on the proportional composition of new truck sales (FCAI 2015) it was assumed that the above full payload loss will apply to around 40 per cent of new sales, with a further 10 per cent excluded from the aggregate loss calculation as they have already been assumed to meet the new emission standards without regulation. A portion of the full payload loss estimate is also applied to a further 50 per cent of new heavy vehicle sales.

Figure 15 shows the estimated annual productivity loss over the evaluation period in the form of lost revenues. These estimates possibly represent a lower bound of the costs, due to difficulty in assessing how large a proportion of the new fleet will be affected by payload restrictions. Similarly, the estimated productivity loss values are highly dependent on whether the assumed weight increase will apply to all vehicles across the projection period, noting that lower levels of weight increase are likely in the future as a result of technological advances or engineering optimisations.

Figure 15: Estimated loss of revenue ($m) for the Euro VI scenario



Road damage costs

If the axle mass limit is to be relaxed to avoid productivity loss, then there is a need to estimate the costs of road damage caused by an increase in the front axle mass.

ARRB research shows an increase in the front axle mass limit from 6.5 to 6.8 tonnes will result in further road wear. As shown in Table 36, for standard tyres, the estimated road damage cost would vary between $455 and $2,543 per truck per year. Using wider tyres would bring down the road wear costs, but it would involve additional costs for tyres. Overall, the road damage costs appear to be significantly higher than the derived unit cost of the lost productivity (averaging at most $540/truck/year across the fleet). Hence, the lost productivity and not the road damage costs has been included into the final implementation costs.

Table 36: Road damage costs ($/truck/year)

	Standard tyres	**(295/80R22.5)**	**Wider tyres**	**(385/65R22.5)**
Front axle mass limit (tonnes)	3-axle rigid truck, average fully laden travelling average 29,000 km per year	6-axle artic travelling average 94,000 km per year	B-double travelling average 177,000 km per year	3-axle rigid truck, average fully laden travelling average 29,000 km per year
6.5	633	1,882	3,545	202
6.8	1,088	3,233	6,088	571
Additional road damage costs	455	1,351	2,543	369

Source: NTC (2006)

Greenhouse Gas Emissions

CO_2 emissions will increase in line with the increased fuel consumption under the Euro VI scenario. The price of CO_2 used (at $A35 per tonne) is based on lower bound values in appraisals conducted for the US Government on the social cost of carbon (SCC) and used by US federal agencies (such as the US EPA) to estimate the possible climate benefits of legislation (see US OMB 2010, 2015).[56]

[56] Note that if the average price of abatement from the first three auctions of the Emissions Reduction Fund

However, net climate warming impacts may yet decrease due to the tighter pollution standard, from a reduction in black carbon emissions. The black carbon warming impact is often assessed as between 100 to 2000 times that of carbon dioxide, with a conservative value of 500 assumed in a sensitivity test of the core Euro VI scenario.

Net Economics Benefits and Benefit-Cost Ratio

Table 37 reports the benefit-cost analysis results for the Euro VI scenario, relative to the Euro V base case. On the implementation cost side, there are net costs relating to the vehicle capital costs, fuel costs, productivity losses and greenhouse gas emissions, and a reduction in costs relating to AdBlue/Diesel Exhaust Fluid. On the benefits side, there are savings from the avoided health costs. Overall, the benefits are higher than costs in the scenario, resulting in an overall discounted net benefit of $ 264 million. The benefit-cost ratio was estimated to be 1.13. It should be noted that the core Euro VI scenario is exclusive of some less well quantified benefit-cost analysis elements (such as possible maintenance cost increases, which biases the benefit-cost ratio upwards, and possible benefits from reduced black carbon emissions and secondary particulates, which biases the benefit-cost ratio downwards); where some ballpark (order of magnitude) modelling of such poorly known impacts generally derived net benefit results roughly similar to the core scenario. For example, a scenario adding in estimates of possible maintenance costs, possible climate benefits of reduced black carbon emissions and possible health benefits of reduced secondary particulates had an estimated net benefit of about $422 million (benefit-cost ratio of 1.18). See the results of the following sensitivity tests for more detail on possible estimation variations.

Table 37: Summary of costs and benefits under the Euro VI scenario–undiscounted and discounted–($m)

Undiscounted cash flow

Financial year	Capital costs	Maintenance costs	Fuel costs	AdBlue/Diesel Exhaust Fluid	Product-ivity loss	GHG emissions	Total costs	Health costs avoided	Net benefit
2016	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2019	172.1	0.0	0.8	-0.8	5.0	0.1	177.2	8.1	-169.1
2020	286.4	0.0	3.3	-3.7	14.1	0.4	300.4	32.8	-267.6
2021	262.2	0.0	6.5	-7.4	23.0	0.8	285.1	65.2	-219.9
2022	231.2	0.0	9.7	-9.8	32.0	1.2	264.4	99.1	-165.2
2023	200.3	0.0	13.0	-11.7	40.9	1.6	244.0	132.6	-111.4
2024	169.5	0.0	16.2	-13.7	47.8	2.0	221.7	165.8	-55.9
2025	165.7	0.0	19.4	-15.7	52.6	2.4	224.3	199.2	-25.1
2026	161.2	0.0	22.5	-17.8	56.8	2.7	225.4	232.2	6.8
2027	155.7	0.0	25.6	-20.0	60.1	3.1	224.5	264.8	40.3
2028	149.7	0.0	28.7	-22.2	62.7	3.4	222.2	296.7	74.5
2029	143.1	0.0	31.6	-24.5	64.5	3.7	218.4	327.3	108.9
2030	135.9	0.0	34.5	-26.9	65.8	4.0	213.3	356.9	143.6

(ERF) of $12.10 per tonne was used (instead of $35 per tonne), the net benefits of this scenario would be higher.

Financial year	Capital costs	Maintenance costs	Fuel costs	AdBlue/Diesel Exhaust Fluid	Product-ivity loss	GHG emissions	Total costs	Health costs avoided	Net benefit
2031	128.0	0.0	37.2	-29.2	66.6	4.3	206.9	384.4	177.5
2032	119.5	0.0	39.7	-31.5	67.0	4.5	199.3	410.1	210.7
2033	110.3	0.0	42.1	-33.8	67.2	4.7	190.6	433.9	243.4
2034	100.1	0.0	44.4	-36.5	67.2	4.9	180.2	456.4	276.2
2035	89.0	0.0	46.6	-39.3	66.9	5.1	168.4	477.1	308.7
2036	77.0	0.0	48.6	-42.1	66.6	5.3	155.4	496.1	340.7
2037	64.0	0.0	50.5	-45.0	66.1	5.5	141.1	513.0	371.9
2038	49.9	0.0	52.2	-47.9	65.6	5.6	125.3	528.4	403.0
2039	34.6	0.0	53.8	-51.0	65.0	5.7	108.1	542.8	434.7
2040	18.1	0.0	55.3	-53.9	64.3	5.8	89.5	555.4	465.9
Total	3,023.6	0.0	682.2	-584.6	1,187.7	76.8	4,385.7	6,978.2	2,592.5

Discounted cash flow at 7 per cent

Financial year	Capital costs	Maintenance costs	Fuel costs	AdBlue/Diesel Exhaust Fluid	Product-ivity loss	GHG emissions	Total costs	Health costs avoided	Net benefit
2016	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2019	140.5	0.0	0.7	-0.7	4.1	0.1	144.6	6.6	-138.0
2020	218.5	0.0	2.5	-2.8	10.7	0.3	229.2	25.0	-204.2
2021	186.9	0.0	4.6	-5.3	16.4	0.6	203.3	46.5	-156.8
2022	154.1	0.0	6.5	-6.6	21.3	0.8	176.2	66.0	-110.1
2023	124.7	0.0	8.1	-7.3	25.5	1.0	152.0	82.6	-69.4
2024	98.7	0.0	9.4	-8.0	27.8	1.2	129.0	96.5	-32.5
2025	90.1	0.0	10.5	-8.6	28.6	1.3	122.0	108.3	-13.6
2026	82.0	0.0	11.4	-9.1	28.9	1.4	114.6	118.0	3.5
2027	74.0	0.0	12.2	-9.5	28.6	1.5	106.7	125.8	19.1
2028	66.5	0.0	12.7	-9.9	27.8	1.5	98.7	131.7	33.1
2029	59.4	0.0	13.1	-10.2	26.8	1.5	90.6	135.8	45.2
2030	52.7	0.0	13.4	-10.4	25.5	1.5	82.7	138.4	55.7
2031	46.4	0.0	13.5	-10.6	24.1	1.5	75.0	139.3	64.3
2032	40.5	0.0	13.5	-10.7	22.7	1.5	67.5	138.9	71.4
2033	34.9	0.0	13.3	-10.7	21.3	1.5	60.3	137.4	77.0
2034	29.6	0.0	13.1	-10.8	19.9	1.5	53.3	135.0	81.7
2035	24.6	0.0	12.9	-10.9	18.5	1.4	46.6	131.9	85.4
2036	19.9	0.0	12.6	-10.9	17.2	1.4	40.2	128.2	88.0

Financial year	Capital costs	Maintenance costs	Fuel costs	AdBlue/Diesel Exhaust Fluid	Product-ivity loss	GHG emissions	Total costs	Health costs avoided	Net benefit
2037	15.5	0.0	12.2	-10.9	16.0	1.3	34.1	123.9	89.8
2038	11.3	0.0	11.8	-10.8	14.8	1.3	28.3	119.3	91.0
2039	7.3	0.0	11.4	-10.7	13.7	1.2	22.8	114.5	91.7
2040	3.6	0.0	10.9	-10.6	12.7	1.1	17.6	109.5	91.8
Total	1,581.5	0.0	230.2	-195.8	452.9	26.4	2,095.2	2,359.3	264.1

Sensitivity Tests

Given the inevitable uncertainties in the modelled estimates, especially dealing with some of the input assumptions used in the Euro VI scenario, a range of sensitivity tests were undertaken on the values for:

- unit health costs;
- impacts on fuel and urea consumption;
- discount rates;
- impacts on capital costs;
- impacts on productivity;
- impacts on maintenance costs;
- reductions in secondary air pollutants; and
- impacts on greenhouse gas emissions

Sensitivity tests were conducted against the core Euro VI scenario reflecting variations on the extent to which the included cost and benefit categories can be accurately quantified.

Health benefits

As discussed previously, the unit health costs used in the core analysis of the Euro VI scenario were substantially based on the unit health costs in the Final RIS for the Review of Euro 5/6 Light Vehicle Emissions Standards (prepared by the Department of Infrastructure and Transport in November 2010), adjusted to 2015-16 prices; supplemented by results from a range of recent studies on the likely health costs associated with air pollution.

Sensitivity tests were undertaken for high and low values for unit health costs. Under the rather unlikely scenario where mean unit health cost values are reduced by 50 per cent (given the levels most typically quoted in literature), the introduction of the new standards for heavy vehicles would become economically unviable, with a benefit-cost ratio of 0.56 (Table 38).

Table 38: Changes in unit health costs

Sensitivity test	Benefit-cost ratio	Net benefits ($m)
Using unit health costs in core Euro VI scenario	1.13	264.1
Upper range values for unit health costs	1.91	1,910.8
Lower range values for unit health costs	0.56	-915.6

In their review of the benefit-cost analysis, ACIL Allen referred to a recent UK Department for Environment, Food and Rural Affairs report, which provided estimated ‘damage’ costs per tonne for NOx that were significantly higher than those used for this analysis.

If these high health costs for NOx given in the UK report were found to be valid for Australian conditions, BITRE has advised that the BCR would be strongly affected (with the current value close to 1.0 increasing to around 8.0).

Impacts on fuel and urea consumption

In addition to the fuel and urea consumption effects modelled in the core Euro VI scenario, three alternative scenarios with respect to fuel/urea use inputs were tested. If diesel and urea use are not changed by the new pollution standards (i.e. average consumption rates are kept at the baseline trends), the estimated benefit-cost ratio increases to 1.29. On the other hand, if average fuel consumption losses increase to at least one per cent higher (over baseline consumption values) for all new vehicles, the benefit-cost ratio will reduce to about 1.0. Furthermore, if fuel consumption losses increase to at least two per cent over baseline consumption, and there is some accompanying reduction in average urea use per kilometre, such as from more intensive Exhaust Gas Recirculation use, the estimated benefit-cost ratio falls to about 0.92 (Table 39).

Table 39: Changes to average fuel/urea use rates

Sensitivity test	**Benefit-cost ratio**	**Net benefits ($m)**
Core Euro VI scenario	1.13	264.1
No change to baseline fuel consumption rates	1.29	528.3
Higher fuel consumption losses (one per cent over baseline)	1.00	0.1
Higher fuel consumption losses (two per cent over baseline) and reduction in urea use per kilometre	0.92	-205.6

Note that the assumed urea advantages of the move to Euro VI standards has been set at relatively conservative levels in all these modelled scenarios (to provide for the wide uncertainty in possible urea consumption outcomes); and there is reasonable likelihood that the actual urea reductions could be larger (i.e. that the net benefits in Table 39 are somewhat underestimated for his factor of the analysis).

Discount Rates

The results of sensitivity testing in relation to the discount rates are shown in Table 40. With a discount rate of three per cent, the benefit-cost ratio reaches a value of 1.45. The results show that even with a high discount rate, the benefit-cost ratio does not fall far below one (at about 0.9).

Table 40: Changes to discount rates

Sensitivity test	**Benefit-cost ratio**	**Net benefits ($m)**
Core Euro VI scenario (7 per cent)	1.13	264.1
Low discount rate (3 per cent)	1.44	1,309.3
High discount rate (11 per cent)	0.90	-146.5

Impacts on capital costs

As there are uncertainties in the assumed capital cost estimates, a sensitivity test was undertaken for the additional capital costs (Table 41). If capital costs inputs are increased, using upper range values for initial additional capital costs (consisting of higher values for initial implementation while retaining downwards adjustment proportions for future economies of scale or from learning by doing), the benefit-cost ratio decreases to 0.85. While if overall capital cost inputs are increased by using the core Euro VI scenario values for initial implementation but assuming no downwards adjustment proportions for future economies of scale or from learning by doing, the benefit-cost ratio decreases to 0.75. Alternatively, if the capital costs are decreased, using the lower range values for extra capital costs, the benefit-cost ratio increases to 1.66.

Table 41: Changes to capital costs

Sensitivity test	Benefit-cost ratio	Net benefits ($m)
Core Euro VI scenario	1.13	264.1
Upper range values for initial extra capital costs (higher values for initial implementation, retain downwards adjustment for future economies of scale or from learning by doing)	0.85	-413.7
Higher average values for extra capital costs (using core scenario values for initial implementation, but assuming no downward cost adjustment over time for future economies of scale or from learning by doing)	0.75	-777.6
Lower range values for extra capital costs (retain downwards adjustment for future economies of scale or from learning by doing)	1.66	941.9

Impacts on productivity

In addition to the productivity impacts modelled in the core Euro VI scenario, an additional productivity loss scenario was tested as shown in Table 42. In this scenario, the productivity losses were assumed to be 50 per cent higher than estimated for the core Euro VI scenario.

Table 42: Changes to productivity impacts

Sensitivity test	Benefit-cost ratio	Net benefits ($m)
Core Euro VI scenario	1.13	264.1
High productivity losses (increase of 50 per cent)	1.02	37.7

Impacts on maintenance costs

Due to limited information, additional maintenance costs were not included in the ‘core’ Euro VI scenario. This will lead to a slight under-estimation of the total implementation costs.

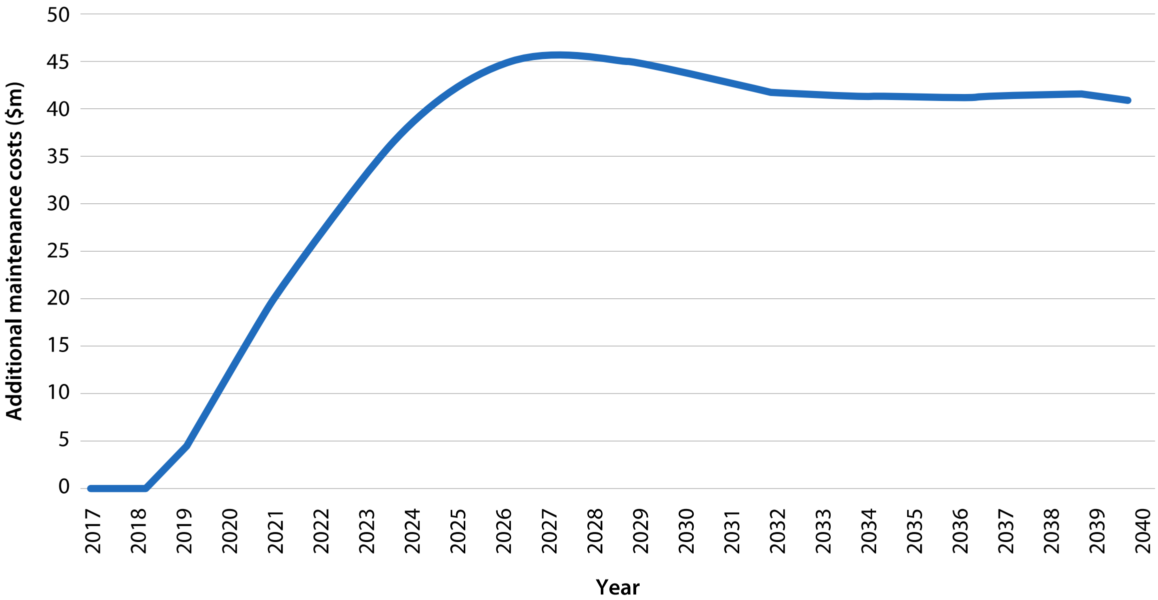
To estimate the possible impact, two alternative maintenance cost scenarios were tested as shown in Table 43.

In one scenario it was assumed that the additional maintenance costs incurred would include roughly equal proportions of:

- Vehicles with minimal to no increase in annual service costs with many manufacturers offering equivalent service plans for Euro V and Euro VI;
- Vehicles with a slight increase in annual service costs due to more detailed equipment calibration requirements; and
- Vehicles with substantial increases in annual service costs due to greater equipment failure rates until the technology fully matures.

When combined, these factors led to a rough estimate for average maintenance cost increases of $300 per vehicle in 2017, with a reduction in maintenance costs over time due to a learning scale factor. The maintenance costs were also adjusted to take into account an assumed reduction in task intensity with vehicle age, leading to the total maintenance costs shown in Figure 16.

Figure 16 Total additional maintenance costs ($m)



In the second scenario, the maintenance costs were assumed to be twice as high as those estimated for the first alternative scenario.

Table 43: Changes to maintenance costs

Sensitivity test	Benefit-cost ratio	Net benefits ($m)
Core Euro VI scenario (no additional costs)	1.13	264.1
Using maintenance costs roughly modelled	0.97	-77.7
High maintenance costs (double modelled costs)	0.85	-419.5

Impacts on secondary particulates

The overall magnitude of reductions in emissions and hence avoided health costs are conservative for the core Euro VI scenario, in that they do not include secondary particulates which are difficult to quantify precisely. The emission reductions in core Euro VI scenario refer solely to changes in *primary* particulate volumes (i.e. those released directly from the vehicle exhausts), and do not include any reductions in *secondary* particulates (PM formed in the atmosphere from chemical processes involving vehicle exhaust emissions). The reductions in exhaust emission volumes flowing from implementation of the stronger standards are likely to lead to subsequent reductions in secondary PM formation. However, due to the complicated nature of their formation, with rates typically strongly dependent on local atmospheric conditions, the exact amount of such reductions cannot be readily calculated. Given that secondary particulate volumes due to vehicle exhausts can be of a similar magnitude to the primary PM mass output, and that the new standards are highly likely to significantly reduce secondary nitrate aerosols, the health benefits provided in the analysis are likely to underestimate actual PM savings by the order of 20 per cent (based on rough modelling results). Table 44 shows the result of a sensitivity test with the roughly estimated impact of stronger emission standards on secondary particulate levels added to the core Euro VI scenario results, leading to substantially higher estimated net benefits.

Table 44: Rough inclusion of secondary particulate effects

Sensitivity test	Benefit-cost ratio	Net benefits ($m)
Core Euro VI scenario	1.13	264
With reductions in secondary particulates included	1.34	710.2

Impacts on Greenhouse Gas Emissions

The core Euro VI scenario estimated an increase in CO_2 emissions as a result of a possible increase in fuel consumption due to the additional technology that may be required to satisfy Euro VI requirements. However, as the introduction of Euro VI would reduce black carbon emissions, there may be a reduction in overall climate impacts. The black carbon warming impact is often assessed as between 100 to 2000 times that of CO_2 (see BITRE 2010b and Mamakos et al. 2013). Table 45 shows the result of a sensitivity test applied to the core Euro VI scenario by adding in the possible net climate effects of reduced PM emissions (with a conservative Global Warming Potential value of 500, relative to that of CO_2, assumed for black carbon emissions).

Table 45: Rough inclusion of black carbon effects

Sensitivity test	**Benefit-cost ratio**	**Net benefits ($m)**
Core Euro VI scenario	1.13	264
With reductions black carbon emissions included	1.15	299.3

Note that if the average price of abatement from the first three auctions of the Emissions Reduction Fund (ERF) of $12.10 per tonne was used in the Table 45 calculations for CO_2equivalent black carbon impacts, then the estimated net benefit rise would be less; giving a rough value of about $294 million (at a benefit-cost ratio of about 1.14).

Appendix B References

ABS 2008, Population Projections, Australia, 2006 (base) to 2101, ABS CAT No. 3222.0.

ABS 2013, Population Projections, Australia, 2012 (base) to 2101, ABS CAT No. 3222.0.

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Appendix C–Acronyms and Abbreviations

ABS	Australian Bureau of Statistics
ADR	Australian Design Rule
AIP	Australian Institute of Petroleum
ANCAP	Australasian New Car Assessment Program
ATA	Australian Trucking Association
BCR	Benefit-cost ratio
BITRE	Bureau of Infrastructure, Transport and Regional Economics
CO	Carbon monoxide
CO_2	Carbon dioxide
Department	Department of Infrastructure and Regional Development
EU	European Union
Euro NCAP	European New Car Assessment Program
FCAI	Federal Chamber of Automotive Industries
GDI	Gasoline Direct Injection
Global NCAP	Global New Car Assessment Program
GVM	Gross vehicle mass
HC	Hydrocarbons
ICCT	International Council on Clean Transportation
MVEm	Motor Vehicle Emission suite
MVSA	*Motor Vehicle Standards Act 1989*
NEPM	National Environment Protection (Ambient Air Quality) Measure
NCAA	National Clean Air Agreement
NCAP	New Car Assessment Program
NOx	Nitrogen oxides
OBPR	Office of Best Practice Regulation
PM	Particulate matter
$PM_{2.5}$	Particulate matter 2.5 micrometres or less in diameter
PM_{10}	Particulate matter 10 micrometres or less in diameter
ppm	Parts per million
PULP	Premium unleaded petrol
RDE	Real Driving Emissions
RIS	Regulation Impact Statement
SCC	Social cost of carbon
SOx	Sulfur oxides
SUV	Sports Utility Vehicle
SVSEG	Strategic Vehicle Safety and Environment Group
TIC	Truck Industry Council
ULP	Unleaded petrol
UN	United Nations
US EPA	United States Environmental Protection Agency
VKT	Vehicle kilometres travelled
VOC	Volatile organic compound
WHSC	Worldwide Harmonised Stationary Cycle

WHTC	Worldwide Harmonised Transient Cycle
WLTP	Worldwide harmonized Light vehicle Test Procedure
WP.29	World Forum for the Harmonization of Vehicle Regulations
WTO	World Trade Organisation