Australian Government

Improving the efficiency of new light vehicles

Draft Regulation Impact Statement

December 2016

Department of Infrastructure and Regional Development

Contents

Glossary of Terms

AAA	Australian Automobile Association
ABS	Australian Bureau of Statistics
ADR	Australian Design Rule
BAU	Business As Usual
BITRE	Bureau of Infrastructure, Transport and Regional Economics
BCR	Benefit Cost Ratio
CCA	Climate Change Authority
CO_2	Carbon Dioxide
CO_2-e	Carbon Dioxide equivalent (in terms of global warming potential)
DIIS	Department of Industry, Innovation and Science
DoE	Department of the Environment
DoEE	Department of the Environment and Energy
DPMC	Department of the Prime Minister and Cabinet
EC	European Commission (governing body of the European Union)
EU	European Union
EV	(Pure) Electric Vehicle
FCAI	Federal Chamber of Automotive Industries
4WD	Four Wheel Drive
GDI	Gasoline Direct Injection
g/km	grams of (carbon dioxide) emitted per kilometre
GHG	Greenhouse Gas
GVG	Green Vehicle Guide
HFCV	Hydrogen Fuel Cell Vehicle
ICCT	International Council for Clean Transportation
IEA	International Energy Agency
LCV	Light Commercial Vehicle
LPG	Liquefied Petroleum Gas
Mt	Megatonne
NEDC	New European Drive Cycle
NEPP	National Energy Productivity Plan
NHTSA	(United States) National Highway Traffic Safety Administration
NPV	Net Present Value (Net Benefit)
NTC	National Transport Commission
OCE	Office of the Chief Economist
PC	Productivity Commission
PHEV	Plug-in Hybrid Electric Vehicle (electric vehicles with an internal combustion engine as an auxiliary power source)
ppm	parts per million
RIS	Regulation Impact Statement
SCC	Social Cost of Carbon
SUV	Sports Utility Vehicle
2WD	Two Wheel Drive
UK	United Kingdom

US	United States
US EPA	United States Environmental Protection Agency
US OMB	United States Office of Management and Budget
WLTP	Worldwide Harmonised Light Vehicles Test Procedure

Executive Summary

As part of a global response to climate change, the Australian Government has internationally committed to reduce our greenhouse gas emissions by 26–28 per cent below 2005 levels by 2030.

Fossil fuels, such as petrol and diesel, are the principal fuel source for road vehicles in Australia. The fuel burnt by light vehicles currently contributes ten per cent of Australia's greenhouse gas emissions or 57 million tonnes per annum. As Australia's population and economy grows, so will its light vehicle fleet–which will increase fuel usage and emissions. Even with the current improvement trend in vehicle efficiency, the growth in the light vehicle fleet would add an estimated 8 million tonnes of greenhouse gas emissions and estimated $5 billion in energy costs to the economy per annum by 2030.

Australia's light vehicle fleet is less efficient than many other countries. In 2015, the average efficiency of new light vehicles sold in Australia (in grams of carbon dioxide (CO_2) emitted per kilometre) was 184g/km (175g/km for passenger vehicles (cars and sports utility vehicles (SUVs)) and 229g/km for light commercial vehicles (vans and utilities)). By way of comparison, the average efficiency of new light vehicles sold in the European Union (EU) in 2015 was 120g/km for passenger vehicles (cars and SUVs) and 168g/km for light commercial vehicles. Light vehicles sold in the United States (US), which are larger on average and have fewer diesel options than Australia, were estimated to have achieved an average efficiency of 183g/km in 2014[1] (157g/km for passenger cars and 222g/km for 'light trucks' (SUVs and light commercial vehicles)).

These differences in efficiency are influenced by a variety of factors. Key amongst them is that approximately 80 per cent of the global light vehicle market–including the US, EU, Canada, Japan, China, South Korea and India–have adopted mandatory fuel efficiency standards. These standards aim to drive improvements in vehicle efficiency at a faster rate than could otherwise be expected from market forces alone.

While fuel efficiency is valued by consumers, these benefits tend to be less immediate and tangible than other considerations, such as vehicle price, size and performance. Fuel efficiency standards that are in place in markets that supply light vehicles to Australia may help improve the efficiency of the same vehicles sold in Australia–however these improvements are likely to be smaller in the absence of an incentive for manufacturers to supply their most efficient models and variants to Australian consumers. For example, a comparison of the most efficient variants of top selling passenger vehicle models offered in Australia found the best performing variants sold in Australia were about 27 per cent worse on average than the most efficient model variants offered in the UK.

A government fleet purchasing policy and a voluntary industry target were examined as options to improve the fuel efficiency of Australia's vehicle fleet. They were found to be unlikely to deliver significant improvements above and beyond the business as usual trajectory. The Australian Government's capacity to influence the average efficiency of new vehicles through an efficient vehicle fleet purchasing policy is minimal given it comprises less than 0.1 per cent of the broader Australian vehicle fleet. Any such fleet purchasing impacts would be strongly dependent on other government and private fleets adopting similar policies.

A voluntary target negotiated with manufacturers is unlikely to be effective as manufacturers and consumers lack a shared interest in optimising social outcomes and manufacturers would be unable to pass on increased manufacturing costs to consumers when in competition with manufacturers who choose not to adopt a voluntary target.

Three different fleet average efficiency targets were considered for the year 2025–105, 119 and 135 grams of carbon dioxide emitted per kilometre travelled (gCO_2/km). A target of 105g/km would broadly align Australia with the EU targets for 2020-21 and the overall US target for 2025.

The Bureau of Infrastructure, Transport and Regional Economics undertook a benefit-cost analysis for each of the three proposed fleet average efficiency targets–phased in from 2020. The main benefit identified in the analysis was a reduction in fuel costs to the economy of $10.8-$27.5 billion. Additional benefits would arise from a cumulative reduction in greenhouse gas emissions of 25-65

---

[1] Latest comparable data available for the US at the time of publishing.

million tonnes by 2030 and 91-231 million tonnes by 2040. The main cost was the additional production cost of supplying vehicles incorporating technologies required to meet the proposed targets. These costs are more than offset by fuel savings with all three targets producing a net benefit ranging from $5.8-$13.9 billion and a benefit cost ratio between 1.86-1.97.

Table E1 summarises the results of the analysis, which shows that the benefits exceed the cost under all three possible targets (A, B and C). As fuel savings exceed the production cost under all three targets, the cost of abatement under a fuel efficiency standard is negative (that is, Australia saves $48.70-$52.60 for every tonne of CO_2 avoided).

Table E1: Estimated Benefits and Costs by 2040

Options	**Target A 105gCO_2/km phased in from 2020 to 2025**	**Target B 119gCO_2/km phased in from 2020 to 2025**	**Target C 135gCO_2/km phased in from 2020 to 2025**
Fuel Savings[2]	*$27.5 billion*	*$19.7 billion*	*$10.8 billion*
Greenhouse gas reduction benefit	*$2.7 billion (65Mt by 2030, 231Mt CO_2 by 2040)*	*$1.9 billion (46Mt by 2030, 164Mt CO_2 by 2040)*	*$1.0 billion (25Mt by 2030, 91Mt $CO_2$by 2040)*
Total savings	$30.1 billion	$21.6 billion	$11.8 billion
Total costs	$16.2 billion	$11.2 billion	$6 billion
Net benefits	$13.9 billion	$10.4 billion	$5.8 billion
Benefit Cost Ratio	1.86	1.93	1.97
Cost of Abatement[3]	-$48.70/tonne	-$52.00/tonne	-$52.60/tonne

Sensitivity tests were also conducted on the Target A scenario to consider the implications of different assumptions such as production cost, fuel price, discount rate and carbon price. These tests found that under a range of possible scenarios, Target A would still deliver a net benefit.

At a retail fuel price of $1.30 per litre, it was estimated that an average motorist purchasing an average performing passenger vehicle in 2025, could save between $237 and $519 per year in fuel costs. For an average performing light commercial vehicle purchased in 2025, it was estimated that an average motorist could save between $182 and $666 per year in fuel costs. Table E2 provides a summary of the estimated fuel savings under all three possible targets.

---

2 Excludes taxes such as excise and GST which are considered transfers in a BCA.

3 Additional production cost, minus fuel savings, divided by tonnes of CO_2 avoided by 2040.

Table E2: Possible consumer fuel savings in 2025[4][5][6]

Possible consumer fuel saving in 2025 at a fuel price of $1.30/litre	**Target A 105gCO_2/km**	**Target B 119gCO_2/km**	**Target C 135gCO_2/km**
Average performing petrol passenger vehicle travelling 16,100km per annum[5]	$519	$399	$237
Average performing light commercial vehicle travelling 21,700km per annum[6]	$666	$383	$182

In addition to the targets, which reflect the magnitude of improvement required, the design of the standard can also affect the cost of meeting a standard and the range of vehicles manufacturers supply to Australia. The manner in which a standard is implemented needs to be considered carefully, including so as not to limit the range of vehicles manufacturers can offer to Australian consumers. It has not been the experience in the US nor the EU that fuel efficiency standards reduce the range of vehicles available, as these markets have adopted attribute based standards on a sales weighted average basis to a vehicle supplier, rather than at an individual vehicle level, to minimise impacts on the range of vehicles available to consumers.

This draft Regulation Impact Statement evaluates the level of improvement in vehicle efficiency that could be achieved through a fuel efficiency standard phased in from 2020 to 2025 and at what cost. It has been released for public comment to elicit views from interested parties on its key proposals, particularly:

- the implications of the range of potential target(s) which might apply under the standards based on an assessment of compliance costs and consumer/societal benefits; and
- the appropriate regulatory design for implementing the standard. Further information about regulatory design parameters can be found in Appendix A, including a range of questions you may wish to consider when providing feedback.

The views received in response to this draft Regulation Impact Statement will help inform development of the final Regulation Impact Statement for consideration by the Australian Government in mid-2017. A summary of the public comment will be included in the final RIS, which will be published once the Government announces a decision.

Comments on this draft Regulation Impact Statement are requested by 10 March 2017. They should be submitted electronically 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

4 These estimates assume no changes to consumer behaviour resulting from a fuel efficiency standard (i.e. motorists travel the same distance, and purchase an average performing vehicle utilising the same fuel type and grade). Improvements in the efficiency of individual vehicle models and variants will vary depending on the level of improvement required by the manufacturer to meet a standard and broader product development at a global level.

5 Average annual km for passenger vehicles less than five years old reported in the 2014 ABS Survey of Motor Vehicle Use.

6 Average annual km for light commercial vehicles less than five years old reported in the 2014 ABS Survey of Motor Vehicle Use.

Introduction

In 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:

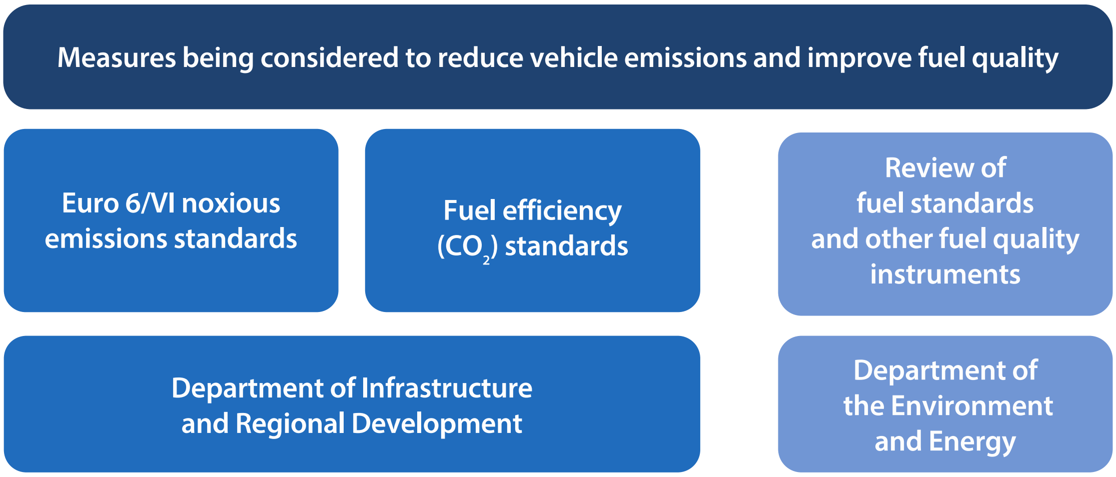
- implementation of Euro 6 or equivalent standards for new vehicles;
- fuel efficiency (CO_2) measures for new light vehicles;
- fuel quality standards;
- emissions testing arrangements for vehicles in conjunction with international regulatory agencies to ensure robust testing;
- Australian Government measures under the National Clean Air Agreement;
- 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
- the National Energy Productivity Plan.

In 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 in April 2016. Eighty submissions were received from a range of stakeholders, including vehicle manufacturers, fuel companies, consumer groups, health and environment groups, and private individuals.

The discussion 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), a standards regime for fuel efficiency for light vehicles and fuel quality standards. Also considered were complementary or stand-alone measures to address vehicle emissions.

This draft Regulation Impact Statement was foreshadowed in the discussion paper. It forms part of a comprehensive package of activities being undertaken to deal with emissions from road vehicles captured in Figure 1. The Department of Infrastructure and Regional Development is responsible for two bodies of work to consider the proposed introduction of Euro 6/VI vehicle emission standards for light and heavy vehicles, and fuel efficiency standards, relating to carbon dioxide emissions. A review of fuel quality standards is being led by the Department of the Environment and Energy.

Figure 1: Relationship between Australian Government motor vehicle emissions reduction activities



This draft Regulation Impact Statement examines the case for Australian Government action to reduce greenhouse gas emissions by improving the efficiency of new light passenger and commercial road vehicles supplied to the Australian market for use in transport. It follows the Australian Government requirements for an Early Assessment Regulation Impact Statement, addressing fully the first four questions as set out in the Australian Government Guide to Regulation (DPMC 2014):

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 process discussed in Section 5 addresses the fifth question:

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

The final Regulation Impact Statement will inform the Government's decision, taking into account public comments on this draft. It will include a summary of the public comments received on this draft and address the sixth and seventh 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 draft Regulation Impact Statement are requested by 10 March 2017. They should be submitted electronically 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.

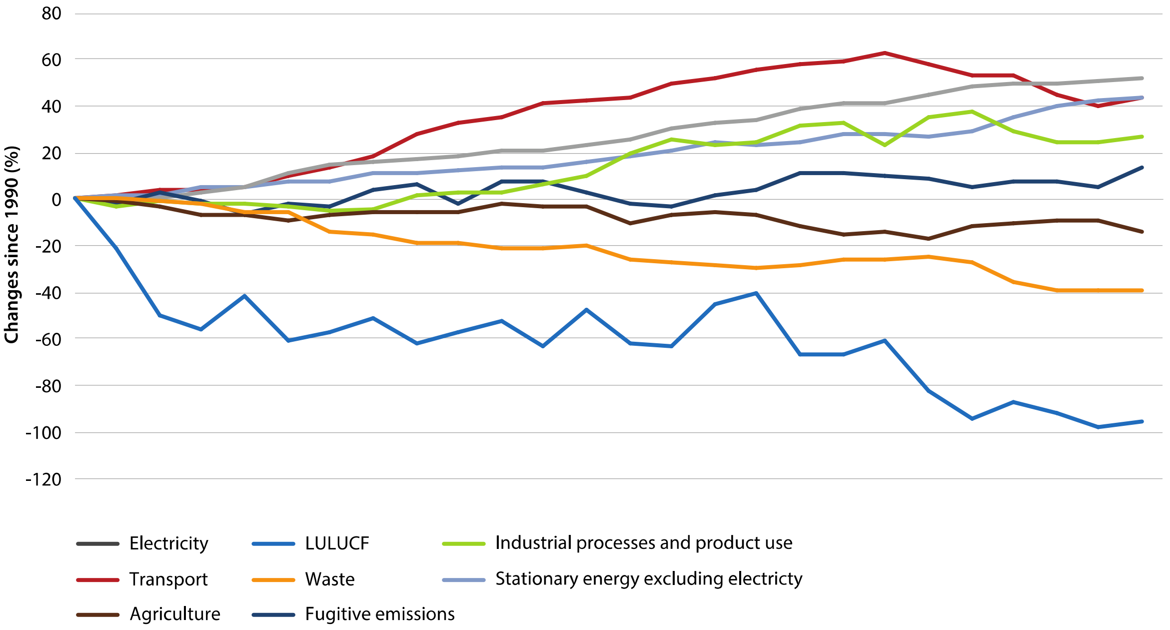
1 What is the Problem?

1.1 Transport fuel use and greenhouse gas emissions are increasing

Carbon dioxide (CO_2) is the dominant greenhouse gas contributing to climate change, and the most significant greenhouse gas produced by the transport sector. Greenhouse gas emissions from transport[7] are mainly attributable to the combustion of liquid fuels to power vehicles, with the road transport sector accounting for 97 per cent (618PJ) of petrol, 59 per cent (578PJ) of diesel and 54 per cent (51PJ) of liquefied petroleum gas (LPG) consumed in Australia in 2014–15 (OCE 2016).

As illustrated in Figure 2, greenhouse gas (CO_2-e)[8] emissions from transport fuel use have grown steadily over the past 25 years. Australia's transport emissions increased by 51.7 per cent (31.7Mt CO_2-e) between 1989-90 and 2014-15, which was the fastest sectoral growth over the period (DoEE 2016a), with growth in transport activity and associated fuel use outpacing improvements in efficiency.

Figure 2: Percentage Change in Greenhouse Gas (CO_2-e) Emissions by Sector 1989-90–2014-15 (DoEE 2016a)



In the year to December 2015, transport accounted for 93.3 Mt CO_2-e or 17 per cent of greenhouse gas emissions in Australia (DoEE 2016a). Of this, light vehicles accounted for 57 Mt CO_2-e or 10 per cent of Australia's greenhouse gas emissions (DoEE 2016a).

Under current policy settings, transport emissions are projected to increase by 20 per cent to 115 Mt CO_2-e in 2029-2030 (DoE 2015). Projections by the Bureau of Infrastructure, Transport and Regional Economics (BITRE) estimates that greenhouse gas emissions for light vehicles will

---

[7] For consistency with greenhouse gas accounting, transport emissions in this RIS refer to the 'tailpipe' emissions produced by vehicles. Emissions from generation of electricity used by electric vehicles are accounted for in the electricity sector. Combustion of biofuels produces zero emissions for transport accounting purposes, but biofuel production emissions can be substantial and are included in the agriculture or industry sectors.

[8] As there are a number of different greenhouse gases which vary in terms of global warming potential, greenhouse gases are measured in terms of CO_2 equivalency (CO_2-e). CO_2 is the main greenhouse gas produced by motor vehicles.

increase to 65Mt CO_2-e in 2030, as growth in overall light vehicle activity and fuel use continues to outpace improvements in efficiency.

In addition, increasing fuel use by light vehicles in the transport sector will also increase the cost to the Australian economy of moving goods and people–estimated by the Bureau of Infrastructure, Transport and Regional Economics to be in the order of $5.5 billion in 2030. The problem that the measures analysed in this draft Regulation Impact Statement (RIS) are designed to address is the growing level of fuel costs and greenhouse gas emissions from fuel use in the light vehicle sector. The draft RIS proposes to address this problem by improving the efficiency of new light vehicles[9] supplied to Australia.

1.2 Fuel use and emissions are increasing despite improved efficiency

In the year to December 2015, light vehicles accounted for 57 Mt CO_2-e, or 61 per cent of total transport emissions (DoEE 2016a). Light vehicles account for 91 per cent of all road kilometres travelled and around 75 per cent of road transport fuel consumed (ABS 2015a). Passenger vehicles are predominantly fuelled by petrol (81 per cent), accounting for 87 per cent of petrol consumption, while 55 per cent of all fuel consumed by light commercial vehicles was diesel (ABS 2015a).

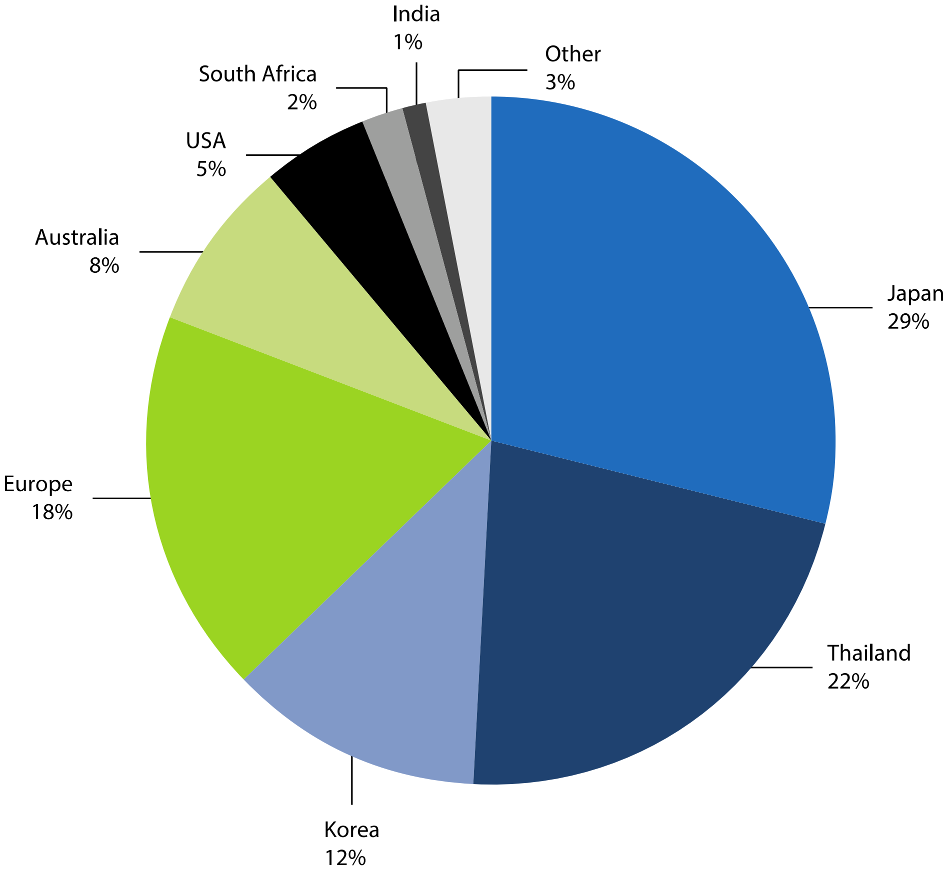
In January 2016, there were approximately 17 million registered light vehicles (passenger cars, sports utility vehicles (SUVs) and light commercial vehicles (LCVs) with a gross vehicle mass up to 3.5 tonnes), with the Australian light vehicle fleet growing by approximately 2.3 per cent per annum over the last five years (ABS 2016). In 2016, the average passenger vehicle was 9.8 years old and the average light commercial vehicle was 10.4 years old (ABS 2016). About 4 per cent of the Australian vehicle fleet is retired each year (ABS 2016).

In 2015, over 1.1 million new light vehicles were sold in Australia (FCAI 2015). Households accounted for 54 per cent of new light vehicles sold in 2015, with 42 per cent of vehicles purchased by businesses and 4 per cent by governments (NTC 2016). Vehicles purchased by households were on average more efficient than those purchased by corporate and government fleets. Between 2005 and 2015, the average efficiency of vehicles for each class of purchaser improved, with the largest improvements in efficiency coming from business purchases (25 per cent over the period), followed by government (22 per cent) and households (21 per cent) (NTC 2015, 2016).

Most new vehicles sold in Australia are imported, with the domestic industry supplying 8.4 per cent of the new vehicles in 2015. Figure 3 shows that the largest source of imported vehicles was Japan, which supplied 29 per cent of Australia's new light vehicles, followed by Thailand (22 per cent), Europe (18 per cent) and the Republic of Korea (12 per cent) (FCAI 2015).

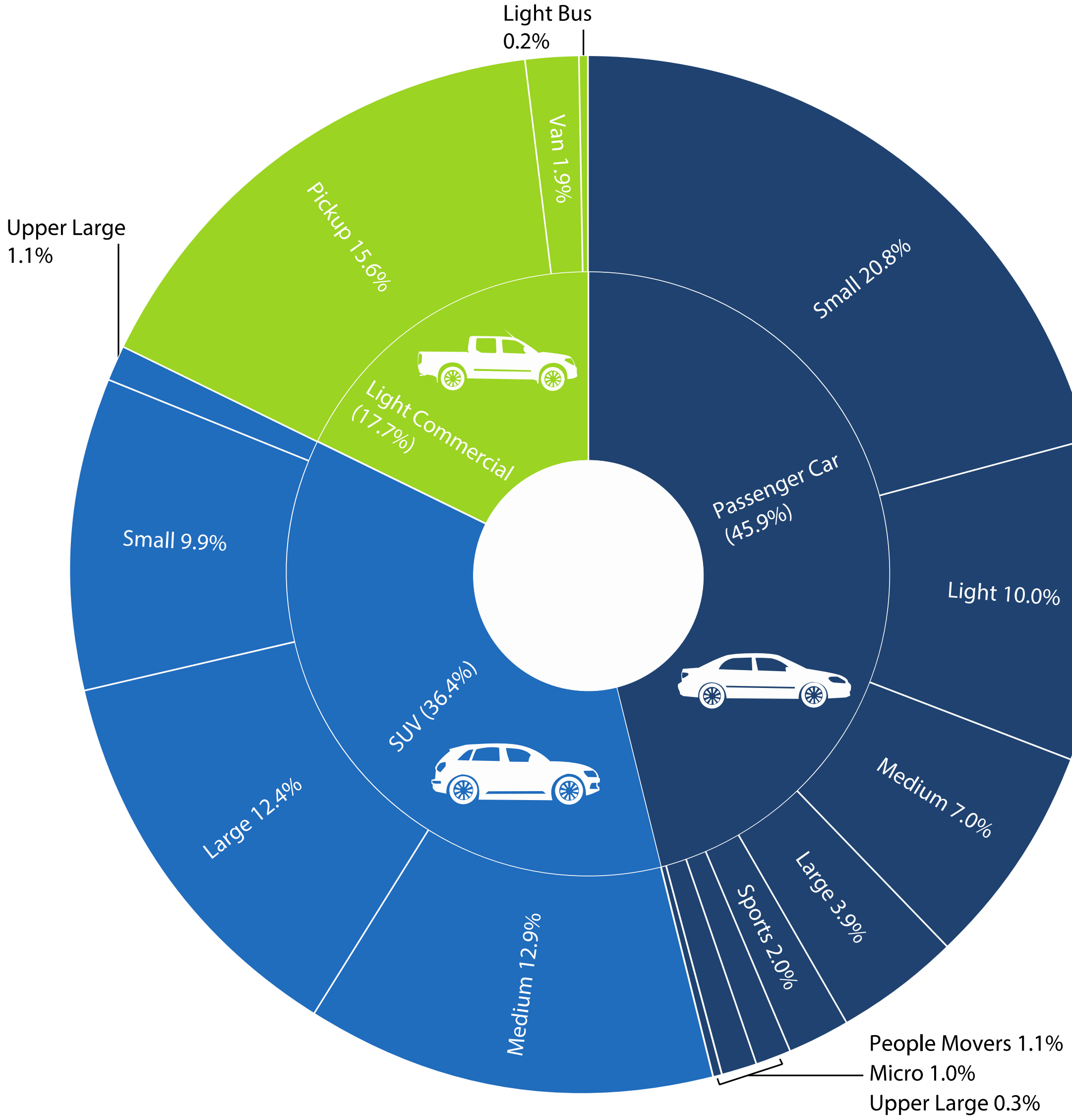
9 For the purposes of this Regulation Impact Statement, light vehicles refer to passenger cars, sports utility vehicles (SUVs) and commercial vehicles with gross vehicle mass up to 3.5 tonnes.

Figure 3: 2015 sales by country of manufacture (FCAI 2015)



Of the new light vehicles sold in Australia in 2015 (Figure 4), approximately 46 per cent were passenger cars, with approximately two-thirds of these being ‘small’ or ‘light’ cars. Sports utility vehicles (SUVs) accounted for approximately 36 per cent of new vehicle sales, with roughly one-quarter of these being ‘small’ SUVs, one-third ‘medium’ and one-third ‘large’. Light commercial vehicles (utes/light trucks, vans and light buses) accounted for approximately 18 per cent of new vehicle sales, with almost ninety per cent of these being ‘pick-up/cab chassis’ (utes).

Figure 4: 2015 sales by segment (FCAI 2015)



Since 2002, the average efficiency of new light vehicles sold in Australia (in terms of grams of CO_2 produced per kilometre travelled) has improved from 252g/km in 2002 to 184g/km in 2015 (NTC 2016). The average efficiency of new passenger vehicles (cars and SUVs) sold in 2015 was 175 g/km, with light commercial vehicles (LCVs) averaging 229 g/km. Table 1 shows the annual improvements in light vehicle efficiency since 2002. While the rate of improvement has varied from year to year, the average rate of improvement over the last ten years has been higher than the longer term (1979-2013) average of around one per cent per annum (BITRE 2014a).

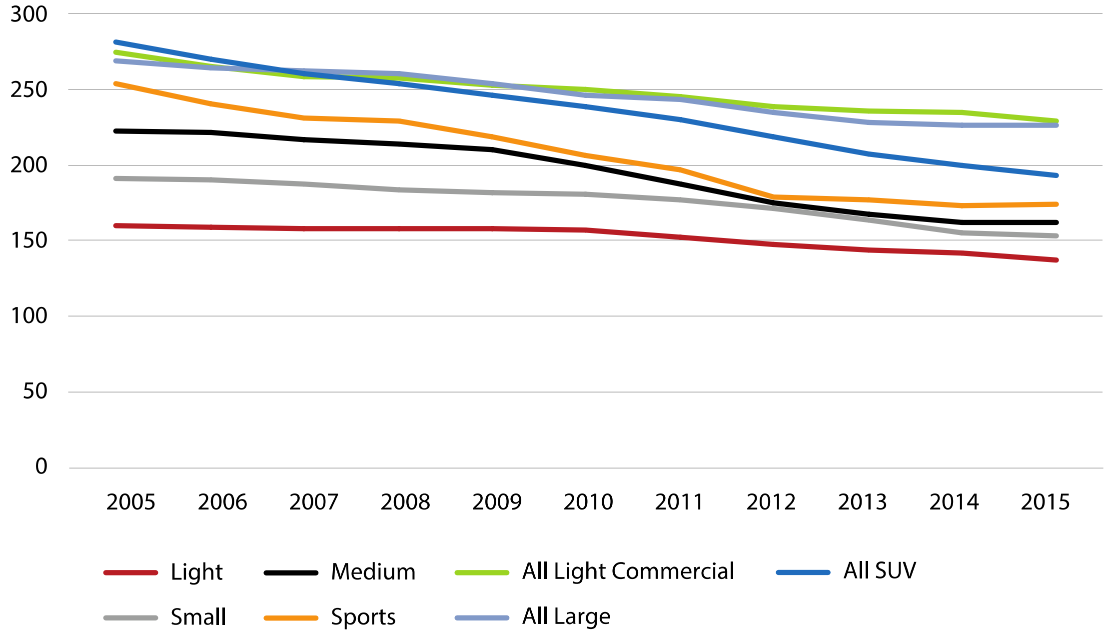
Table 1: Average rate of improvement in efficiency of new light vehicles sold in Australia (NTC 2016)

Year	Average Efficiency (gCO_2/km)	Annual Rate of Improvement
2002	252.4	n/a
2003	249.5	1.1%
2004	246.5	1.2%
2005	240.5	2.4%

Year	Average Efficiency (gCO_2/km)	Annual Rate of Improvement
2006	230.3	4.2%
2007	226.4	1.7%
2008	222.4	1.8%
2009	218.6	1.7%
2010	212.6	2.7%
2011	206.6	2.8%
2012	199.0	3.7%
2013	192.2	3.4%
2014	187.8	2.3%
2015	184.2	1.9%

All classes of light vehicles in Australia have become more efficient over the last ten years (Figure 5), with the largest improvements being in the sports car and SUV segments. A shift from large cars to SUVs over this period has also improved the overall sale weighted average efficiency of new light vehicles, with the average SUV sold in 2015 being 15 per cent more efficient than the average large vehicle (NTC 2016).

Figure 5: Average New Vehicle Efficiency (gCO_2/km)by segment, 2005–15, (NTC 2015, 2016)[10]



Despite improvements in light vehicle efficiency, fuel use and greenhouse gas emissions from the light vehicle fleet continue to increase, as growth in light vehicle activity continues to outpace improvements in light vehicle efficiency. Over the period from 1990 to 2014, emissions from light passenger vehicles increased by 23.2 per cent (8.1Mt CO_2-e) and emissions from light commercial vehicles increased by 82.6 per cent (6.3Mt) (DoEE 2016b).

[10] Note: due to changes in vehicle segment classifications over this period, some segments have been combined. Light commercial vehicles include vans, light buses and pickup/cab-chassis, light includes micro cars, and large includes upper large and people mover classes.

While per capita ownership and use of light passenger vehicles has stabilised after decades of growth, light commercial vehicle activity has continued to grow strongly. These trends are reflected in relatively stable automotive petrol consumption and increases in diesel consumption over the past five years (DIIS 2016), as 88 per cent of new light commercial vehicles sold in 2015 have diesel fuelled engines (FCAI 2015).

Under current policy settings, the Bureau of Infrastructure, Transport and Regional Economics (BITRE) estimates that overall light vehicle fuel costs will increase from $17.9 billion in 2015 to $23.4 billion in 2030 and greenhouse gas emissions will increase to 65Mt CO_2-e in 2030, as growth in overall light vehicle activity and fuel use continues to outpace improvements in efficiency.

2 Why is Government Action Needed?

2.1 Improving light vehicle efficiency can help meet emissions targets

A new global climate change agreement (the Paris Agreement), to apply from 2020, was established at the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) during December 2015. On 9 November 2016, the Australian Government announced it would ratify the Paris Agreement.

196 countries joined together in the Paris Agreement to take on commitments to address climate change and will regularly review and update those commitments. The agreement aims to strengthen the global response to climate change, including by setting a collective goal to keep the global temperature increase to well below 2 degrees Celsius and pursue efforts to keep warming below 1.5 degrees Celsius above pre-industrial levels.

Each Party is required to communicate their intended actions to address climate change (known as Nationally Determined Contributions, NDCs) every five years (the first of which applies from 2020) and to increase their ambition over time. Part of Australia's NDC includes a commitment to reduce emissions by 26-28 per cent below 2005 levels by 2030.

To meet Australia's target, the Government has implemented a number of emissions reduction measures including the Emissions Reduction Fund and its safeguard mechanism. In 2017, the Government will review how to best calibrate policies beyond 2020 to achieve further emissions reductions.

In announcing its 2030 emissions reduction target, the Australian Government committed to consult on and implement initiatives that can deliver low cost emissions reductions and other co-benefits, including measures to improve light vehicle efficiency.

Analysis by the Bureau of Infrastructure, Transport and Regional Economics (BITRE) suggests that improvements in light vehicle efficiency to levels being pursued by the EU and the US could save vehicle users $48.70 for each tonne of CO_2 avoided. This means, in addition to reducing CO_2, measures to improve light vehicle efficiency could also save consumers money, as increases in the cost of a new vehicle would be more than offset by fuel savings over a vehicle's lifetime.

2.2 Improving light vehicle efficiency improves energy productivity

In addition to mitigating the impact of climate change, improvements in the energy efficiency of light vehicles could yield significant productivity gains and better economic performance more broadly, as businesses and households would require less fuel to move goods and people. An ongoing or systematic failure to make energy efficiency gains in the Australian vehicle fleet could make Australian goods less competitive and increase living costs for consumers, compared to other countries with a more efficient vehicle fleet.

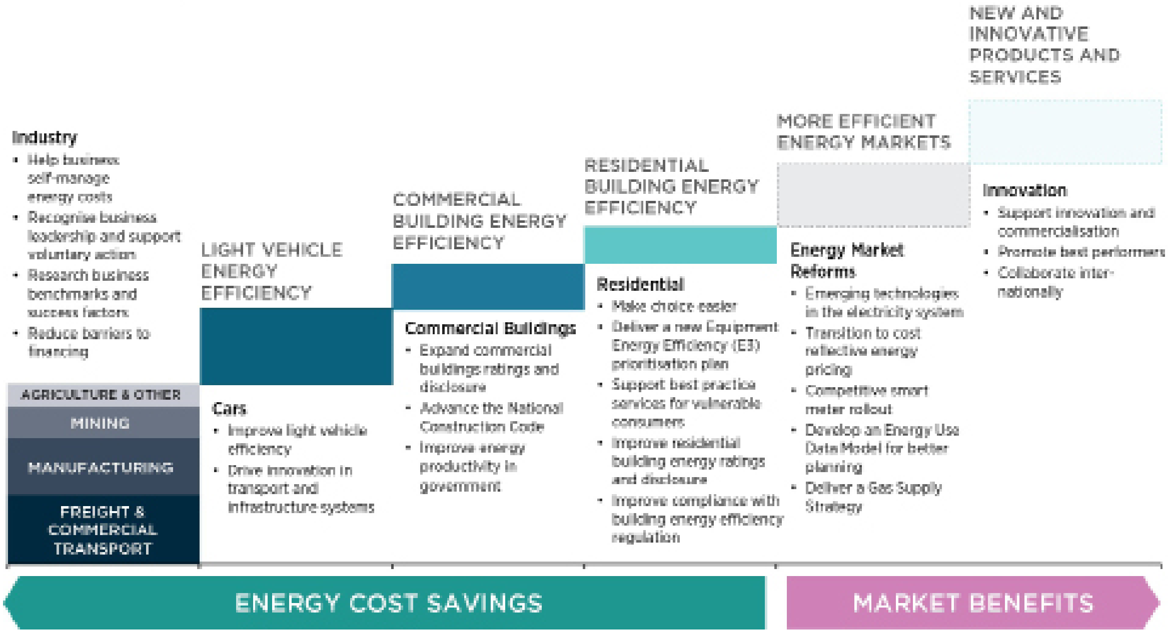
In December 2015, the Council of Australian Governments' (COAG) Energy Council launched a new National Energy Productivity Plan (NEPP) to meet a commitment to an energy productivity target of 40 per cent improvement between 2015 and 2030. The NEPP is expected to contribute more than a quarter of the savings required to meet Australia's 2030 greenhouse gas emissions reduction target. The NEPP complements existing policies such as the Emissions Reduction Fund. It aims to avoid placing additional burdens on business.

The NEPP covers all energy use, including electricity, gas and transport fuels, and will include both new and existing initiatives to support more productive consumer choices, through for example, cost-reflective pricing, smart meters and access to information. It also aims to facilitate more productive energy services through innovation and competition, such as reducing barriers to entry in the market for new technologies and service options, and energy efficiency measures that support better energy use in buildings, equipment and vehicles.

In order to meet Australia's proposed energy productivity target, Australia must increase its annual productivity improvement from 1.5 to 2.3 per cent per annum. This target has been designed to be large enough to promote real change while still being achievable. Figure 6 shows that light vehicles have the potential to make a significant contribution to Australia's national energy productivity target.

Figure 6: Sectoral Contribution to Energy Productivity

Illustrative examples



2.3 Government action could help address market failures

Market failures are departures from the characteristics necessary for unregulated markets to deliver outcomes that maximise both private (household and business) as well as overall (social) wellbeing (PC 2005, DPMC 2014). The most relevant market failure with respect to light vehicle efficiency is the amount and/or distribution of information in the market, and the ability to process this information.

Vehicle suppliers and buyers generally have asymmetric information about the costs of improving vehicle efficiency (Green 2010). Vehicle makers know the relationship between fuel efficiency and additional vehicle costs for a large range of technologies, including those not currently included in their vehicles, while vehicle buyers generally only know (and can act on) the trade-offs between vehicle costs and efficiency that are currently on offer. If buyers undervalue efficiency improvements, or have limited capacity to assess the value of those improvements when making purchasing decisions, then manufacturers have less incentive to supply vehicles that maximise private or social wellbeing.

An important behavioural barrier is that any individual's ability to obtain and process complex, changing and uncertain information is finite. In response to complexity, rather than calculate the best possible private decision, individuals tend to adopt rules-of-thumb. Such strategies include purchasing the same brand as a friend, purchasing the same brand that they have bought before, or using simplified choice criteria that focus on a subset of the features of a good (Green 2010).

To encourage households and businesses to purchase more efficient vehicles, the Australian Government has adopted measures to help consumers compare the efficiency and emissions intensity of light vehicles via the fuel consumption labelling standard for new vehicles and the Green Vehicle Guide website. The Government has also adopted measures to encourage the purchase of more efficient vehicles via the Emissions Reduction Fund and the Clean Energy Finance Corporation, as well as a Luxury Car Tax concession for fuel efficient vehicles. Some state and territory governments have also adopted incentives in their stamp duty and registration charges to encourage the purchase of more efficient vehicles.

While these measures help consumers assess the relative efficiency of new vehicles and provide an incentive for consumers to consider the purchase of a more efficient vehicle, these measures do not address the difficulties consumers face in assessing the benefits of efficiency, relative to other attributes such as price, size and performance. As the benefits of purchasing a more efficient vehicle tend to be less immediate and tangible to consumers, this can make it less attractive for vehicle manufacturers to use efficiency as a selling point.

While a recent survey found that Australians rate fuel efficiency along with reliability as the two most important considerations when buying a car (AAA 2016), there is very little evidence on how they assess the benefits of fuel efficiency–particularly over the longer term. Calculating the benefits from improved fuel efficiency requires both specific information and strong mathematical skills, and is unlikely to be done by all purchasers or for all purchases (see, for example, ABS 2013a). Evidence from overseas markets such as the US indicates that buyers behave as if they heavily discount future savings from reduced fuel use (Green 2010, IEA 2012). Factors such as the risk and uncertainty around fuel costs, due to fuel price fluctuations and the correlation between tested and on-road efficiency may also encourage the discounting of future fuel savings.

These behavioural barriers are likely to have a more pronounced effect on household rather than business vehicle purchases. Nevertheless, there is substantial evidence that similar barriers can also prevent businesses investing in cost-effective efficiency improvements, especially if fuel use is a relatively small component of overall costs (ClimateWorks 2013). For example, fleet buyers are likely to require payback periods of three years or fewer on a more efficient vehicle because most fleet vehicles are re-sold within this period. As just under half of new cars are purchased by fleets (FCAI 2015), this ‘split incentive’ could limit the take-up of vehicles that would deliver overall financial benefits for motorists but not their first owner (CCA 2014).

2.4 Other countries have successfully improved vehicle efficiency

International experience suggests the Australian Government could improve the efficiency of the light vehicle fleet, by adopting measures that would give manufacturers stronger incentives to supply more efficient vehicles.

It is widely observed that light vehicles sold in other markets are on average, more efficient than those sold in Australia. For example, the average efficiency of new light vehicles sold in the European Union (EU) in 2015 was 120g/km for passenger vehicles (cars and SUVs) and 168g/km for light commercial vehicles (EEA 2016). In contrast, the average efficiency of new passenger vehicles sold in Australia in 2015 was 175g/km and 229g/km for light commercial vehicles (NTC 2016). Light vehicles sold in the United States (US), which are larger on average and have fewer diesel options[11] than Australia, were estimated to have achieved an average efficiency of 183g/km (157g/km for passenger cars and 222g/km for ‘light trucks’ (SUVs and light commercial vehicles)) in 2014[12] (ICCT 2015a).

Differences in the average efficiency of vehicles sold in a particular market are influenced by a complex interaction of a range of factors including:

- consumer preferences for particular categories or types of vehicles;
- the degree to which lower emission technologies and fuels are adopted in the vehicles offered for sale in the market, and
- information and policies which influence both consumers and manufacturers.

A key policy measure adopted in many countries to give manufacturers stronger incentives to supply more efficient vehicles has been the adoption of fuel efficiency or CO_2 standards. These standards are in place in approximately 80 per cent of the global light vehicle market–including the US, EU, Canada, Japan, China, South Korea and India.

These standards require manufacturers to deliver improvements in vehicle efficiency beyond those that could reasonably be expected under market forces alone.[13] For example, when considered in

[11] Diesel engines are generally more efficient than equivalent petrol engines.

[12] Latest comparable data available for the US at the time of publishing. The US average is an estimate by the International Council for Clean Transportation (ICCT), as the US uses a different test to the EU and Australia to measure efficiency.

[13] The average rate of improvement in Australia over the last 10 years (2006-2015) is around 2.7% per annum for passenger vehicles (cars and SUVs) and 1.7% per annum for light commercial vehicles (data

annual percentage reduction terms, the US standards will require an average reduction of around 4 per cent each year from 2013 to 2025. In the EU, the rates of reduction required to achieve the agreed standards are 3.6 per cent each year from 2013-2021 for passenger vehicles and 2.3 per cent each year from 2013-2020 for light commercial vehicles.[14] China's standards for passenger vehicles are targeting an annual reduction rate of 5.3 per cent each year between 2013-2020. In South Korea, standards for passenger vehicles are targeting a rate of 5.8 per cent each year between 2012-2020 (ICCT 2015a).

A 2015 study for the European Commission found that adoption of a regulated standard played an important role in improving the efficiency of new light vehicles sold in the EU (EC 2015).

The US EPA's manufacturer performance report for 2015 (US EPA 2016a) found that the current standards, which commenced in 2012 had helped achieve a 10 per cent improvement in efficiency since 2011. These improvements have been achieved despite the US having larger vehicles on average than Australia, with fewer diesel options and lower fuel prices.

from NTC 2009, 2011, 2012, 2013, 2014, 2015, 2016). Average improvements in tested vehicle efficiency in Australia since 1979 have been around 1 per cent per annum (BITRE 2014a).

[14] EU target for passenger vehicles is 95g/km by 2021 and 147g/km by 2020 for light commercial vehicles.

3 What Policy Options Are Being Considered

3.1 Objectives of Government action

The objectives of Government Action to improve vehicle efficiency are to:

- mitigate the risks of climate change and help achieve Australia's 2030 greenhouse gas reduction target by reducing greenhouse gas emissions from transport fuel use;
- reduce fuel use and transport fuel costs for household and businesses; and
- improve Australia's energy productivity;

in the most cost effective way.

3.2 Technology focused measures do not restrict consumer choice

Measures to encourage the purchase of smaller vehicles could reduce greenhouse gas emissions, as they are on average, more efficient than larger vehicles. However, measures to encourage the purchase of smaller vehicles would only reduce greenhouse gas emissions to the extent these vehicles could meet the needs of individual consumers. It its therefore important to focus on measures that improve the efficiency of both smaller and larger vehicles.

Australia's recent history shows that improvements in light vehicle efficiency can be achieved through improvements in technology, which are estimated to have delivered over 70 per cent of the improvements in
light vehicle efficiency achieved between 2002 and 2011 (H-D Systems 2012).

There are many proven, cost-effective and currently available technologies that could improve the efficiency of all light vehicles; such as reducing vehicle weight and adopting more efficient engines and drive trains.

Table 2 shows an a range of technologies that could be adopted to improve the efficiency of a medium sized car with a 4-cylinder petrol engine[15] (ABMARC 2016).

Table 2: Estimated CO_2 benefits and costs[16] of selected technologies (ABMARC 2016)

a. Engine Technologies	CO_2 Reduction	Cost in 2020	Cost in 2025
LPG engine	12.0%	$1,800	$1,800
Petrol engine with Multi Point Fuel Injection: Dual Overhead Cam with Variable Valve Timing or Variable Valve Timing & Lift	2.6%	$1,097	$954
Petrol engine with Stoichiometric Direct Injection	10.0%	$550	$410
Petrol engine with Direct Injection, Turbocharging & Downsizing	12.0%	$1,954	$1,797
Standard Diesel Engine	16.0%	$3,000	$2,800
V6 Variable Geometry Turbo Diesel	28.0%	$5,200	$4,700
Inline 4 cylinder Variable Geometry Turbo Diesel	28.0%	$4,800	$4,300
Inline 4 cylinder Twin Turbo Diesel	32.0%	$4,900	$4,400
Downsized Turbo Diesel	38.0%	$4,700	$4,200

15 With Single Overhead Cam (SOHC), fixed valve timing with port fuel injection and 4 speed automatic transmission

16 Additional cost incurred by the manufacturer relative to forecast technology adoption under current policy settings. Costs for diesel engines are for a Euro 5 compliant engine–costs for a Euro 6 compliant engine would be higher.

b. Transmissions	CO_2 Reduction	Cost in 2020	Cost in 2025
5 Speed automatic	2.5%	$0	$0
6 Speed automatic	4.4%	$0	$0
7 Speed automatic	5.0%	$138	$117
8 Speed or higher automatic	6.0%	$138	$117
6 Speed manual	2.0%	$483	$411
Continuously variable transmission	5.0%	$388	$315
6 speed dual clutch transmission	6.7%	$67	$54
7 speed dual clutch transmission	7.5%	$493	$485
8 speed dual clutch transmission	8.5%	$493	$485

c. Hybrid/Electric Technology	CO_2 Reduction	Cost in 2020	Cost in 2025
Belt Drive Alternator Starter (42V)	7.5%	$735	$556
Mild Petrol Hybrid	31.0%	$3,685	$3,150
Mild Diesel Hybrid	39.0%	$6,048	$4,838
Petrol Dual Motor Full Hybrid	45.0%	$4,600	$3,870
Electric vehicle (300 km nominal range)	100.0%	$19,000	$10,000

d. Body Technology	CO_2 Reduction	Cost in 2020	Cost in 2025
5% Mass Reduction	3.3%	$115	$115
10% Mass Reduction	6.5%	$522	$522
15% Mass Reduction	9.6%	$717	$717

e. Accessory Technology	CO_2 Reduction	Cost in 2020	Cost in 2025
Electric Power Steering	1.5%	$188	$159
Idle Stop/Start	3.0%	$362	$273
Cylinder Deactivation	7.5%	$160	$160
Electric Coolant Pump	1.0%	$50	$50

3.3 Possible Options to improve vehicle efficiency

There are a range of non-regulatory and regulatory options that could be adopted to increase the supply of more efficient vehicles. These include:

Option 1–Maintain existing policy settings

Rely on existing arrangements and market forces to increase the supply of more efficient vehicles.

Option 2–Fleet Purchasing

Adopt minimum efficiency requirements for Government fleet purchases to encourage manufacturers to supply more efficient vehicles.

Option 3–Voluntary Fuel Efficiency Standard

Vehicle manufacturers through the Federal Chamber of Automotive Industries enter into an agreement with the Australian Government to meet a fleet average efficiency target.

Option 4–Legislated Fuel Efficiency Standard

Australian Government legislates to introduce a fleet average efficiency target for manufacturers to meet.

3.4 Australia is unlikely to fully benefit from standards in other countries

As noted in section 1.2, the efficiency of the Australian fleet is improving, but not to the same extent as countries that have adopted standards to improve vehicle efficiency. BITRE projections suggest that in the absence of any changes to existing policy settings, the current rate of improvement could return closer to historical averages of around 1 per cent per annum, which could see an increase in differences in light vehicle efficiency between Australia and other countries. Evidence suggests that Australia currently obtains some but not all of the benefits of standards adopted in other markets, as these standards are based on a sales weighted average and fuel saving technologies are not uniformly adopted across all variants. Data from the National Transport Commission (NTC) suggests that the rate of improvement in Australia has been slowing since 2013, despite the European standards having come into force over that period (NTC 2014, 2015, 2016).

While Australia will import all of its light vehicles from 2018, this is not expected to significantly change the rate of improvement, as imports already make up almost 92 per cent of the new vehicle fleet (FCAI 2015) and over 70 per cent of imported vehicles come from countries with fuel efficiency standards. Despite this, new light vehicles sold in Australia are on average, less efficient than those sold in many other markets. These differences can be explained to some extent by differences in the mix of vehicles purchased by consumers. For example, the NTC found Australian consumers purchased a higher proportion of large passenger vehicles, with more powerful engines and automatic transmissions than consumers in the UK (NTC 2014). However, it is also the case that the most efficient variants of vehicle models offered in Australia are considerably less efficient than the most efficient variants[17] of the same model offered in other markets. For example, a comparison of the most efficient variants of top selling passenger vehicle models offered in Australia found the best performing variants sold in Australia were about 27 per cent worse on average than the most efficient model variants offered in the UK (Table 3).

[17] The most efficient variant of a vehicle model sold in the UK may not be identical in specification to the most efficient variant of the same vehicle model range sold in Australia.

Table 3: Comparison of the best performing variants of top selling passenger models in Australia and the best performing variants of the equivalent model sold in the UK (Aug 2016) (Green Vehicle Guide (Australia), carfueldata.direct.gov.uk (UK))[18]

Model	Best Australian variant	Tailpipe CO_2 (g/km)	Best UK variant	Tailpipe CO_2 (g/km)	Difference
Hyundai i30	1.6L Turbo Diesel, 6 Spd Manual	125	1.6L Turbo Diesel, 6 Spd Manual	94	25%
Toyota Corolla (sold as Auris in UK)	1.8L Petrol Hybrid	96	1.8L Petrol Hybrid	79	18%
Mazda 3	2.2L Turbo Diesel, 6 Spd Manual	129	1.5L Turbo Diesel, 6 Spd Manual	99	23%
Mazda CX-5	2.0L Petrol, 6 Spd Auto, 2WD	148	2.2L Turbo Diesel, 6 Spd Manual, 2WD	119	20%
Volkswagen Golf	2.0L Turbo Diesel, 6 Spd Auto	124	e-Golf (Pure EV)	0	100%
Toyota RAV4	2.2L Turbo Diesel, 6 Spd Manual, 4WD	149	2.5L Petrol Hybrid, 2WD	115	23%
Mazda CX-3	1.5L Turbo Diesel, 6 Spd Auto, 2WD	125	1.5L Turbo Diesel, 6 Spd Manual, 2WD	105	16%
Hyundai Tucson	2.0L Turbo Diesel, 6 Spd Auto, 4WD	169	1.7L Turbo Diesel, 6 Spd Manual, 2WD	119	30%
Nissan X-Trail	1.6L Turbo Diesel, CVT, 2WD	139	1.6L Turbo Diesel, 6 Spd Manual, 2WD	129	7%
Mitsubishi ASX	2.2L Turbo Diesel, 6 Spd Auto, 4WD	160	1.6L Turbo Diesel, 6 Spd Manual, 2WD	119	26%
Toyota Prado (sold as Landcruiser in UK)	2.8L Turbo Diesel, 6 Spd Manual	208	2.8L Turbo Diesel, 6 Spd Manual	190	9%
Mazda 2	1.5L Petrol, 6 Spd Auto	114	1.5L Turbo Diesel, 6 Spd Manual	89	22%

In many cases, the most efficient model variants offered in the UK are different in specification to those offered in Australia. However, as Australia comprises less than two per cent of the global vehicle market, manufacturers generally lack sufficient scale to develop products specifically for Australia. While some manufacturers have suggested that minor adjustments are made to vehicles supplied to Australia to accommodate differences in minimum fuel specifications, manufacturers

[18] The most efficient model variant offered in the UK is not necessarily identical in specification to the most efficient model variant offered in Australia. This analysis simply shows the most efficient option in that model range available to consumers in the Australia and the UK. Both Australia and the UK use the New European Drive Cycle as the basis of measurement.

ultimately choose a range of vehicles from their global portfolio that will maximise their profit in the Australian market.

It is therefore reasonable to expect Australia will continue to realise some of, but not all, the benefits of standards applied in other countries for those models and variants that are also supplied to Australian markets. However, in the absence of further policy measures, it is likely global vehicle manufacturers will continue to only offer those vehicles that are the most cost effective to supply to the Australian market. In many cases, this will mean that Australian consumers will not be offered some of the most efficient variants available to consumers in other markets with fuel efficiency standards.

3.5 Minimum efficiency requirements for fleet purchasing

In 2015, over 500,000 new light vehicles were purchased by government, business and rental fleets, representing approximately 46 per cent of new light vehicles sold in Australia (FCAI 2015). Purchasing and leasing decisions by fleet operators 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 more efficient vehicles, the Australian Government could play a leadership role in fleet purchasing by setting minimum efficiency requirements for Australian Government fleet purchases. These requirements could set an example for other fleets to follow. To provide further guidance to other fleets, vehicles that meet Australian Government requirements could receive recognition on the Green Vehicle Guide website.

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 (Nesbit & Sperling 2001);
- fleet vehicles are on average driven twice as far annually than household vehicles, thus maximising the use of any technology benefits of more efficient vehicles (Nesbit & Sperling 2001); and
- average emission levels from vehicles purchased by fleets are higher than the national average (NTC 2016), suggesting a greater potential for improvement in the short term.

To be cost-effective, fleet purchasing policy would need to balance vehicle efficiency objectives with operational needs and value for money. For example, a uniform minimum efficiency level covering all light vehicles would not achieve this balance, as government purchases of smaller vehicles would be relatively unrestricted, providing limited incentive for manufacturers to improve the efficiency of these vehicles, whereas agencies requiring larger vehicles such as people movers or light commercial vehicles would have more limited options and may be forced to seek an exemption for operational reasons.

To achieve an appropriate balance, a minimum efficiency requirement could be set at the top 25 per cent of current model vehicles for each class as defined on the Green Vehicle Guide website. Table 4 shows the CO_2 emissions at the 25th percentile of each class for current model vehicles on the Green Vehicle Guide.

Table 4: CO_2 Emissions at 25th percentile of each class for current models on Green Vehicle Guide (September 2016)

GVG Class[19]	Combined tailpipe CO_2 at 25th Percentile
Small Car (car and SUVs with plan area up to 7.2m^2) Typically marketed as micro or light cars	119g/km
Medium Car (cars and SUVs with plan area of 7-8.2m^2) Typically marketed as small cars/SUVs	137g/km

[19] GVG vehicle classes are not mutually exclusive, so some vehicles may be in more than one class.

GVG Class[19]	Combined tailpipe CO_2 at 25th Percentile
Large Car (cars and SUVs with plan area over $8m^2$) Typically marketed as medium, large or upper large cars/SUVs	162g/km
Off-road[20] Typically marketed as four-wheel drive SUVs	180g/km
Vans	163g/km
Ute/Light Truck	206g/km
People Mover (all vehicles with 6 or more seats) Includes vehicles marketed as 'People Movers', as well as vans and SUVs with 6 or more seats.	199g/km

To ensure the most appropriate vehicles are purchased, vehicles meeting minimum efficiency requirements would still be subject to assessment on the basis of operational needs and value for money (based on capital and operating (including but not limited to fuel) costs). Depending on differences in capital costs relative to operating costs, this may also encourage the purchase of more efficient vehicles.

By setting an official benchmark for fleet purchasing, the Australian Government would encourage manufacturers to supply a higher proportion of vehicles that met these requirements, especially if a similar benchmark was adopted by other governments and private fleets. As a result of this and expected improvements in the absence of any further government action, the proportion of vehicles meeting the official benchmark would increase over time. To ensure the proposed benchmark continued to encourage manufacturers to improve the efficiency of their vehicles, these benchmarks could be adjusted in line with expected improvements in the efficiency of the light vehicle fleet. By putting such a mechanism in place now, manufacturers could plan ahead to meet these benchmarks, maximising the potential for improving and minimising the costs for fleets adopting this arrangement.

As the Australian Government fleet is less than 0.1 per cent of the broader Australian vehicle fleet, and around 0.3 per cent of new vehicle sales, the benefits to the community from adopting minimum efficiency requirements in the Australian Government fleet alone would be relatively small. The ability of a fleet purchasing policy to influence the efficiency of the broader vehicle fleet would be enhanced if other government and private fleets adopted similar policies. The widest possible adoption would be required to make it commercially viable for many manufacturers to offer a wider range of more efficient vehicles than are currently sold in Australia.

The costs of adopting this option would be largely associated with the cost of developing a new fleet purchasing policy and updates to the Green Vehicle Guide to recognise vehicles meeting the fleet purchasing policy.

As the costs and benefits of this policy are highly dependent on voluntary action by other government and corporate 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 evaluated further.

3.6 Voluntary fuel efficiency standard

To improve vehicle efficiency, a voluntary standard could be developed through an agreement between the Australian Government and the Federal Chamber of Automotive Industries (FCAI). This agreement would specify targets and timeframes, as well as monitoring and reporting arrangements.

[20] Vehicles meeting the definition of ADR category MC (Off-road vehicle). In addition to four-wheel drive, an MC category vehicle must also meet specific ground clearance requirements.

In 1978, the Australian Government and the FCAI negotiated voluntary fuel-economy targets for new petrol-fuelled motor vehicles to be achieved in 1983 and 1987, which required 15 per cent and 20 per cent reductions respectively in average fuel consumption. A subsequent target was also agreed to achieve an average of 8.2 litres per 100 km in 2000, a further reduction of just under 12 per cent from the 1990 level of 9.16 litres per 100 km (Scoular 2004). These three targets were not achieved, with the outcomes being slightly above the agreed targets (Onoda 2008, Productivity Commission 2005, Scoular 2004).

In 2003, the FCAI and the Australian Government agreed to a fuel-economy target for petrol-fuelled cars (including four-wheel drive vehicles, but excluding utilities) of 6.8 litres per 100 km for 2010. This was subsequently abandoned due to a change in the test cycle used to measure efficiency (from the US Federal Test Procedure to the New European Drive Cycle), which affected the ability to assess progress. In 2005, FCAI set a voluntary industry target for 2010, for an average of 222 grams of CO_2 per km for new light vehicles (SUVs, other passenger cars, vans and light trucks), labelled the National Average Carbon Emissions target, which was achieved in 2008. This voluntary arrangement did not achieve the original goal of 6.8 litres per 100 km and was not renewed.

For a voluntary standard to work effectively, participants need to share a collective interest that aligns with best interests of consumers and the general public, and an incentive to develop standards that support social and environmental outcomes (Marsden-Jacob Associates 2016).

In the case of vehicle efficiency, there is limited collective interest or incentive to develop standards that support social and environmental outcomes, as the vehicle industry has an incentive to maximise its profits in selling vehicles and minimise development costs. These interests directly compete with any intention to maximise benefits to motorists or society generally.

As discussed in Section 2.3, the difficulties consumers face in assessing the benefits of vehicle efficiency due to imperfect and uncertain information lead to buyers undervaluing fuel savings, relative to other aspects such as size and performance. As a result, it is unlikely that manufacturers would do significantly more to meet a voluntary standard than they would do under existing policy settings, as they may not be able to pass on any additional vehicle manufacturing costs through increased retail prices, particularly in competitive segments of the market.

For these reasons this option has not been evaluated further.

3.7 Legislated fuel efficiency standard

To drive improvements in light vehicle efficiency and reduce the growth of greenhouse gas emissions from the transport sector, fuel efficiency or CO_2 standards have been adopted in approximately 80 per cent of the global light vehicle market–including the US, EU, Canada, Japan, China, South Korea and India (ICCT 2015a).

International experience suggests that these standards have been successful in driving improvements in light vehicle efficiency in other markets. The International Energy Agency (IEA) strongly encourages governments to implement policies that include standards for light vehicles because they have proven to be effective in mobilising the large, low-cost opportunity available in light vehicle efficiency technologies (IEA 2012).

Under this approach, the Australian Government would legislate targets for vehicle efficiency. To ensure manufacturers can continue to offer a wide range of vehicles to consumers, fuel efficiency standards are typically applied on a sales weighted average basis to manufacturers (or a manufacturing group), rather than an individual vehicle level, as is done under the noxious emission standards adopted as Australian Design Rules.

Fuel efficiency standards would set a national average target for new light vehicles sold in Australia. Entities that supply vehicles to the Australian market[21] would have obligations to report on the volume and efficiency of the vehicles they supply to ensure a national average target is met.

---

[21] In this discussion, entities refer to organisations that supply vehicles to the Australian market for use in transport. This would generally be the manufacturer or a subsidiary of the manufacturer, but could include independent distributors that import and sell vehicles on behalf of a manufacturer.

Over time, this would contribute to improvements in vehicle efficiency and reductions in greenhouse gas emissions as more efficient vehicles enter the fleet.

3.7.1 Three targets have been evaluated

The Department with the assistance of the Bureau of Infrastructure, Transport and Regional Economics (BITRE) has assessed the costs and benefits of three possible targets phased in from 2020 to 2025. The targets for 2025 are based on the 'strong', 'medium' and 'mild' standards proposed by Climate Change Authority in 2014 (CCA 2014).

The first option evaluated is an overall fleet average target of 105g/km in 2025, which would equate to a 33 per cent improvement on the expected fleet average for 2025 under current policy settings. This target is broadly equivalent in stringency to the EU targets for 2020-21[22] and the US target for 2025.

The second option evaluated is an overall fleet average target of 119g/km in 2025, which would equate to a 24 per cent improvement on the expected fleet average for 2025 under current policy settings.

The third option evaluated is an overall fleet average target of 135g/km in 2025, which would equate to a 14 per cent improvement on the expected fleet average for 2025 under current policy settings.

Chapter 4 provides an estimate of the likely benefits, costs and regulatory burden of implementing these three possible targets.

3.7.2 Implementation of a standard

While fuel efficiency standards have been adopted in over 80 per cent of the global vehicle market, standards have been implemented in different ways, to suit the needs of their local vehicle markets.

In addition to the fleet average targets, the manner in which a standard is implemented can influence incentives for manufacturers to supply particular vehicles.

Options for implementing a fuel efficiency standard are outlined in Table 5. Discussion of the potential implications of adopting a particular approach can be found in Appendix A, including a number of questions to guide your feedback.

Table 5: Options for implementing a fuel efficiency standard in Australia

Design element	Possible Options
What could be regulated?	A standard could regulate: • Tailpipe CO_2 emissions (g/km), and/or • Fuel consumption (L/100km).
How could efficiency be measured?	Vehicle efficiency could be measured via using the: • New European Drive Cycle currently adopted in UN Regulation 101 and ADR 81/02; or • World harmonised Light vehicles Test Procedure (WLTP), expected to be adopted in European and UN Regulations by 2020.
How could a sales weight average target be applied?	Target could be applied as a: • Uniform average target for all manufacturers; • Uniform percentage improvement for all manufacturers; or • Attribute based targets adjusted by the mass/footprint of vehicles sold.
If an attribute based standard is	An attribute based standard could be based on:

22 EU targets are 95g/km by 2021 for passenger vehicles and 147g/km by 2020 for light commercial vehicles.

Design element	Possible Options
adopted, what attributes could be used to determine manufacturer targets?	• Mass in running order (EU approach); or • Footprint (US approach).
How could targets be applied to different vehicle types?	Targets could be applied in the following manner: • One target covering all light passenger and commercial vehicles; or • Separate targets could be applied to different vehicle categories. For example: o One target for cars and SUVs and another for light commercial vehicles (EU approach); or o One targets for cars and another for SUVs and light commercial vehicles (US approach).
How could targets be phased in from 2020 to 2025?	Targets could be phased in from 2020 to 2025 via: • Annual targets that progressively increase in stringency from 2020 to 2025; or • Applying the target to an increasing proportion of sales from 2020 to 2025. To allow flexibility in compliance and product development: • Borrowing, banking and trading provisions could be adopted to allow compliance over a number of years, or across segments, and/or • Suppliers/manufacturers could comply as group.
What other incentives could a standard adopt to encourage supply of more efficient vehicles under a standard?	Credits could be offered to encourage the supply of: • Ultra low emission vehicles/powertrains (e.g. electric or hydrogen fuel cell vehicles); and/or • Technologies that could improve vehicle efficiency in an on-road setting, that are not captured in standardised test conditions.
Which entities could be required to comply?	Targets could be applied to: • The entity holding a type approval under the *Motor Vehicle Standards Act 1989*; or • The entity responsible for the distribution and management of sales in Australia (that is the importer/national distributor, not dealers).
Should all entities be subject to the same requirements?	Entities that supply less than a certain number of vehicles in a compliance period could be granted a concessional arrangement, such as: • An alternative sales weighted average target; and/or • An exemption from meeting any sales weighted average target.
What penalties could be applied if entities failed to comply?	Penalties could be applied in the form of: • A financial penalty could be applied per vehicle for each unit of exceedance (i.e. gCO_2/km or L/100km over target); • Type approvals could be suspended, cancelled or refused; and/or • Suppliers/manufacturers could be excluded from government fleet purchasing.

4 What are the likely net benefits of each option?

To determine the net benefit of a fuel efficiency standard identified in Section 3.7, the Bureau of Infrastructure, Transport and Regional Economics (BITRE) undertook a range of analyses to underpin a benefit-cost analysis (BCA) for each of the targets in Section 3.7.1 of this RIS. The full details of the analysis are contained in Appendix B.

Under this benefit–cost analysis, the base and price year has been set to 2016 with the evaluation period extending to 2040. This allows for a 20-year analysis period from a proposed commencement in 2020. A standard discount rate of seven per cent was used, as required by the Office of Best Practice Regulation (DPMC 2014). Sensitivity testing was conducted on discount rates of three and 11 per cent (see Table 13). The key indicators for economic viability are Net Present Value (NPV) and Benefit–Cost Ratio (BCR). The BCA also includes a number of sensitivity tests.

The main quantifiable benefit identified is the fuel cost avoided due to lower levels of fuel consumption from the adoption of technologies required to meet the fuel efficiency targets. There are also additional benefits from a reduction in greenhouse gas emissions. The main cost identified is the additional capital costs incurred to manufacture vehicles incorporating additional fuel saving technologies to meet the new standards. Table 6 shows the targets considered in this analysis.

Table 6: Targets considered in this analysis

Scenario	Standard	Vehicle Group	Description of Scenario[23]
Business as usual (BAU)	No standard, improvements driven purely by market forces and existing measures.	New passenger and commercial vehicles up to 3.5 tonnes.	Improvements in vehicle efficiency, roughly 1.5-1.6 times the historical average, resulting in an overall fleet average of 157g/km in 2025.
Target A	Standard phased in from 2020 with a fleet average target of 105g/km in 2025.	New passenger and commercial vehicles up to 3.5 tonnes.	Improvements in vehicle efficiency up to five times faster than BAU, resulting in an overall fleet average 33 per cent better than expected under BAU in 2025.
Target B	Standard phased in from 2020 with a fleet average target of 119g/km in 2025.	New passenger and commercial vehicles up to 3.5 tonnes.	Improvements in vehicle efficiency up to four times faster than BAU, resulting in an overall fleet average 24 per cent better than expected under BAU in 2025.
Target C	Standard phased in from 2020 with a fleet average target of 135g/km in 2025.	New passenger and commercial vehicles up to 3.5 tonnes.	Improvements in vehicle efficiency up to 2.5 times faster than BAU, resulting in an overall fleet average 14 per cent better than expected under BAU in 2025.

23 Note that the values given in the table refer to rated or test fuel consumption levels, based on standard laboratory or dynamometer results over specified drive cycles, where such levels are typically lower than actual on-road fuel consumption. The table values refer to compliance results obtained over the NEDC (New European Driving Cycle) test, as specified in current United Nations (UN) regulations setting out procedures for determining fuel consumption and CO_2 emissions from light vehicles. Overall emissions projections have been updated to reflect recent data on vehicle composition, vehicle sales, fuel consumption, new vehicle specifications, vehicle activity trends, fleet modelling parameters and recent studies for on-road efficiency and fleet emission performance from real-world testing.

4.1 Benefits (fuel cost and greenhouse gas savings)

For this benefit-cost analysis, fuel consumption and CO_2 emissions from the Australian light vehicle fleet were modelled using a range of BITRE fleet and projection models. These models are described in a variety of BITRE publications (refer to Appendix B for more information). These models allow for the effects for future urban traffic congestion levels (raising both average urban fuel consumption rates and emission rates) on a city-by-city basis and take separate account of the passenger (car and SUV) and commercial components of the light vehicle fleet.

The BITRE emissions projection modelling suite has been updated and revised for this analysis, using recent data on vehicle composition, vehicle sales, fuel consumption, new vehicle specifications, vehicle activity trends, fleet modelling parameters and improved information for on-road efficiency and fleet emission performance from real-world testing.

The 'business as usual', or reference projections, are based on current trends in major economic and demographic indicators, with continuing growth in national population and average income levels, gradually increasing fuel prices and likely future movements in freight sector performance and vehicle technology.

BITRE then estimated the impacts of the three targets (A, B and C) on total light vehicle fuel consumption and CO_2 emissions. All options analysed incorporate the following assumptions:

- Oil prices remain relatively close to current levels ($US 60-70/barrel in 2020) and then gradually rise over ensuing decades–with the result that the resource cost[24] of standard unleaded petrol (ULP) increases by around 1 per cent per annum, from current levels of about 70c/litre (excluding taxes), over the projection period.
- Income grows in line with Treasury's 2015-16 Mid-Year Economic and Fiscal Outlook for the short term and the Intergenerational Report for the long term (Treasury 2015).
- Vehicle usage projections are based primarily on 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 2013b).
- 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 year, remaining marginally above that of passenger vehicles at around 1.7 per cent per year).
- 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, the current popularity of diesel light vehicles–especially in the SUV and LCV markets–and the niche use of alternatives such as natural gas and electricity).
- There will be no change to current noxious emission or fuel quality standards, though Australia will gain some benefits from a subset of imported vehicles meeting stricter overseas pollution or efficiency standards.
- 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.

[24] Fuel cost excluding taxes such as fuel excise and GST. In an economy wide analysis, taxes are a transfer between consumers and government. Reductions in fuel use will also reduce fuel taxes paid by consumers, which will be cancelled out by a consequential loss of revenue to government.

4.1.1 Changes in average vehicle efficiency

- Figure 7 shows the expected change in average vehicle efficiency under a business as usual scenario. In the business as usual scenario, the average rated[25] efficiency of the Australian new light vehicle fleet reaches a level of about 157g/km, across all new light vehicle sales in 2025 (146g/km for passenger vehicles (cars and SUVs) and 206g/km for light commercial vehicles). This is a decrease of 15 per cent from the 2015 average of approximately 184gCO_2/km (175g/km passenger and 229g/km for light commercial vehicles).

Figure 7: Expected changes in the efficiency of new light vehicles under a business as usual scenario (BITRE estimates)

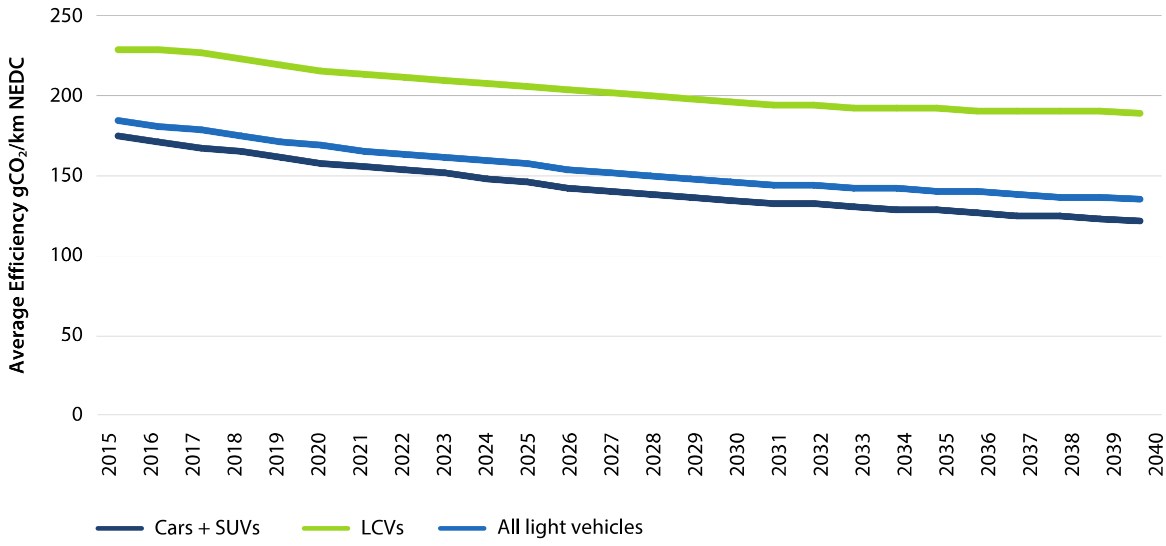


Figure 8 shows the expected changes in vehicle efficiency for light passenger and commercial vehicles under the three targets considered. Under a fuel efficiency standard, additional improvements start to occur from 2018, as manufacturers start to make changes to the range of vehicles supplied to prepare for the introduction of a standard in 2020. Improvements in vehicle efficiency are slower from 2025 onwards, as the modelling does not pre-empt any changes to fuel efficiency standards beyond 2025.

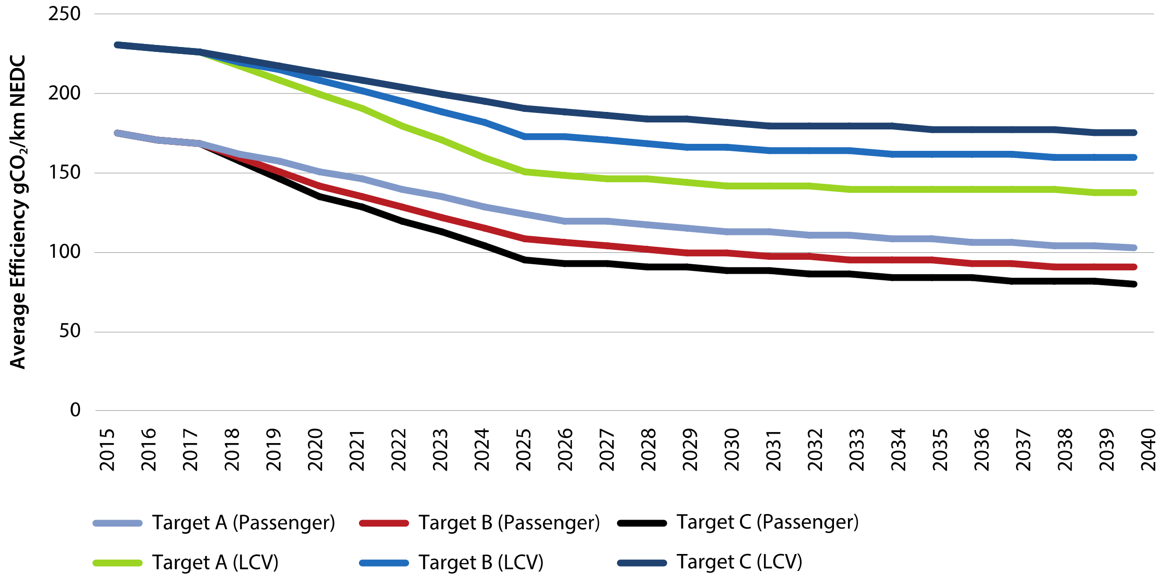
Based on the expected sales mix, the efficiency of new passenger vehicles (cars and SUVs) under Target A is expected to improve from 175g/km in 2015 to 95g/km in 2025, with the efficiency of new light commercial vehicles expected to improve from 229g/km in 2015 to 149g/km in 2025. This is broadly comparable to the European targets for 2020-21 and US target for 2025.

Under Target B, the efficiency of new passenger vehicles (cars and SUVs) is expected to improve from 175g/km in 2015 to 107g/km in 2025, with the efficiency of light commercial vehicles expected to improve from 229g/km in 2015 to 173g/km in 2025.

Under Target C, the efficiency of new passenger vehicles (cars and SUVs) is expected to improve from 175g/km in 2015 to 123g/km in 2025, with the efficiency of light commercial vehicles expected to improve from 229g/km in 2015 to 190g/km in 2025.

[25] Over the New European Drive Cycle test currently adopted in Australian Design Rule 81/02 and equivalent EU and UN Regulations.

Figure 8: Expected changes in passenger and light commercial vehicle efficiency under the three targets (BITRE estimates)



4.1.2 Fuel Savings

Table 7 presents modelling results for community fuel savings ($ million) for the three targets relative to the business as usual scenario. Fuel costs (less taxes) were primarily based on pump price trend data collated by FuelTrac Pty Ltd–and published by the Australian Automobile Association, the Australian Institute of Petroleum, Motormouth Pty Ltd, Viva Energy Australia, Caltex Australia and the NRMA, with projections using the basic assumption of a uniform annual increase of 1 per cent (refer to Appendix B for further information).

Table 7: BITRE estimates of cumulative fuel savings to 2040 compared to the business as usual scenario ($ millions, 7 per cent annual discount rate)

Target A	Target B	Target C
27,456.5	19,705.2	10,787.1

In estimating fuel saving benefits from a reduction in fuel consumption driven by fuel efficiency standards, a wide range of cost values has been applied in sensitivity tests, to reflect uncertainty regarding fuel prices that will be borne by consumers.

These figures are based on resource costs which exclude taxes, such as fuel excise and GST, which are a transfer between consumers and government in an economy wide analysis. Fuel cost savings experienced by consumers will be higher, as a reduction in fuel use will also result in a reduction in fuel taxes paid to government.

Fuel cost savings experienced by consumers will depend on a range of factors, including retail fuel prices, travel behaviour and vehicles purchased. Fuel cost savings for individual vehicle models will depend on the level of improvement required by the manufacturer to meet their sales weighted fuel efficiency target and broader product improvements at a global level.

Further discussion of the possible fuel cost savings that could be experienced for an average performing petrol passenger vehicle and an average performing diesel light commercial vehicle are discussed in Appendix C.

4.1.3 Greenhouse Gas Reductions

Under a business as usual scenario (Figure 9), total CO_2 emissions from the light vehicle fleet (new and existing vehicles) are projected to increase from 56.9Mt in 2015 to 65.2Mt in 2030 and 65.6Mt in 2040.

Under a fuel efficiency standard, growth in CO_2 emissions from the light vehicle fleet starts to slow from 2018, as manufacturers make changes to the range of vehicles supplied to prepare for the introduction of a standard in 2020. Overall CO_2 emissions from the light vehicle fleet (Figure 11) start to decline from 2022 (under Target A), 2024 (under Target B) and 2026 (under Target C), as improvements in vehicle efficiency start to offset growth in activity in the light vehicle fleet.

Figure 9: Estimated changes in total light vehicle CO_2 emissions under the three targets relative to the business as usual scenario (BITRE estimates)

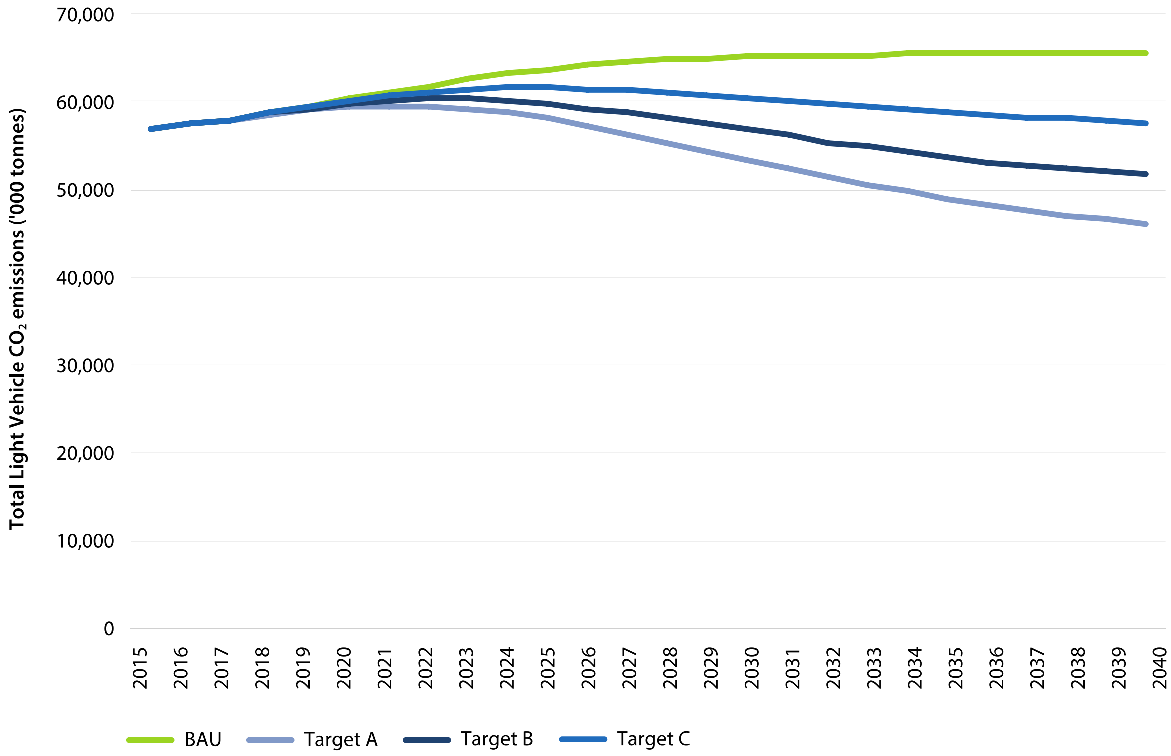


Table 8 presents modelling results for cumulative reductions in CO_2 emissions for the three targets relative to the business as usual scenario in 2030 and 2040.

Table 8: Estimated cumulative reductions in total light vehicle CO_2 emissions (Mt) to 2030 and 2040 compared to the business as usual scenario

Timeframe	Target A	Target B	Target C
2018-2030	65.372	46.033	24.713
2018-2040	231.056	164.322	91.207

Table 9 presents modelling results for the cumulative value of reductions in CO_2 emissions for the three targets relative to the business as usual scenario. An estimate of $35/per tonne of CO_2 abated, kept constant over the analysis period, has been used to estimate greenhouse benefits from a reduction in aggregate vehicle CO_2 emissions. This unit value has been based on appraisals conducted for the United States Government (US OMB 2010, 2015) on the social cost of carbon and used by the US EPA to estimate the possible climate benefits of legislation. An alternative value of $12.10, based on the average cost of abatement from the first three auctions under the Emissions Reduction Fund has also been assessed as a sensitivity test.

Table 9: Estimated cumulative greenhouse gas reduction benefits to 2030 and 2040 compared to the business as usual scenario ($ millions, annual discount rate of 7 per cent)

Timeframe	Target A	Target B	Target C
2018-2030	1,116.1	783.7	417.2
2018-2040	2,655.8	1882.7	1,034.4

4.2 Costs (vehicle production and other costs)

4.2.1 Capital costs

There are a wide range of technologies that have been adopted by vehicle manufacturers to meet fuel efficiency standards in other countries, which vary by manufacturer and other market requirements. Obtaining reliable cost estimates for these technologies as a package and subsequent vehicle on-costs to users is difficult due to the sensitive nature of cost information and difficulty in apportioning costs.

Additional cost estimates for supplying vehicles with additional fuel saving technologies are primarily informed by US estimates for packages of various fuel-saving technologies (derived as part of the US Government's assessment of efficiency standards), and International Council for Clean Transportation (ICCT) summary values for European studies adjusted for the different make-up of the European fleet, and the indirect cost multipliers[26], to scale up extra manufacturing costs to final market-delivered levels. These extra costs typically increase as the standard becomes more stringent, until 2025. After 2025, the cost estimates stabilise or decline slowly, as the modelling does not pre-empt any further changes to efficiency standard beyond 2025. Further information on how these were derived can found in Appendix B.

Separate cost curves for light passenger and commercial vehicles were developed from the technology assessment data. There is uncertainty in the determination of these cost curves, as the exact mix of future technologies that will be successfully marketed in Australia are unknown. There are many unknown factors that could also affect future technology component costs (such as economies of scale, technical advances or 'learning' enhancements). The ensuing modelled cost functions are non-linear (i.e. exhibit faster increases in net costs for larger improvements in fuel efficiency than for slight improvements) and could be regarded as approximately median results (i.e. are both higher than some literature results and lower than others, as well as being more non-linear than some and less than others). This level of additional vehicle cost uncertainty is addressed in sensitivity tests.

Table 10 shows the estimated average additional cost per vehicle (for non-electric vehicles) under the three targets analysed. These extra capital cost estimates (averaged across all the different vehicle types and sizes) include an allowance for administrative compliance costs (such as testing, reporting and record keeping) under the proposed standards.

As vehicle manufacturers will incur additional costs to supply a range of vehicles to meet the standard, it is possible these costs may be passed on to consumers through higher retail prices. The extent to which these costs may be passed on to consumers will depend on factors such as competition, pricing strategies adopted by manufacturers to ensure they meet a sales weighted average target and other changes to vehicle specifications, as part of any model updates.

Table 10: Estimated average additional capital and compliance costs per vehicle for non-electric vehicles ($/vehicle)

[26] e.g. see US EPA 2009, NRC 2015, BEUC 2013.

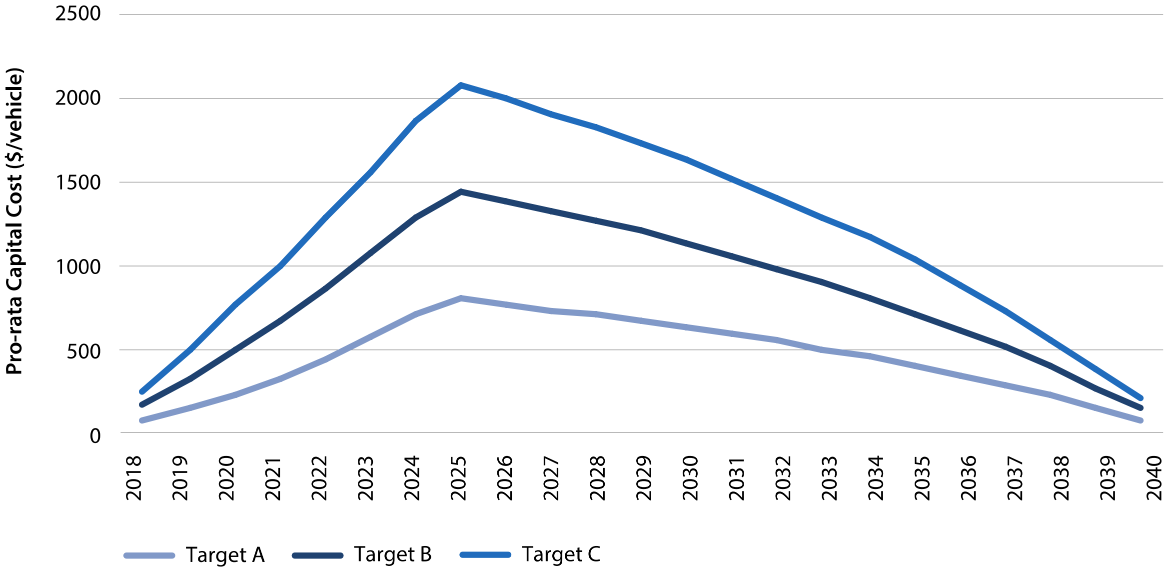
Financial year	Target A (105g/km)		Target B (119g/km)		Target C (135g/km)	
	Passenger	Light Commercial	Passenger	Light Commercial	Passenger	Light Commercial
2018	238.3	231.9	167.8	105.6	77.0	36.7
2019	493.0	490.7	345.2	223.8	157.3	80.6
2020	763.9	776.4	532.4	354.5	241.0	131.3
2021	956.8	1183.2	680.3	588.0	330.1	243.9
2022	1192.5	1622.7	868.6	837.9	456.7	364.1
2023	1437.8	2090.6	1064.2	1099.9	587.6	487.4
2024	1692.7	2590.1	1266.9	1377.1	722.8	617.0
2025	1921.8	3120.1	1441.3	1668.6	826.8	752.0
2026	1901.0	3120.6	1426.9	1671.3	819.4	754.1
2027	1886.6	3120.5	1416.8	1673.6	814.3	756.0
2028	1871.8	3119.7	1406.4	1675.6	808.9	757.7
2029	1856.7	3118.3	1395.7	1677.1	803.3	759.2
2030	1841.1	3116.4	1384.7	1678.3	797.5	760.6
2031	1830.8	3115.2	1377.4	1678.8	793.6	761.2
2032	1820.4	3113.9	1370.0	1679.1	789.7	761.7
2033	1810.0	3113.0	1362.6	1679.3	785.8	762.0
2034	1799.5	3112.1	1355.1	1679.4	781.8	762.3
2035	1789.0	3111.1	1347.5	1679.5	777.8	762.6
2036	1778.4	3110.1	1340.0	1679.6	773.7	762.9
2037	1767.8	3109.1	1332.3	1679.7	769.6	763.1
2038	1757.1	3108.0	1324.7	1679.7	765.5	763.3
2039	1746.5	3106.9	1317.0	1679.7	761.4	763.5
2040	1735.8	3105.7	1309.3	1679.6	757.2	763.7

Sources: BITRE estimates based on US EPA (2012a, 2012b), US EPA & NHTSA (2011, 2012), Mock (2015a, 2015b), IKA 2014, Citigroup 2011, AEA Technology 2012, European Commission 2015, Ricardo-AEA 2014, NRC 2015 and ICCT (2012b, 2012c, 2013b).

Vehicles purchased during most years of the evaluation period will deliver fuel saving benefits beyond 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, as the vehicle fleet emission models simulate the fleet-wide impact of technology penetration over time, and separating out the effects after the end of the evaluation period would be relatively imprecise and impractical for wide-ranging scenario analyses. Since the benefits from fuel saving technology are fairly constant over the lives of the vehicles, a good approximation is obtained by prorating the cost of the technology over the lives of the vehicles, then only counting costs attributed to years before 2040.

The average vehicle life was assumed to be 17 years. For vehicles purchased during the last 16 years of the evaluation period, the cost of the fuel saving technology was annuitised over 17 years at a discount rate of 7 per cent. Figure 10 shows the effects of annuitising costs for vehicles purchased over the last 16 years of the evaluation period. The pro-rata curves approach zero by the end of the period, with vehicles purchased in 2039 having only one year of cost included, as only one year of their fuel saving benefit is captured in the benefit-cost analysis.

Figure 10: Pro-rata capital costs under the three standards scenarios (BITRE estimates)



In estimating the total implementation costs for the three targets, it was assumed that announcement of the standards in 2017 would encourage some manufacturers to either start promoting their high-efficiency models more strongly or slightly bring forward planned technology enhancements, with some vehicles sold in 2018 and 2019 incorporating additional fuel saving technology (over the base case) in anticipation of the 2020-2025 requirements.

As a rough test into whether the pro-rata cost methodology might introduce some bias into the calculations (relative to the more usual 'residual value' method), a sensitivity test was run on the Target A scenario, with fleet technology penetration following the same path as the Target A scenario up to 2040, but with technology implementation reverting to the base case scenario after 2040. The modelled emission reductions over the next 10 years (2040-2050) were then used to approximate residual values for the continuing emission benefits of the pre-2040 vehicles. The result of this sensitivity test was that the pro-rata methodology did not greatly alter the derived outcome (see Section 4.4).

Table 11 shows the cumulative additional capital costs over the period to 2040 relative to the business as usual scenario for each of the three targets.

Table 11: BITRE estimates of cumulative capital costs to 2040 compared to the business as usual scenario ($ millions, 7 per cent annual discount rate)

Target A	Target B	Target C
16,214.4	11,157.7	5,990.3

4.2.2 Other costs

Depending on how a fuel efficiency standard is implemented, a standard could impose other costs. For example, a uniform standard for all manufacturers could reduce the range of larger vehicles available to consumers. A standard based on fuel consumption instead of CO_2 could result in higher noxious emissions, particularly if Euro 6 noxious emission standards are not also implemented, as it would provide a stronger incentive for manufacturers to supply diesel powertrains, which generally produce higher levels of noxious emissions than petrol powertrains.

It has not been the experience in the US nor the EU that fuel efficiency standards reduce the range of vehicles available, as these markets have adopted attribute based standards on a sales weighted average basis to a vehicle supplier, rather than at an individual vehicle level, to minimise impacts on the range of vehicles available to consumers.

Due to a lack of information and/or a methodology to reliably estimate these effects, these costs have been excluded.

4.3 All three targets evaluated produce a net benefit

Table 12 reports the analysis results for the three targets. Under all three targets, there are net cost savings.

The fuel cost savings by 2040 ranged from $10.8 to $27.5 billion, with 91-231 million tonnes of greenhouse gases avoided. The capital costs to meet the standard over the assessment range from $6.0 to $16.2 billion, which were more than offset by fuel cost savings over the assessment period.

Table 12: Summary of estimated total costs and benefits to 2040 compared to the business as usual scenario ($ millions, 7 per cent annual discount rate)[27]

Quantified costs and benefits to 2040 ($m)	Target A (105g/km in 2025, phased in from 2020)	Target B (119g/km in 2025, phased in from 2020)	Target C (135g/km in 2025, phased in from 2020)
1. Fuel savings	27,456.5	19,705.2	10,787.1
2. Greenhouse gas savings	2,655.8 (231Mt)	1882.7 (164Mt)	1,034.4 (91Mt)
3. Capital costs	16,214.4	11,157.7	5,990.3
Net benefit (1+2-3)	13,897.9	10,430.3	5,831.2
Benefit-Cost Ratio ((1+2)/3)	1.86	1.93	1.97
Cost of abatement	-$48.70/tonne	-$52.00/tonne	-$52.60/tonne

4.4 Under a range of scenarios there is still a net benefit

Sensitivity tests were undertaken for uncertainties including discount rates, fuel cost values, cost of greenhouse gas emissions, capital costs, vehicle fleet turnover, free rider effects of standards in other markets, correlation between tested and on-road emissions, rebound effects, health costs and lower initial rates of improvement.

Given that Target A generated the highest net benefit, sensitivity testing was based on this scenario. Table 13 reports the findings of these sensitivity tests.

Table 13: Effects of sensitivity tests on the net benefit of Target A

Sensitivity test	Net Benefit ($m)	Benefit Cost Ratio
Base Case	13,897.9	1.86
Low Discount Rate (3%)	31,732	2.40
High Discount Rate (11%)	5,692	1.50
Low petroleum resource cost of 60c/L (excluding taxes) in 2040	6,547	1.40
High petroleum resource cost of $1.20/L (excluding taxes) in 2040	17,809	2.10
$12.10 unit cost for CO_2 [28]	12,160.3	1.75
CO_2 reduction benefits excluded	11,242.1	1.69
High incremental cost (1.3 times higher capital cost per unit of CO_2 reduction)	9,034	1.43
Low incremental cost (highly non-linear decrease in capital cost per unit of CO_2 reduction)	15,859	2.11
Higher capital cost for SUVs	10,661	1.55
Lower vehicle turnover	12,409	1.83
Low free rider effect	20,177	1.95
High free rider effect	9,100	1.77
Lower reduction in on-road emissions relative to tested emissions	10,563	1.65
Rebound effect (elasticity of 0.1)	11,031	1.64

27 Additional production cost, minus fuel savings, divided by tonnes of CO2 avoided by 2040.

28 Average cost of abatement for the first three Emissions Reduction Fund auctions.

Sensitivity test	Net Benefit ($m)	Benefit Cost Ratio
Possible increase in noxious emissions due to wider adoption of diesel and GDI (if Euro 6 is not adopted)	9,915	1.47
Smaller short term improvements	11,501	1.85
Extra capital costs not pro-rated to evaluation period	17,879	1.84

4.5 Adopting a standard will increase regulatory burden

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 (DPMC 2014) 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 reduced fuel use and greenhouse gas emissions for consumers and the wider community. The average annual regulatory costs were established by calculating the average undiscounted capital cost for each option over the period from 2020-2029 inclusive.

The average annual regulatory costs under the RBM of targets identified in Option 4 are set out in Table 14. There are no costs associated with Option 1 as it is the business as usual case. The average annual regulatory costs associated with three targets proposed in Option 4 are estimated to be $2,005.78 million (for Target A), $1,381.43 million (for Target B) and $742.93 million (for Target C).

Table 14: Regulatory burden estimate for the three possible targets under a mandatory standard

Average annual regulatory costs (from business as usual)				
Change in costs ($ million)	Business[29]	Community organisations	Individuals	Total change in costs ($ million)
Total, by sector	2,005.78 (Target A) 1,381.43 (Target B) 742.93 (Target C)			2,005.78 (Target A) 1,381.43 (Target B) 742.93 (Target C)

[29] To the extent that market forces allow, costs may be passed on to consumers.

5 Consultation

5.1 Previous Consultation

This draft Regulation Impact Statement has been prepared by the Department following the consideration of:

- Feedback received at the Ministerial Forum stakeholder meetings on 7 December 2015 and 4 April 2016.
- Submissions received in response to the Vehicle Emissions 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.
- Completion of a detailed set of independent analyses of the light vehicle fleet over 2015–2025 under existing policy settings, and projections of the anticipated costs and benefits from the introduction of fuel efficiency standards of various levels of stringency.

5.2 Consultation Plan

This draft Regulation Impact Statement evaluates the level of improvement in vehicle efficiency that could be achieved through a fuel efficiency standard phased in from 2020 to 2025 and at what cost. It has been released for public comment to elicit views from all interested parties on its key proposals, particularly:

- the implications of the range of potential target(s) which might apply under the standards based on an assessment of compliance costs and consumer/societal benefits; and
- the appropriate regulatory design for implementing the standard.

Further information about regulatory design parameters can be found in Appendix A, including a range of questions you may wish to consider when providing feedback.

Comments on this draft Regulation Impact Statement are requested by 10 March 2017. They should be submitted electronically 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

The feedback received in response to this draft Regulation Impact Statement and further stakeholder discussions will help inform development of the final Regulation Impact Statement for consideration by the Australian Government in mid-2017. A summary of the public comment will be included in the final Regulation Impact Statement, which will be published once the Government announces a decision.

Appendix A–Implementing a fuel efficiency standard

A1 There is no internationally consistent approach

While fuel efficiency standards have been adopted by over 80 per cent of the global vehicle market, the manner in which these standards have been implemented varies between markets. The manner in which standards are implemented can influence the types of vehicles manufacturers choose to supply to that market. The Department has not settled on a preferred approach for implementing a standard at this point and is seeking the views of stakeholders on these implementation aspects before recommending a preferred approach in the final RIS to be considered by the Australian Government in mid-2017. To help inform discussion on how a fuel efficiency standard could be implemented, this Appendix explores the possible implications of adopting a particular approach.

To further inform the merits of adopting a particular approach in Australia, the Department commissioned an independent expert consultant, ABMARC, to undertake an analysis of the 2015 Australian new vehicle fleet, which included an assessment of the correlation between mass/footprint and CO_2 in Australia and the possible effects of adopting a particular approach on the top 10 selling manufacturers in Australia, which account for around 80 per cent of new light vehicles sold in Australia.

A2 What could be regulated?

Fuel efficiency standards adopted internationally have been applied on the basis of a vehicles' fuel/energy consumption and/or CO_2 emissions, which tend to reflect the principal objectives of standards in those markets. Some countries, such as the United States, have adopted a standard for both fuel consumption and CO_2. A standard based on CO_2 emissions would reflect the Government's primary objective of reducing greenhouse gas emissions by improving vehicle efficiency.

A standard based on CO_2 emissions rather than fuel consumption would also treat different fuel types more equitably. Some alternative, lower carbon fuels, such as Liquefied Petroleum Gas (LPG), have a lower energy content which increase fuel consumption per kilometre, but also produce lower CO_2 emissions per litre of fuel consumed and kilometre travelled. Other fuels, such as diesel, have a higher energy and carbon content which reduces fuel consumption per kilometre, but produces higher levels of CO_2 (and noxious) emissions per litre of fuel consumed. As a result, a reduction in fuel consumption (in litres per km) by switching from petrol to diesel, will result in a lower percentage reduction in CO_2 per kilometre.

If a standard based on fuel consumption was adopted, manufacturers may have a strong incentive to increase the sale of diesel powertrains to meet a standard. In the absence of more stringent (Euro 6) noxious emission standards, this could have unintended consequences for urban air quality, as diesel vehicles generally produce higher levels of noxious emissions, such as oxides of nitrogen, than petrol fuelled vehicles (and are permitted to do so under current noxious emission standards).

Question

1. **What parameter (CO_2 emissions or fuel consumption) should be used for an Australian fuel efficiency standard and why?**

A3 How could efficiency be measured?

As the vast majority of a vehicle's CO_2 emissions occur during a vehicle's use phase (rather than the vehicle's manufacture), the core data element required to assess compliance with the standards are the tailpipe CO_2 emissions produced by the vehicle.

As there are a range of variables that can affect a vehicle's fuel consumption and emissions in an on-road setting, all fuel efficiency currently adopted in other markets use a standardised laboratory test in controlled conditions to determine a vehicle's efficiency. A standardised approach to testing ensures test results can be independently verified and vehicles can be assessed on a common basis.

A standardised laboratory test currently applies to all new light vehicles supplied to the Australian market via Australian Design Rule (ADR) 81/02, which adopts the New European Drive Cycle (NEDC) test used in United Nations Regulation 101 and current European regulations. This data is provided to the Department under the authority of the *Motor Vehicle Standards Act 1989* and as such, is subject to audit by the Department.

The Department notes that the European Union plans to adopt a new Worldwide Harmonised Light Vehicles Test Procedure (WLTP) as the basis of measurement for its 2020 standards to improve the correlation between tested and on-road emissions. A new UN Regulation adopting the WLTP is also currently under development through the UN World Forum for the Harmonisation of Vehicle Regulations' Working Party on Pollution and Energy.

If Australia continued to use the NEDC for the purposes of a fuel efficiency standard, and the UN and EU Regulations adopt the WLTP, vehicle manufacturers may bear additional compliance costs if they were required to retest vehicles already tested to the WLTP. Even if test results to the WLTP were automatically accepted in lieu of NEDC test results, manufacturers submitting such results could be at a competitive disadvantage, as the WLTP is intended to be more demanding than the NEDC.

In line with Australia's commitment to harmonisation with UN vehicle regulations, the Department plans to review the fuel consumption labelling standard and test cycle adopted in ADR 81/02, with a view to facilitating a transition to the WLTP, once a UN Regulation adopting the WLTP for the measurement of fuel consumption and CO_2 emissions enters into force. However, as the NEDC is currently used as the basis for determining vehicle efficiency, the analysis and targets analysed in this RIS are based on the NEDC. If the WLTP replaces the NEDC as the basis for measurement of vehicle efficiency in Australia, a transitional arrangement may be required to determine an appropriate adjustment to any targets adopted under a fuel efficiency standard.

It is acknowledged that no standardised laboratory test will always represent "real world" driving, which can be affected by a number of variables that are controlled in a laboratory test and these tests do not take into account the non-road CO_2 emissions from the production and supply of various transport fuels (including electricity for electric vehicles). This approach does however, provide robust, uniformly collected, verifiable and comparable data for the least cost and is currently the only such data available at an individual model/variant level for all light vehicles.

To improve the correlation between laboratory tested and on-road emissions, the Department notes that the EU is implementing an on-road test regime (known as the real driving emissions or RDE test) as part of the next stage of the Euro 6 noxious emission standards commencing in September 2017. While this test could measure CO_2 emissions, the Department understands that this test is intended to complement rather than replace laboratory testing, and laboratory testing will continue to be used to determine the official CO_2 value, as a wider range of variables would affect the repeatability of results from an on-road test.

While there is international interest and research focussed on the development of robust data for life-cycle emissions for all vehicle types, this research has not yet advanced enough to reliably provide comparable information at an individual vehicle level. The Department also notes that other measures, such as the Renewable Energy Target and the Emissions Reduction Fund could be utilised to address greenhouse gas emissions from other aspects of a vehicle's lifecycle (such as electricity generation and fuel production).

Question

2. **How should a vehicle's efficiency for the purposes of an Australian fuel efficiency standard be assessed and why?**

A4 How could a sales weighted average target be applied?

The most common means of applying a fleet average standard that have been evaluated internationally are:

- a flat standard for the fleet (or sections of it), usually an absolute cap or uniform percentage reduction of efficiency, which applies to every manufacturer; and
- an attribute-based fleet-average standard, where the level of the standard varies with an attribute of the vehicle (typically vehicle mass or footprint).

In determining the best option, a reasonable starting point is to consider the simplest model possible that delivers significant emissions reductions, is cost-effective to administer and is equitable across manufacturers. The selected approach also needs to be objective and transparent so that liable entities clearly understand their obligations (CCA 2014).

Flat standards which set absolute limits (caps) and those based on uniform percentage reductions, satisfy the simplicity test. However, such approaches face major equity problems because of the heterogeneous nature of the vehicle model mix produced by different manufacturers and the relative position and emphasis on fuel consumption improvements across different manufacturers.

Applying a uniform flat standard to all manufacturers could force manufacturers with larger vehicles sitting above the standard to remove certain models from its range even if such models are relatively efficient for their size, important for their commercial viability and strongly favoured by consumers (CCA 2014). On the other hand, a uniform percentage reduction target would penalise a manufacturer that has previously invested heavily in improving vehicle efficiency relative to a manufacturer that has not.

In considering potential regulatory models, the international research strongly supports standards based on "parameter" or "attribute" based functions linked to CO_2 emissions as being the most cost-effective and equitable.

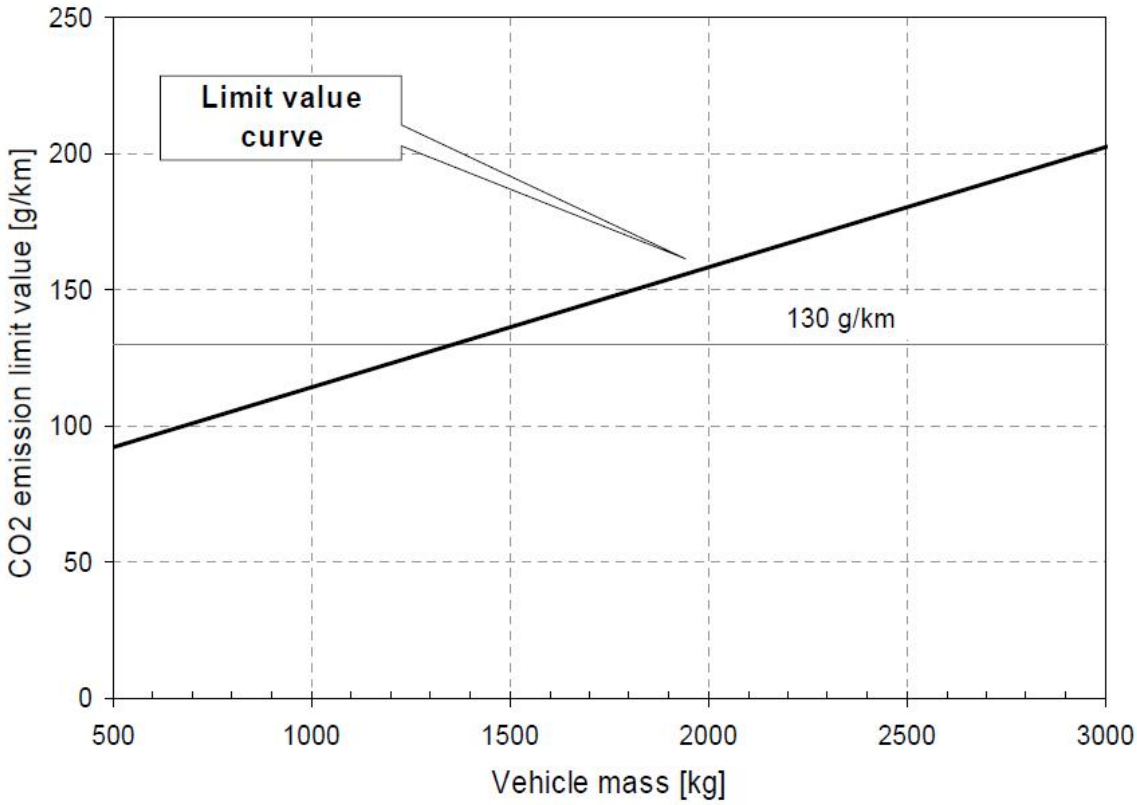
The 2011-12 US assessment (US EPA and NHTSA 2011 and 2012) for the 2017-2025 US standards, for example, identifies four key benefits of attribute based standards (relative to fixed limits or uniform percentage reductions). It argues that attribute based standards:

- achieve greater emissions reductions overall by encouraging manufacturers to aim for continued improvement across their vehicle range, because achieving the target is linked to the model mix and this can change over time;
- provide little incentive to simply build smaller vehicles to meet the standard (with potentially adverse safety impacts), as smaller vehicles will be required to meet more stringent compliance targets;
- are more equitable and spread the regulatory cost burden across all manufacturers, whereas a single industry wide average "imposes disproportionate cost burdens and compliance difficulties on the manufacturers that need to change their product plans to meet the standards, and puts no obligation on those manufacturers that have no need to change their plans"; and
- better respect economic conditions and consumer choice.

A 2011 ICCT assessment (Mock 2011) also noted that it is desirable to index standards to a vehicle attribute that "...allows a fleet to remain diverse in terms of vehicle shape, size and functionality and to improve efficiency without compromising vehicle functionality."

Both the EU and US have adopted attribute based standards, albeit using different attributes. The relationship of the attribute and vehicle CO_2 emissions is defined by a mathematical function or "limit value curve" which ultimately sets the average CO_2 emissions target for each vehicle linked to the particular attribute. Figure A1 schematically illustrates the limit value curve in the EU standards (where the attribute is vehicle mass), which is a continuous function. The US standard also utilises a continuous function, but sets minimum and maximum CO_2 values beyond specified upper and lower footprint values.

Figure A1: EU Limit Value Curve for Passenger Cars (2015)



While Japan and China use mass based “stepped” systems, continuous functions such as those adopted in the EU and the US remove potentially perverse incentives associated with the boundaries at the step change points.

Under attribute based standards using continuous functions, manufacturers have the flexibility to produce models above or below the target value set by the limit curve, provided the average value of all of their models sold in the target year meets the specified target as calculated according to the mathematical function (and as defined by the limit curve). The example on the next page shows how an attribute based standard could work. This example illustrates the flexibility that an attribute approach can provide for manufacturers in achieving their required emissions outcome and ultimately satisfy the Government’s targets for improved efficiency across the new light vehicle fleet overall.

How an Attribute Based Standard Works

Step 1 The Government sets the overall fleet average target for the specified year.

Step 2 The limit curve (and associated mathematical relationship between CO_2 emissions as measured under the standardised test and the agreed attribute) is established under the standard.

Step 3 Early in the year following the target year, each manufacturer provides data to the Government to demonstrate it has complied with the standard. The manufacturer can comply by ensuring that the average CO_2 emissions of all the light vehicles it sells on the market in the specified year (the fleet) is less than or equal to the average emissions of that fleet if all the vehicles in the fleet had met the nominal CO_2 value applicable to each vehicle according to the limit curve. This can be illustrated by the simplified example below where a manufacturer sells four models in the target year (using mass as the attribute):

Model	**Model Mass (kg)**	**Measured CO_2 Emissions (g/km)**	**Nominal CO_2 Emissions Value* (g/km)**	**No. of Vehicles Sold**
A	1000	118	115	2,000
B	1200	120	125	15,000
C	1500	133	135	4,500

Model	Model Mass (kg)	Measured CO_2 Emissions (g/km)	Nominal CO_2 Emissions Value* (g/km)	No. of Vehicles Sold
D	1600	150	140	900

* As per limit curve

The average sales weighted emissions value that the manufacturer is required to achieve for their fleet in 2015 is a function of the number of vehicles sold in that year and the nominal emissions value for each vehicle, viz:

Required Fleet Average =

$$\frac{\text{(Model A Nom. Emissions} \times \text{Model A Sales)} + \text{(Model B Nom. Emissions} \times \text{Model B Sales)} + \ldots}{\text{Total Sales (Model A+B+C+D)}}$$

In this case,

$$\textit{Required Fleet Average} = \frac{115 \times 2000 + 125 \times 15000 + 135 \times 4500 + 140 \times 900}{2000 + 15000 + 4500 + 900} = 127$$

$$\textit{Actual Fleet Average} = \frac{118 \times 2000 + 120 \times 15000 + 133 \times 4500 + 150 \times 900}{2000 + 15000 + 4500 + 900} = 124$$

Thus, in this case, the manufacturer has complied with the standard, even though models A and D have emissions value over the target value, because the higher emissions rate of these models have been offset by sufficient sales of models B and C which are under the target emissions value.

Question

3. How should a sales weighted average target be applied in Australia and why?

A5 If an attribute based standard is adopted, what attributes could be used to determine manufacturer targets?

If a standard is based on an attribute based methodology, the next step would be to determine the most appropriate attribute. The two principal attributes used in standards adopted in other markets are vehicle weight (usually measured as mass) and vehicle size (usually measured as "footprint").[30]

Of the two major markets that use sales or production weighted attribute based standards based on a continuous function (the EU and the US), the EU has selected mass as the attribute for its standards, while the US has selected footprint.

Possible effects on product development

Studies supporting a standard based on footprint over mass, tend to do so on the premise that footprint provides a stronger incentive for manufacturers to improve vehicle efficiency by making vehicles lighter, whereas a mass based standard discourages mass reduction by imposing a more stringent CO_2 target. However, ABMARC's study for the Department (ABMARC 2016), also found that a mass based standard:

- could encourage the development and adoption of heavier but more efficient hybrid, electric and alternatively fuelled powertrains; and
- could more readily enable the adoption of safety and emission control technologies that also add mass to a vehicle.

To mitigate the risk of a mass based standard creating an incentive to reduce CO_2 targets by increasing vehicle mass, the EU standards provide for an annual update of the reference mass based on the average mass of the previous three years of data. The example provided below,

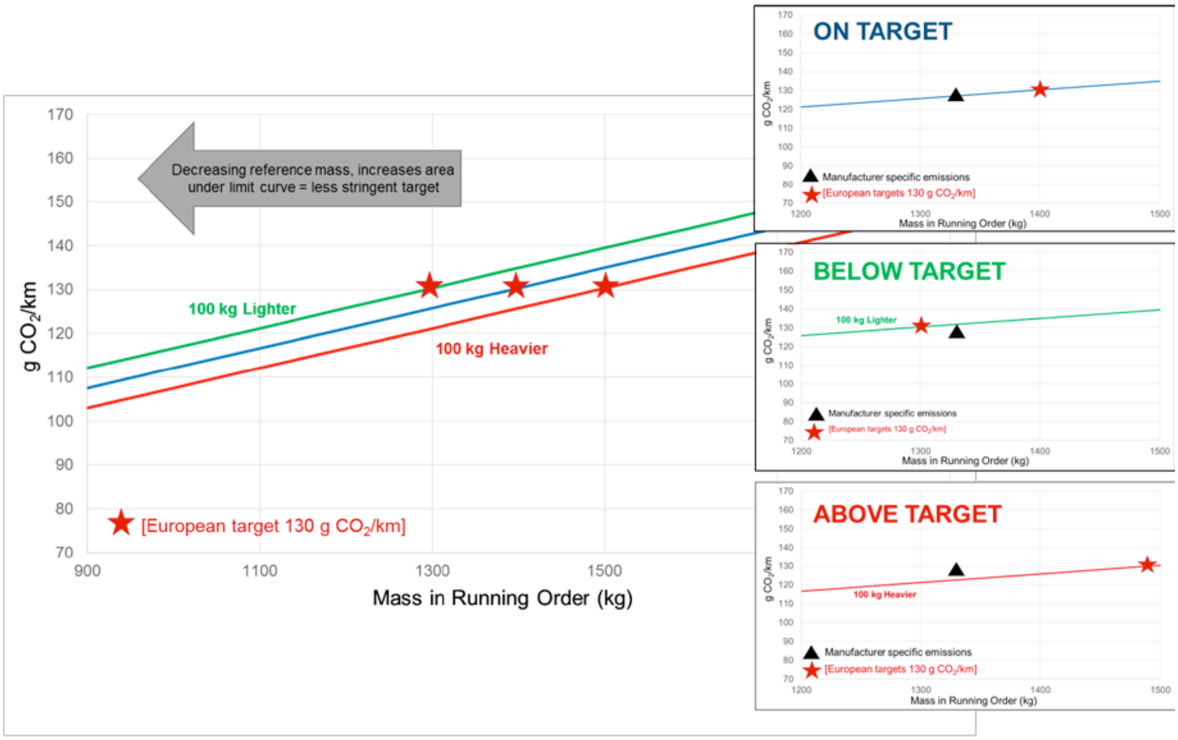
[30] Footprint is defined as the product of track width (calculated as the average of front and rear track widths) multiplied by the wheelbase.

shows the effects of this mechanism on the EU limit curves for the passenger and SUV segment based on:

8. The average mass of the passenger car and SUV fleet over a period of 3 years (blue)
9. A reference mass 100 kg heavier than the 2016 reference mass (red)
10. A reference mass 100 kg lighter than the 2016 reference mass (green)

The impact of this mechanism on a manufacturer's ability to meet the target is demonstrated in figure A2. If manufacturers make vehicles lighter on average, the reference mass will decrease (in this case by 100kg), which will make it easier for manufacturers to meet the limit curve. If manufacturers make vehicles heavier, the reference mass increases, which makes it more difficult for manufacturers to meet the limit curve. As a result, this mechanism could encourage mass reduction in the longer term.

Figure A2: Effects of a change in average vehicle mass under the EU standards (ABMARC 2016)



Impacts on compliance costs

International studies have mixed views on whether a mass or footprint based standard is likely to impose higher compliance costs on vehicle manufacturers. Some studies (such as Mock 2011) suggest that compliance costs are likely to be similar under both attributes, while others (such as Meszler et al 2013) suggest that a footprint based standard would have lower compliance costs relative to mass, as manufacturers could readily utilise weight reduction.

Research commissioned by the Department in 2012 suggested that overall compliance costs under a mass or a footprint based standard were likely to be similar (H-D Systems 2012). Subsequent research by ABMARC (2016) found that although there was a general trend for increasing CO_2 with both increasing mass and footprint, the range of CO_2 emissions in the Australian vehicle fleet for a given footprint was more variable than that for a given mass. As a result, compliance costs for individual vehicle models would more likely vary under a footprint based standard. This could increase the risk that some manufacturers could choose to remove rather than update particular vehicle models and variants to meet a standard.

It has also been suggested previously that a mass based approach may be more appropriate for Australia, as Australian Design Rules (ADRs) for vehicle emissions are largely based on UN vehicle regulations, which are strongly influenced by European vehicle regulations. While harmonisation with UN vehicle regulations is a key tenet of Australia's vehicle standards policy, and it is intended that a fuel efficiency standard will utilise the standardised test adopted in the relevant UN Regulations, a fuel efficiency standard will be fundamentally different in design to a UN regulation, as a fuel efficiency standard is set on the basis of vehicle sales, rather than an individual vehicle level (unlike the ADRs). Even if the Australian fuel efficiency standards framework adopted the EU's mass based approach, the actual relationship (as defined by the limit curve) will be different in Australia and thus manufacturers supplying vehicles to the Australian market would not necessarily be disadvantaged by choosing a different attribute. This issue was also considered by the US EPA and NHTSA in their 2011-12 assessments (US EPA and NHTSA 2011 and 2012), which concluded that:

"...there could be benefits for a number of manufacturers if there was greater harmonization of fuel economy and GHG standards for light-duty vehicles, but this is largely a question of how stringent standards are and how they are tested and enforced. It is entirely possible that footprint-based and weight-based systems can coexist internationally and not present an undue burden for manufacturers if they are carefully crafted."

Question

4. If an attribute based standard is adopted, which attribute should be adopted in Australia and why?

A6 How could targets be applied to different vehicle types?

Passenger vehicles (cars and SUVs) account for 82 per cent of new light vehicles sold in Australia and are responsible for the majority of CO_2 emissions produced by light vehicles. Approximately 46 per cent of light vehicles sold in 2015 were classified as passenger cars, 36 per cent were classified as SUVs and 18 per cent were classified as light commercial vehicles (FCAI 2015). Light commercial vehicles travel 23 per cent further per annum on average than passenger vehicles (ABS 2015a) and BITRE estimates anticipate a 50 per cent increase in light commercial vehicle kilometres from 2015 to 2030, compared to a 34 per cent increase over the same period for passenger cars and SUVs.

In many other markets, separate targets apply to passenger and light commercial vehicles, with light commercial vehicles subject to targets that are nominally less stringent than passenger vehicles. This is partly due to the history of the introduction of standards in these countries, which initially applied to passenger vehicles only, with separate standards subsequently adopted for light commercial vehicles.

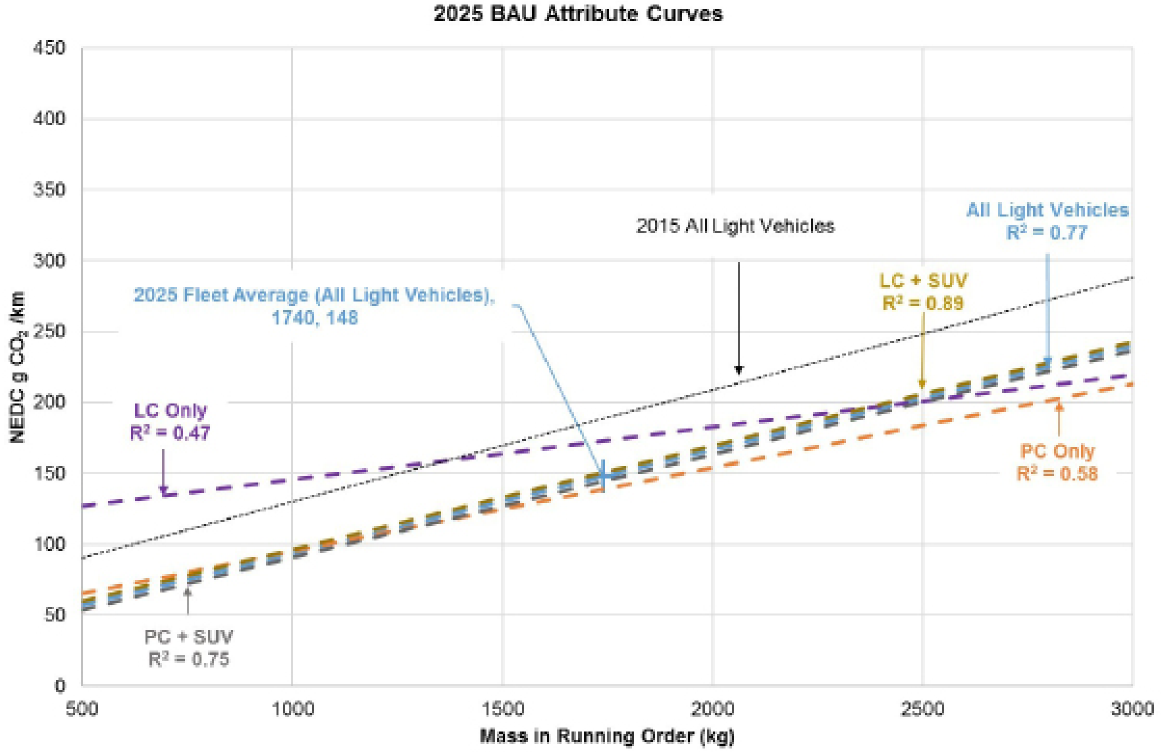
The strongest argument for setting separate standards for passenger and light commercial vehicles is to avoid imposing a heavier burden on manufacturers who sell a higher proportion of light commercial models. Analysis undertaken by H-D Systems (2012) and ABMARC (2016) suggests that light commercial vehicles already have a high level of dieselisation and some technologies that could be utilised to improve the efficiency of passenger vehicles, such as a hybrid powertrain with a continuously variable transmission, could compromise attributes valued by consumers in the light commercial segment, such as torque and towing capacity.

The extent to which sales of light commercial vehicles would affect an individual manufacturer's ability to comply with a standard covering all light vehicles would depend in part on the mix of vehicles sold by the manufacturer. While most of the top selling light commercial vehicle manufacturers also sell a significant number of passenger vehicles (FCAI 2015) and could comply by varying the relative mix of passenger and light commercial vehicles sold, this may require some manufacturers to restrict the availability of popular light commercial vehicle models.

Research commissioned by the Department by ABMARC also found that changes in the efficiency of light commercial vehicles relative to mass in Australia tend to be smaller than those for passenger cars and SUVs. As a result, a standard that applied a common target to passenger and light commercial vehicles would effectively impose more stringent requirements on light commercial vehicles, particularly for those with a mass in running order under two tonnes (Figure A3).

Figure A3: Mass based attribute curves for all light vehicles, cars, cars and SUVs, light

commercial vehicles and light commercial vehicles and SUVs (ABMARC 2016)



Treatment of Sports Utility Vehicles (SUVs)

In the US and Canada, SUVs are generally considered light commercial vehicles ('light trucks') for the purposes of their fuel efficiency standards. The EU standards include all SUVs in their passenger vehicle standards. The Federal Chamber of Automotive Industries (FCAI) submission to the Vehicle Emissions Discussion Paper indicated a preference for a similar approach to the US on the premise that the mix of vehicles sold in Australia is closer to that of the US than the EU (FCAI 2016).

If separate standards for passenger and light commercial vehicles were adopted in Australia, and SUVs were included in a light commercial vehicle target, a key issue that would need to be resolved would be to define which vehicles are classified as SUVs for the purposes of a light commercial vehicle standard, as there is currently no discrete vehicle category that covers all vehicles marketed as SUVs in Australia. All two-wheel drive and most four-wheel drive SUV models sold in Australia are currently certified as ADR category MA (passenger car), with some, mostly larger, four-wheel drive SUV models certified as ADR category MC (off-road vehicle). Table A1 provides a breakdown by vehicle category of SUVs models sold by the ten biggest selling brands in Australia.

Table A1: ADR Category of SUVs sold by the top 10 selling manufacturers[31]

Make	MA Category	MC Category
Toyota	RAV4, Kluger	FJ Cruiser, Fortuner, Prado, Landcruiser
Mazda	CX-3, CX-5, CX-9 (2WD)	CX-9 (4WD)
Holden	Trax, Captiva	Trailblazer
Hyundai	Tucson, Santa Fe	
Mitsubishi	ASX, Outlander	Pajero, Pajero Sport
Ford	EcoSport, Kuga, Everest, Territory	

31 Based on Road Vehicle Descriptor (RVD) information for current models on the RVCS website

Make	MA Category	MC Category
Nissan	Juke, Qashqai, X-Trail, Murano, Pathfinder	Patrol
Volkswagen	Tiguan	Touareg
Subaru	XV	Forester, Outback
Honda	HR-V, CR-V	

The FCAI's submission to the discussion paper proposed treating MC category SUVs as light commercial vehicles, which is similar to the approach adopted in the US. However, if this approach was adopted, MA category SUVs would be subject to more stringent requirements than MC category SUVs with similar attributes. In some cases, four-wheel drive MA category SUVs could be recertified as MC category vehicles to qualify for a less stringent target.[32] However, this would not be an option under current vehicle category definitions for two-wheel drive SUVs, which are generally more efficient and affordable than four-wheel drive SUVs. As a result, this approach could encourage manufacturers to cease the sale of SUVs that cannot meet MC category requirements, which could reduce the range of SUVs available to consumers without improving overall efficiency.

Possible impacts on compliance costs

ABMARC's analysis of the Australian light vehicle fleet (ABMARC 2016) suggests that a (mass-based) standard combining light commercial vehicles and SUVs would have a steeper limit curve than a separate standard for light commercial vehicles only and a similar slope to a standard that combined cars with SUVs or single standard for all light vehicles. As a result, a standard that combined light commercial vehicles and SUVs could effectively impose more stringent requirements on light commercial vehicles.

The Department also notes that a larger number of manufacturers would need to comply with two sets of standards under an approach that applied a separate target to light commercial vehicles and SUVs than would be the case under an approach that only applied a single target to all light vehicles or one target covering all passenger vehicles (cars and SUVs) and a separate target for light commercial vehicles. As a result, a 'US style' approach would increase administrative burden and complexity for both manufacturers and the Australian Government.

In terms of average per vehicle compliance costs under each approach, ABMARC's analysis found that the overall average per vehicle compliance costs for the ten highest volume manufacturers were broadly similar under all three possible approaches (Car+SUV+LCV, LCV+SUV/Car, Car+SUV/LCV) but would vary for individual manufacturers.

Possible limit curves under single or segment based targets

Figures A4 to A8, show the possible (mass-based) limit curves that could apply under a single or segment based approach for the three targets proposed in 2025 and the anticipated position of the top 10 selling manufacturers under current policy settings in relation to these curves.

---

[32] In addition to four-wheel drive, an MC category vehicle must meet at least 4 of the following 5 characteristics calculated when the vehicle is at its '*Unladen Mass*' on a level surface, with the front wheels parallel to the vehicle's longitudinal centreline, and the tyres inflated to the *'Manufacturer's'* recommended pressure:

(i) *'Approach Angle'* of not less than 28 degrees;

(ii) *'Breakover Angle'* of not less than 14 degrees;

(iii) *'Departure Angle'* of not less than 20 degrees;

(iv) *'Running Clearance'* of not less than 200 mm;

(v) *'Front Axle Clearance'*, *'Rear Axle Clearance'* or *'Suspension Clearance'* of not less than 175 mm each.

The limit curves take the form:

CO_2 Limit = CO_2Ref + a x (Mass–M_0); where:

CO_2 Limit = manufacturers sales weighted average target

CO_2Ref = the (overall or segment based) fleet average target

a = slope of the limit curve, based on the correlation between mass and CO_2 modelled by ABMARC

Mass = the sales weighted average mass of the vehicles sold by the manufacturer

M_0 = the reference mass (currently based on the 2015 fleet average). In the EU this is based on the three previous years of data.

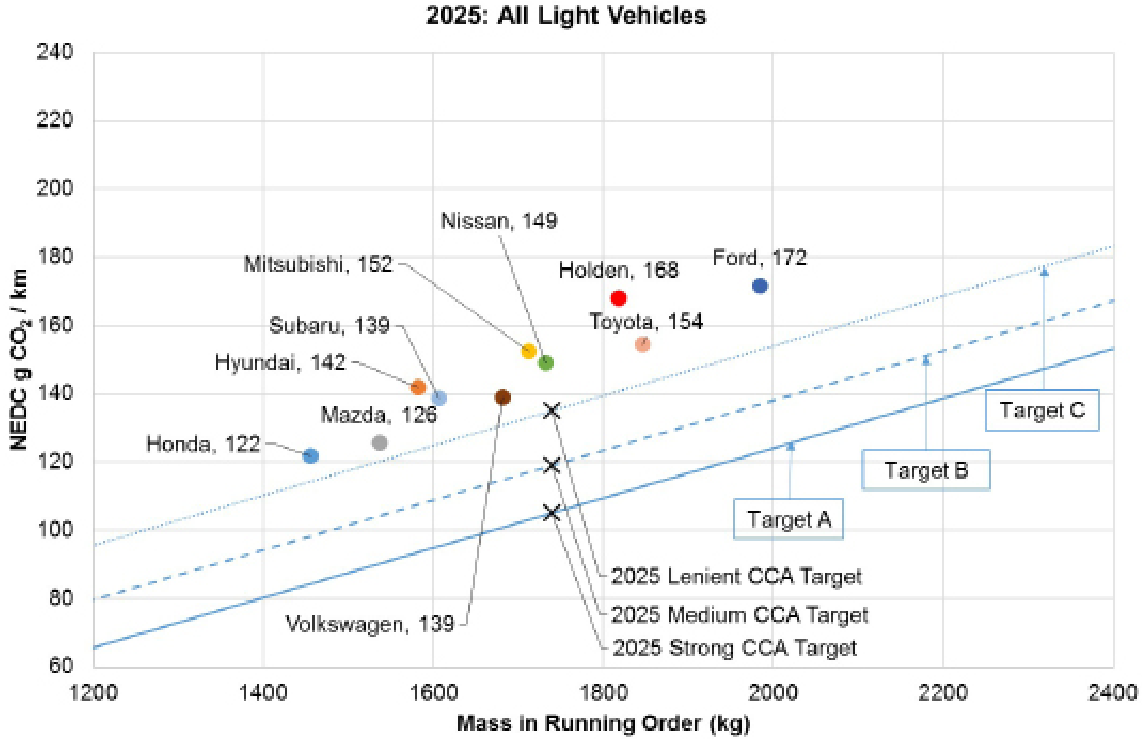
Table A2 shows the segment based targets that may be required to achieve the three overall targets based on ABMARC's modelling.

Table A2: Possible Australian targets (in grams of CO_2 per km), if a segment based approach was adopted (ABMARC 2016)

Overall target in 2025	'US' approach		'EU' approach	
	Car	SUV+LCV	Car+SUV	LCV
A (105g/km)	83	116	94	151
B (119g/km)	96	131	109	162
C (135g/km)	109	147	125	173

Figure A4 shows possible limit curves for a mass based standard covering all light vehicles.

Figure A4: Possible limit curve for 2025, if a single fleet average target was adopted for all light vehicles (ABMARC 2016)



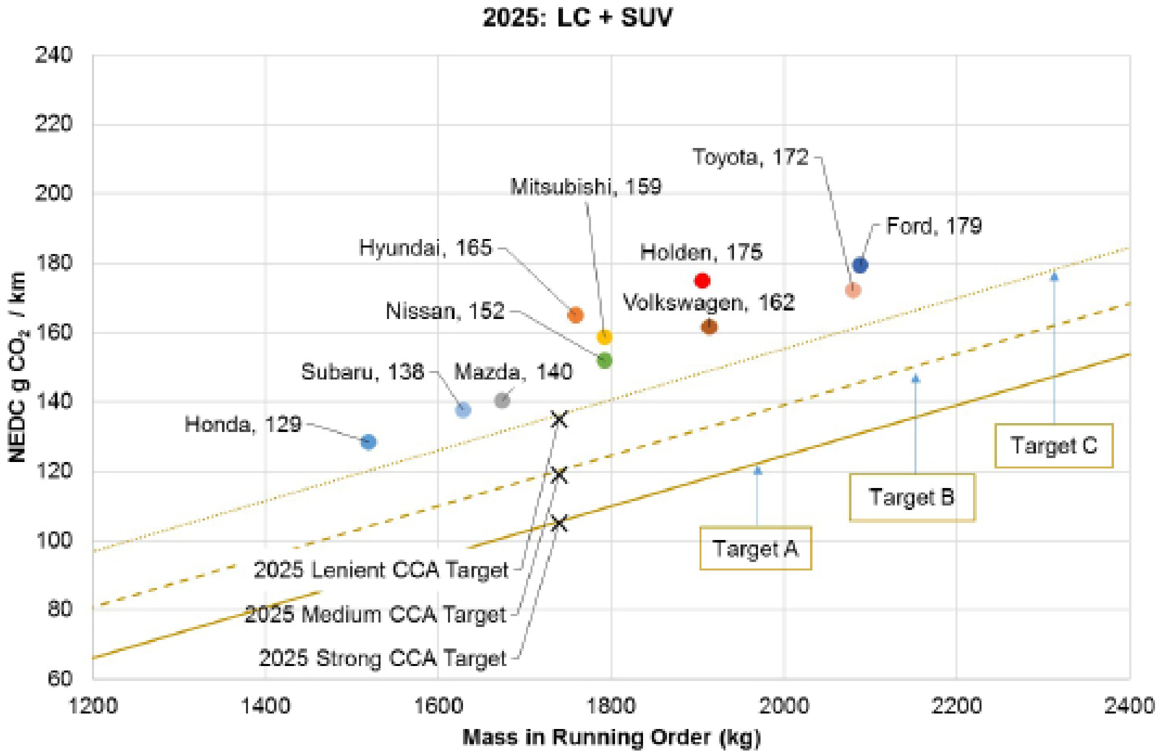
Target A CO_2 Limit = 105 + 0.073 (Mass–1740)

Target B CO_2 Limit = 119 + 0.073 (Mass–1740)

Target C CO_2 Limit = 135 + 0.073 (Mass–1740)

Figure A5 shows possible limit curves for a mass based standard covering all light commercial and sports utility vehicles.

Figure A5: Possible limit curve for 2025, if a separate target was adopted for LCVs and SUVs (ABMARC 2016)



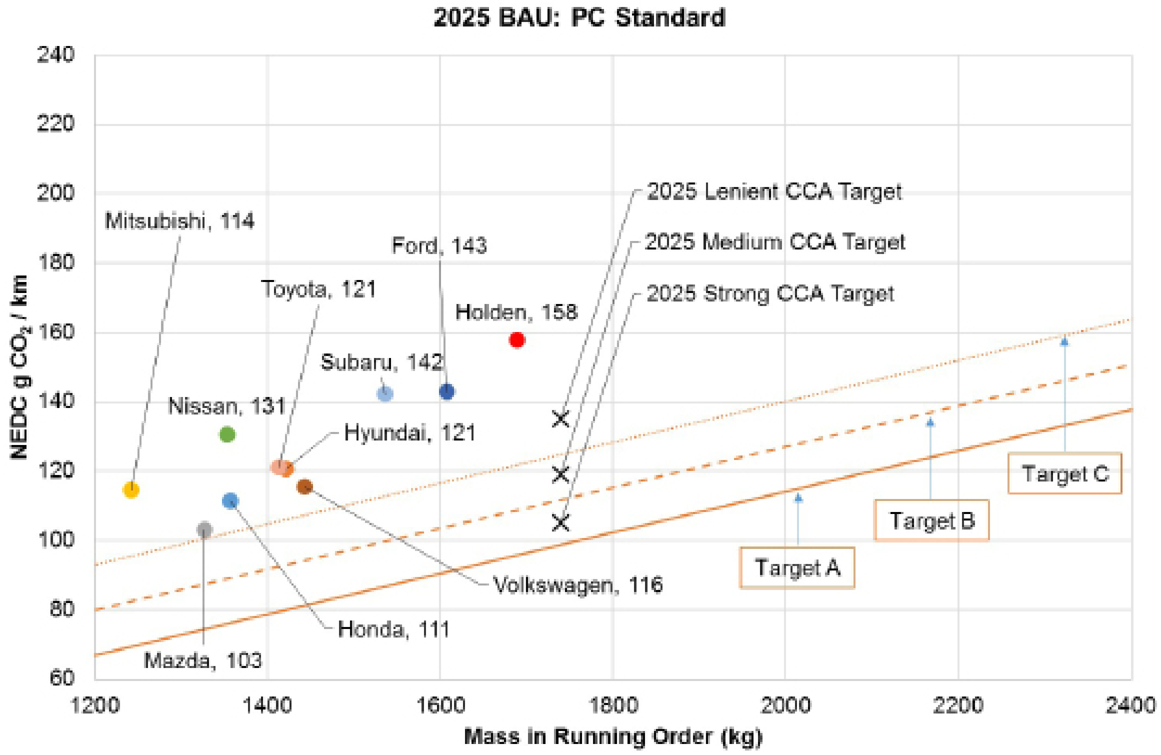
Target A CO_2 Limit = 116 + 0.073 (Mass–1884)

Target B CO_2 Limit = 131 + 0.073 (Mass–1884)

Target C CO_2 Limit = 147 + 0.073 (Mass–1884)

Figure A6 shows possible limit curves for a mass based standard covering passenger cars.

Figure A6: Possible limit curve for 2025, if a separate target was adopted for passenger cars (ABMARC 2016)



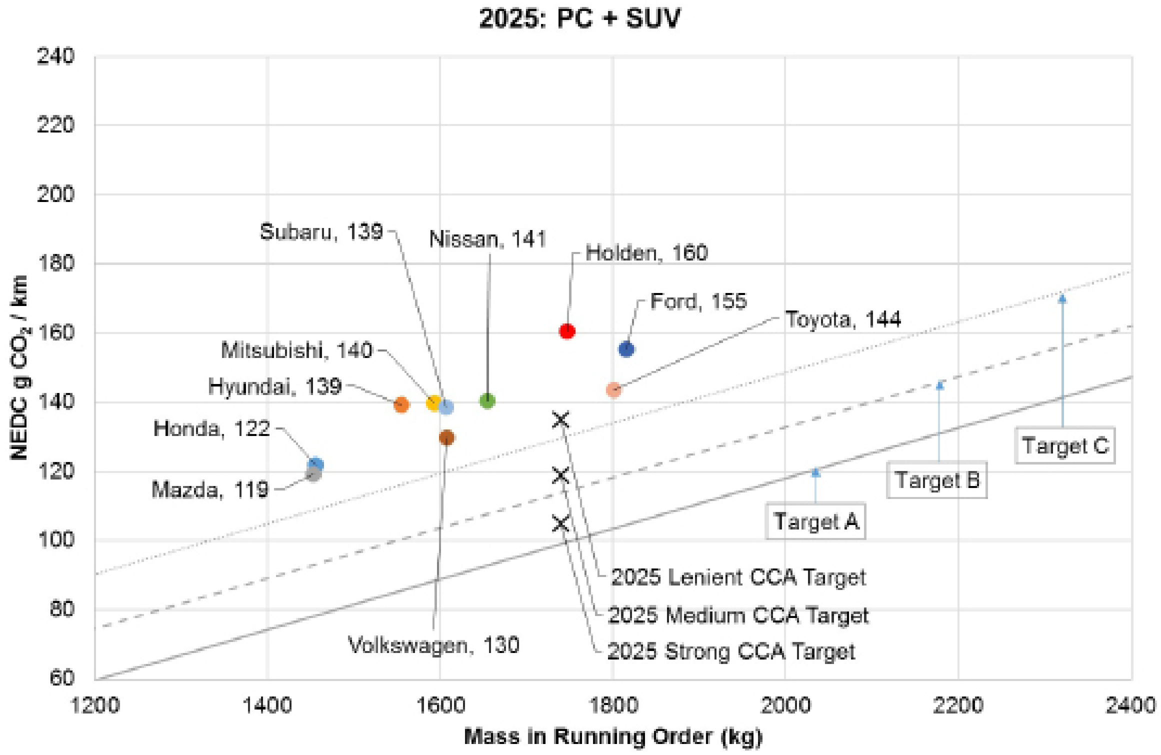
Target A CO_2 Limit = 83 + 0.059 (Mass–1473)

Target B CO_2 Limit = 96 + 0.059 (Mass–1473)

Target C CO_2 Limit = 109 + 0.059 (Mass–1473)

Figure A7 shows possible limit curves for a mass based standard covering all passenger cars and sports utility vehicles.

Figure A7: Possible limit curve for 2025, if a separate target was adopted for passenger cars and SUVs (ABMARC 2016)



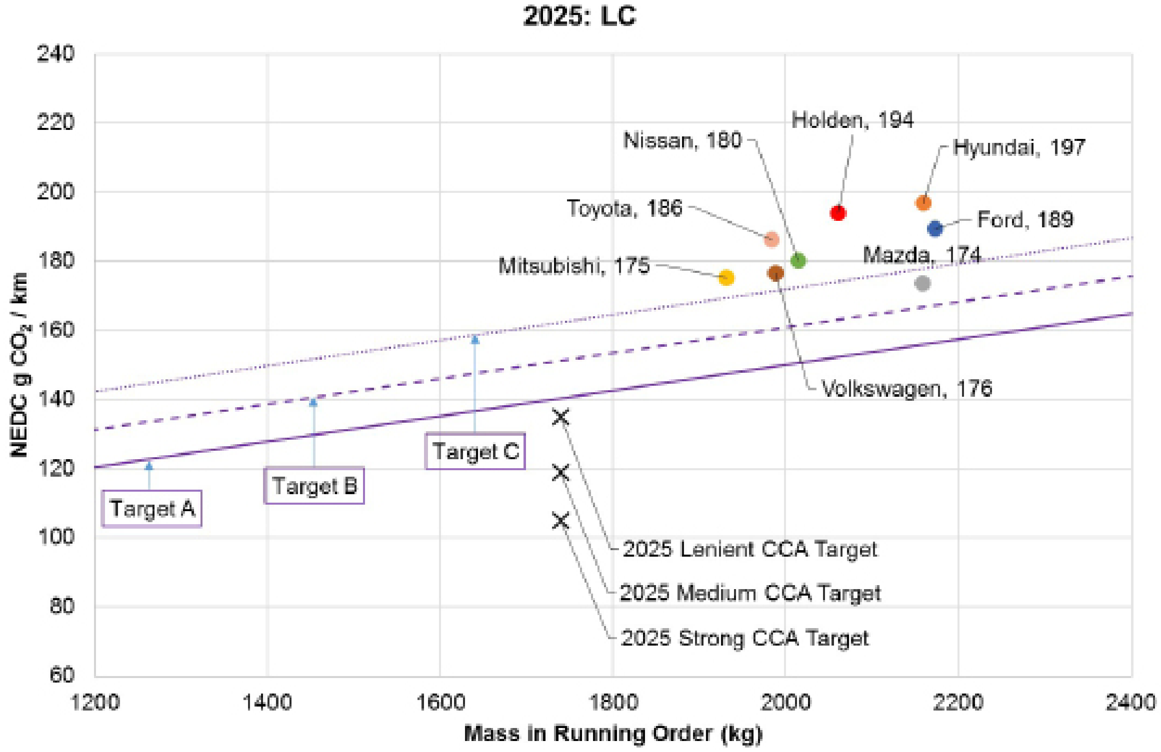
Target A CO_2 Limit = 94 + 0.073 (Mass–1677)

Target B CO_2 Limit = 109 + 0.073 (Mass–1677)

Target C CO_2 Limit = 109 + 0.073 (Mass–1677)

Figure A8 shows possible limit curves for a mass based standard covering light commercial vehicles.

Figure A8: Possible limit curve for 2025, if a separate target was adopted for LCVs (ABMARC 2016)[33]



Target A CO_2 Limit = 151 + 0.037 (Mass–2029)

Target B CO_2 Limit = 162 + 0.037 (Mass–2029)

Target C CO_2 Limit = 172 + 0.037 (Mass–2029)

Questions

5. How should a fuel efficiency standard be applied to each light vehicle category and why?

6. If SUVs are subject to a different target to passenger cars, how should SUVs be defined, and why?

A7 How could targets be phased in from 2020 to 2025?

If a fuel efficiency standard is phased in from 2020 to 2025, a key issue that would need to be resolved is how targets would be phased in over this period. Earlier implementation of more stringent targets would help maximise the benefits of a fuel efficiency standard. However, appropriate lead times would be required to allow for a regulatory framework to be implemented and time for manufacturers to adjust their product plans for Australia to ensure the vehicles they supply can comply and are fit for purpose.

As all new light vehicles manufactured from 2018 will be imported, and more stringent requirements already apply in most larger vehicle markets, the required adjustment for manufacturers could be largely a choice of which global models and variants are supplied to Australia, rather than fundamental design changes specifically for the Australian market. This suggests that lead times could be shorter than would otherwise be the case.

[33] Honda and Subaru do not supply LCVs to the Australian market and have not announced any plans to do so.

Based on international experience, there are two possible options for phasing in a fuel efficiency standard from 2020 to 2025. The first option would be to adopt annual targets that progressively increase in stringency each year from 2020 to 2025. This approach is currently adopted by the US.

Another option could be to adopt a single fleet average target, phased in on a percentage of sales basis from 2020 to 2025, with the target only changing with the commencement of a new phase. This approach was adopted by the EU from 2012 to 2015, for its passenger vehicle target and from 2013 to 2017 for its light commercial vehicle target. A similar arrangement has been adopted for the next phase of the EU passenger vehicle standards, with 95 per cent of passenger vehicles required to meet a sales weighted average standard of 95g/km from 2020, with 100 per cent of vehicles required to comply from 2021.

Annual targets, as adopted in the US, would help encourage manufacturers to continue improving the efficiency of their vehicles every year. A single target phased in over a number of years could have a lower administrative burden, but may encourage manufacturers to delay improvements to their less efficient models until the full implementation date. As a result, there is also a risk that some manufacturers could lobby for target revisions, which could unfairly disadvantage those who have already taken the necessary steps to meet the standard. This could compromise the stability, credibility and environmental effectiveness of a mandatory standard (CCA 2014).

Flexibility arrangements

As major improvements in the efficiency of vehicle models tend to occur as part of a model generation update, which generally occurs every five to ten years, both the EU and US standards offer manufacturers a degree of flexibility in meeting targets for a given year. These arrangements do however, increase administrative complexity for both manufacturers and government.

The EU standards allow for manufacturers that cannot comply in their own right to ‘pool’ with another manufacturer to comply as a group. The US allows manufacturers to accrue credits for over-compliance to be carried forward, or banked, for up to five years, or carried back three years to cover a debit in a previous year. The US standards also allow for the trading of credits between entities to offset debits (US EPA 2012b).

Questions

7. How should targets for a fuel efficiency standard be phased in and why?

8. If annual targets are adopted, what targets should apply in each year for each segment
and why?

9. If a percentage phase in is adopted, what percentage should apply in each year and each segment, and why?

10. What flexibility arrangements should be allowed under an Australian fuel efficiency standard and why?

A8 What other incentives could a standard adopt to encourage supply of more efficient vehicles under a standard?

Credits

Some countries that have adopted standards have adopted provisions which enable manufacturers to further reduce their reported average emissions (as measured on the core CO_2 value) through the use of “multipliers” or “credits” for certain “advanced technology” vehicles. The principal rationale for such measures is to support/encourage manufacturers to move early to introduce advanced (and often expensive) low emissions technologies such as electric vehicles (EVs), or to provide recognition of CO_2 benefits not captured in a standardised laboratory test.

Inclusion of such provisions would broaden the policy intent of the standards beyond the primary purpose of reducing CO_2 by improving vehicle efficiency, and it can be argued that some measures are inconsistent with the general principle of a performance based standard, where every gram of CO_2 saved is treated equally, whether from low or high emission vehicles. Such measures also need to be evaluated carefully, as their merits in CO_2 emissions terms can be difficult to quantify accurately. It can also be argued that where such measures have clear merit, they could be addressed more effectively through separate, but complementary, policies outside of the CO_2 standard itself.

In considering the merits of credits measures in the calculation of the average CO_2 emissions outcome for manufacturers, this RIS categorises the broad range of possible measures into three groups:

- Specific Technology/Fuel Type
- Low Emissions Benchmark(s)
- “Off-cycle” Emissions Technologies.

Group 1–Specific Technology/Fuel Type

In this group, credits or “multipliers” are provided to vehicles utilising specific technologies or fuels which are claimed to reduce CO_2 emissions relative to conventional vehicles. Of the three groups, Group 1 is the most contentious, because credits or multipliers based on specific technologies or fuels:

- may not deliver any additional CO_2 benefits, if the emission reductions from the technology/fuel are already recognised through the test cycle;
- can disadvantage manufacturers of conventional vehicles with equivalent or better CO_2 emissions performance that receive no such benefit; and
- may deter manufacturers from lowering the CO_2 emissions of other models in their fleet.

Multipliers for EVs, plug in hybrid/electric vehicles (PHEV) and hydrogen fuel cell vehicles (HFCV)

Under a standard based on tailpipe CO_2 emissions, electric vehicles and hydrogen fuel cell vehicles would be treated as zero emission vehicles, and PHEVs will have very low CO_2 numbers on the standard test. When emissions from the Australian grid electricity generation are taken into consideration, this approach effectively provides a significant concession to these vehicles.

Under the credits regime adopted in the EU passenger vehicle standards for 2012-2014 and 2020-22, EVs, HFCVs and PHEVs (producing less than 50g/km) are counted as more than one vehicle, which has the effect of lowering the manufacturers fleet average CO_2 emissions to a greater extent than would otherwise be the case under a purely performance based standard.

It is widely accepted that EVs, PHEVs and HFCVs would genuinely satisfy any definition of “advanced” technology vehicles and are significantly higher cost technologies[34] relative to conventional vehicles or to those operating on alternative liquid or gaseous fuels. Thus there may be some merit for multipliers on the grounds of encouraging early supply of these low emission technology vehicles to the market to help address the significant “first mover” costs for manufacturers.

The US has adopted a multiplier of 2 for EVs and HFCVs for 2017, phasing down to 1.5 in 2021 and a multiplier of 1.6 for PHEVs in 2017, phasing down to 1.3 in 2021 (US EPA 2012b), with a complete phase out from 2022. If similar measures were adopted in Australia, higher multipliers could be justified in the absence of additional fiscal and other incentives in place for EVs and PHEVs which operate outside the standards (but complement them). While the expected small volumes of EVs, HFCVs and PHEVs in the short-medium term is likely to mean that the impact of even large multipliers is low, there is a risk that excessive multipliers could, over the longer term, erode the effectiveness of the standards.

[34] As an indication of cost relativities for EVs and PHEVs, the retail price for the Nissan Leaf EV is $40,000 compared to comparable sized vehicles such as the Nissan Pulsar, Toyota Corolla and Mazda 3 which retail from around $20,000.

The ICCT also examined the potential of this adverse outcome in its 2012 submission to the US proposed rule for 2017-2025 (ICCT 2012d). Similar concerns are also raised in a 2011 report for the European Commission (TNO et al 2011) which stated “if the super credits mechanism would be applied in the period between 2016 and 2020, the sales of very low CO_2 emitting vehicles might lead to a decreased incentive for car manufacturers to reduce CO_2 emissions of high emitters, since they can compensate for such vehicles.” An analysis conducted in this report for the EC also concluded that continuation of the super credits could result in higher net CO_2 emissions (compared to the circumstance where no credits apply).

If credits were adopted to provide a stronger incentive for manufacturers to supply a wider range of advanced technology vehicles to the market, there may be a case to offer additional credits for EVs, PHEVs and HFCVs. However, any credit regime would need to be set at a level that did not significantly reduce the incentive to improve the efficiency of petrol and diesel vehicles.

Group 2–Low Emissions Benchmark(s)

As with Group 1, Group 2 credit regimes also incentivise early deployment of vehicles with advanced technology or fuel types that can deliver low emissions outcomes, but does not link the credit to a specific technology/fuel. This is a performance based approach which has a number of advantages including flexibility, more equitable treatment of all technologies and avoiding the potential pitfalls of “picking winners”. And on the assumption that any emissions benchmark is set according to the core CO_2 emissions value from the standardised test, then it confers all the advantages of objective, comparable and robust data measurement.

Nevertheless, low emission benchmarks suffer some of the same shortcomings as technology/fuel based credits, in that they still assign a higher effective value on emissions reductions for vehicles below the threshold(s) relative to those vehicles above, and could discourage improvements in models with higher emissions. For example, if a low emission benchmark was set at 100g CO_2/km or less, and vehicles below that benchmark were allocated a multiplier of 2, a manufacturer who reworks a vehicle to reduce its tested emissions value from (say) 113 g/km to 98 g/km is effectively able to claim that vehicle as having an emissions value of 49 g/km and gets a significantly greater benefit from that 15 g/km reduction than a much larger reduction in a different vehicle model whose final CO_2 value was still higher than 100 g/km.

It should also be recognised that the benchmark level is critical, as certain emissions levels can realistically only be met by particular technologies (at least on the current understanding of vehicle technology developments). In this sense, certain benchmarks can be considered as proxies for particular technologies. For example, the 50 g/km low emission vehicle threshold operating in the current EU standards is currently only achievable by EVs, HFCVs and some PHEVs.

The only benchmark explicitly linked to CO_2 emissions is in the EU standards, which was set at 50g/km. For the current EU passenger vehicle standards, a multiplier of 3.5 was offered in 2012, which was phased out completely in 2016. For the 95g/km target applying from 2020, a multiplier of 2 will apply in 2020, with this phasing out completely by 2023.[35]

In considering the 50 g/km benchmark, it is reasonable to argue that this can only be met by high cost “advanced” technology vehicles (currently only EVs, HFCVs and PHEVs could meet such a benchmark) and, as noted earlier, there is some merit for multipliers on the grounds of encouraging early supply of these very low emission vehicles to the market to help address the significant “first mover” costs for manufacturers.

In contrast, a higher benchmark, such as 100g/km could be met by conventional petrol and diesel vehicles, including, but not limited to (non-plug-in) hybrid vehicles. This is not to imply that achieving a sub-100g/km outcome is not a challenge, but rather that the costs and technological options to achieve this benchmark are on a different scale to those required to achieve a 50g/km outcome.

[35] See Regulation (EC) No 443/2009 of the European Parliament and of the Council of 23 April 2009, as amended by Commission Regulation (EU) No 397/2013 of 30 April 2013, Regulation (EU) No 333/2014 of the European Parliament and of the Council of 11 March 2014 and Commission Delegated Regulation (EU) 2015/6 of 31 October 2014. Access it here

As illustrated in Table A3 and A4, there are currently 26 vehicle models sold in Australia that offer a variant producing less than 100gCO_2/km, which accounted for less than 0.5 per cent of vehicles sold in 2015 (FCAI 2015). Only EVs and some plug-in hybrids would meet a 50g/km benchmark. Broadly speaking the sub-100g/km petrol and diesel vehicles are smaller vehicles and the (non-plug in) hybrids are small or mid-sized.

Table A3: Vehicles currently available in Australia with combined tailpipe CO_2 emissions up to 50 g/km[36]

Fuel/Technology Type	Make	Model	Variants ≤50 g/km	CO_2 Emissions (g/km)
EV	BMW	i3	Pure EV	0
	Renault	Kangoo	ZE	0
	Nissan	Leaf	All	0
	Tesla	Model S	All	0
Plug in Hybrid	BMW	i3	Range Extender	13
	Audi	A3	e-tron	37-39
	Mitsubishi	Outlander	PHEV	44
	Volvo	XC90	T8	49
	BMW	3 Series	330e	49
	BMW	i8	All	49
	BMW	7 Series	740e	50

Table A4: Vehicles currently available in Australia with combined tailpipe CO_2 emissions between 51 and 100 g/km[37]

Fuel/Technology Type	Make	Model	Variants ≤100 g/km	CO_2 Emissions (g/km)
Plug-in Hybrid	Mercedes-Benz	C Class	C 350e, C350T e	56-59
	Mercedes-Benz	S Class	S 500L e	65
	Porsche	Panemera	S E-Hybrid	71
	Mercedes-Benz	GLE Class	GLE500e	78
	BMW	X5	xDrive40e	78
	Porsche	Cayenne	Plug-in Hybrid	79
Petrol/Electric Hybrid	Toyota	Prius	All	80
	Toyota	Prius C	All	90
	Lexus	CT200h	All	95
	Toyota	Corolla	Hybrid	96
Diesel	Citroen	Cactus	1.6L Auto	94
	Renault	Megane	1.5L Auto	98
	Mini	Cooper D	1.5L Manual	97-99
Petrol	Fiat	500	0.9L Twin Air	90-92
	Audi	A1	1.0L Manual	97-98

36 Based on analysis of current models listed on the Green Vehicle Guide website.

37 Based on analysis of current models listed on the Green Vehicle Guide website.

Fuel/Technology Type	Make	Model	Variants ≤100 g/km	CO_2 Emissions (g/km)
	Fiat	Panda	0.9L Twin Air	95-99

While the range of sub-100g/km options available in Australia is relatively small, there is a significantly wider range of the vehicles available in other markets that could be supplied to Australia. For example, there are over 100 passenger models from 30 manufacturers available on the UK market.[38] The provision of sub-100g/km models to the UK market could be attributed to tax incentives for such vehicles and regulatory pressure to reduce emissions across the fleet from the EU CO_2 standards, which do not offer credits for sub-100g/km vehicles.

Based on the range of sub-100g/km vehicles available in the UK, credits for vehicle producing less than 100 g/km are more likely to reduce the incentive for manufacturers to improve vehicle models with higher emissions, which would undermine the objectives of the standards to improve the efficiency of the broader vehicle fleet. If this higher benchmark was adopted for a credits regime, these risks could be reduced, but not eliminated, by limiting the value of the multiplier and/or the market share at which a multiplier would apply.

Group 3–"Off-cycle" Emissions Technologies

Credits under Group 3 are primarily designed to provide recognition for technologies which can deliver actual on-road CO_2 emissions reductions when deployed in a vehicle but are not "captured" in standardised laboratory test results. This Group also includes measures related to reducing greenhouse gas emissions linked to the operation of air conditioners which are, for a range of technical reasons, turned off during laboratory testing.

Unlike multipliers for low emission vehicles, these types of credits could deliver additional CO_2 emissions reductions beyond those captured in standardised laboratory testing. In other words, these measures can deliver reductions beyond those measured in test conditions and thus are less likely to undermine the primary objective of the standards.

If credits were adopted for such improvements, the challenge would then be to develop an objective, repeatable methodology to determine and validate the claimed additional CO_2 benefits delivered by any off-cycle technologies. Internationally, both the US and EU have attempted to provide a capacity within their standards framework to recognise and quantify the CO_2 benefits from off cycle technologies.

In the EU context, Regulation 725/2011[39] provides procedures for approval and certification of "innovative technologies" and in terms of assessing the CO_2 emissions benefits from these technologies, "only those savings that are not captured by the standard test cycle" will be taken into account.

In the US, the EPA and NHTSA have undertaken an extensive analysis covering air conditioners and a broad range of off-cycle technologies including high efficiency lighting, engine heat recovery, solar roof panels, active aerodynamics, electric heater circulation pumps, active transmission and engine warm-up, glazing and solar reflective paint.

The US work has attempted to develop a "menu" of technologies assessed as providing real world CO_2 benefits. The menu assigns default CO_2/mile credit values for each of the technologies that have been assessed as delivering CO_2 benefits. This approach is designed to reduce the need for extensive testing, and utilises analysis and simulations rather than full vehicle testing as much as possible. However, as these calculations/simulations frequently draw on US emissions test procedures, traffic patterns and climatic conditions, the relevance of these default values in an Australian on-road context may be questionable for some measures.

---

[38] Based on analysis of UK Vehicle Certification Agency data on the VCA website

[39] EU Regulation 725/2011 of 25 July 2011 establishing a procedure for the approval and certification of innovative technologies for reducing CO_2 emissions from passenger cars pursuant to Regulation (EC) No 443/2009 of the European Parliament and of the Council, access it here

As the benefits of off-cycle technologies cannot be readily verified in standardised test conditions, both the EU and US apply a "cap" on the maximum overall fleet benefit a manufacturer can claim for innovative or off-cycle technologies–7 g/km in the EU context, 10g/mile (6.2 g/km) in the US.

If Australian standards provided credits for off-cycle technologies, the assessment process would need to:

- establish clear, objective and transparent eligibility criteria for assessing specific technologies;
- describe the methodology for determining the benefit in g/km CO_2 from each technology and how that will be "counted" in the CO_2 standards;
- if possible, identify and clearly define an initial list of off-cycle technologies, based on existing published evidence (and their default CO_2 values) where it can be demonstrated that the evidence is applicable in the Australian context; and
- determine a suitable "cap" on the total credit obtainable under this group.

A possible set of guidelines that could be adopted based on similar provisions adopted by the US and the EU is presented in the box below. The essential test for these technologies would be their ability to deliver of CO_2 emissions reductions beyond those measured through in standardised laboratory testing conditions, that is a performance based outcome.

Possible Guidelines for Assessment of Off-Cycle Technologies

1. Eligibility Criteria

To be considered for assessment, the specific technologies must:

- be supplied and fitted to the vehicle by or on behalf of the manufacturer before the vehicle's first supply to the market (aftermarket technologies fitted to a vehicle by third parties are ineligible);
- not already be a required fitment to satisfy the requirements of any Australian Design Rule applicable to that vehicle type;
- be shown (via objective and agreed assessment methodologies) to reduce tailpipe CO_2 emissions from a vehicle in normal vehicle operation which are not otherwise captured in the core CO_2 emissions result from the standardised laboratory test
- deliver a measurable CO_2 emissions reduction of at least 1g CO_2 / km; and
- not be dependent on driver behaviour or other actions outside of the control of the manufacturer.

2. Assessment Methodologies

Detailed test methodologies need to be developed to reliably measure the claimed CO_2 emission benefit of particular technologies. In general terms, the methodology would adopt the following elements:

- the technology, and its method of fitment to the vehicle, must be described in sufficient detail to enable it to be accurately and uniquely identified;
- the emissions benefit shall be determined as the difference between test results of a "baseline" vehicle not fitted with the technology and a vehicle of identical type fitted with the technology;
- where more than one distinct technology is to be fitted to the vehicle, the technology equipped vehicle shall be tested with all the technologies fitted so as to account for any interactive effects (and avoid the risk of double counting);
- the test to be used shall be a chassis dynamometer based method which is robust and repeatable, unless the manufacturer can reliably demonstrate the emissions benefits of the technology by modelling or simulation techniques;
- the test/analysis shall be conducted by an independent testing facility with NATA (or comparable) accreditation or by a facility operated by the manufacturer which is subject to the audit requirements of the vehicle type approval process administered by the Department; and
- the test and its results should be capable of replication and verification by third parties.

3. Recognition of Existing Data

Results of testing and evaluation of off-cycle technologies undertaken under the auspices of EU Regulation 725/2011 or the US Light Duty Vehicle Greenhouse Gas Emissions Standards could be accepted without the need for additional testing, if it can be demonstrated that the results for the particular technology derived from such programs are valid for both the vehicles supplied to the Australian market and the road transport environment in Australia (that is–the technology is fitted to variants of these vehicles sold in Australia, and the benefits of this technology would be realised in operating conditions typically experienced by Australian road users).

4. Applying the CO_2 Reductions

Where a manufacturer has been able to demonstrate a reduction from a particular technology (or set of technologies) according to the agreed procedures, the value of that reduction in g/km may be subtracted from the tested value for each vehicle to which that technology (or set of technologies) has been fitted by the manufacturer before its first supply to the market. The resultant lower value is to be used for the purposes of reporting under the CO_2 standards framework only and the lab tested value shall remain the data publicly stated by manufacturers and reported on the Green Vehicle Guide.

Given the scope for some uncertainty in the procedures, the maximum reduction a manufacturer can claim from the use of off-cycle technologies for a vehicle model could be 7g/km (consistent with practice in the EU and US).

Credits for off-cycle improvements could have stronger technical merit as they can deliver actual efficiency benefits in real world use of vehicles. The challenge would be to develop and implement robust and transparent procedures to validate manufacturers' claimed CO_2 benefits of particular technologies. There is a potential to draw on work already undertaken in the US and EU, but the US provisions in particular may be of limited value because of the influence of US specific factors in the calculation of default values.

Both the US and EU place a cap on the maximum overall reduction which can be claimed for off cycle technologies, and given that the procedures outlined above do not require every single model to be tested (unlike for the determination of the core CO_2 number) then there would appear to be merit in applying an equivalent cap in the Australian standards.

Refrigerants

It has been suggested that credits could be offered to encourage the adoption of air condition refrigerants with a lower global warming potential. A global phase down of hydrofluorocarbon refrigerants is being implemented through the Montreal Protocol. To support this initiative, the Australian Government announced in June 2016 a domestic phase down of bulk imports of hydrofluorocarbons to start from 2018. Any crediting for the replacement of hydrofluorocarbons under a light vehicle fuel efficiency standard would need to deliver abatement beyond these measures.

Summary

Credit regimes can help manufacturers to comply with standards by encouraging the supply of ultra-low emission vehicles or by recognising CO_2 benefits not captured in standardised laboratory testing. The impact of any credits would depend on the complex interaction of a large range of factors including the "value" of the credit, how long the credit remains in place, whether it delivers real CO_2 reductions or is purely a technology incentive, and its overall uptake in the fleet.

The fundamental objective of a fuel efficiency standards is to reduce the overall CO_2 emissions from the new vehicle fleet, so all credits measures should be considered in this context. Based on the assessment of the three groups discussed, only credits for off-cycle measures could satisfy this fundamental objective.

There is however, recognition internationally that ultra-low emission, advanced technology vehicles such as EVs, HFCVs and PHEVs are in relatively early stages of mass production and manufacturers developing these vehicles face very high development and manufacturing costs that ensure minimal sales in normal market circumstances. It could be argued that there is a case for extending the scope of the CO_2 standards to provide credits encouraging the continued development of such vehicles which the US EPA and NHTSA (US EPA and NHTSA 2011) described as "game-changing technologies that face very significant cost and consumer barriers." These technologies have the potential over the longer term to provide emissions reductions not possible with conventional vehicles.[40] Consistent with a performance based, technology neutral approach, any such credit regime could be based on a g/km benchmark, and in this context, a 50g/km benchmark would appear appropriate. To minimise the risk of manufacturers reducing efforts to improve efficiency from the remainder of their fleet, credits for these vehicles could be phased out once sub-50g/km vehicles are available in reasonable (but still low) volume.

As other countries often have a wider range of fiscal and other incentives in place (outside of the standards) which provide additional support for low emission vehicles, there could be a case for an Australia to adopt a higher multiplier for these vehicles. To mitigate the risk of multipliers reducing the incentive for manufacturers to improve the efficiency of petrol and diesel vehicles, limits could be set on the timeframe or market share, in which manufacturers could receive a credit.

Question

11. What, if any, credits should an Australian fuel efficiency standard adopt to further encourage the supply of more efficient vehicles, and why?

A9 Which entities could be required to comply?

The European regulations[41] place the responsibility for compliance on the manufacturer which is defined as the "...person or body responsible to the approval authority for...the EC type-approval procedure...and ensuring conformity of production". This would be equivalent to the organisation that obtains or holds an Australia whole vehicle type approval (approval to place identification plates on a vehicle under section 10A of the *Motor Vehicle Standards Act 1989*).

However, in many cases the entity holding a type approval for a vehicle model under the *Motor Vehicle Standards Act 1989* may be a different entity to the entity managing the marketing, distribution and sale of vehicles in Australia. Some entities holding type approvals are the overseas based 'parent' entity that controls the supply of vehicles at a global level. In some cases, multiple subsidiaries of a global manufacturing group, may hold type approvals for different brands or models produced by a manufacturer or manufacturing group. Entities managing the sale of vehicles in Australia may be a subsidiary of a global manufacturing group, or an independent distributor that manages the sale of vehicles on behalf of one or more manufacturers.

As a fuel efficiency standard is applied on the basis of vehicle sales rather than individual vehicles, responsibility for compliance could be applied to either the entity holding an Australian type approval or an entity that manages the distribution and sale of vehicles in Australia (importer). While it is generally easier to enforce a penalty on an entity with a corporate presence in Australia, entities holding type approvals are more likely to have processes

in place for ensuring vehicles meet regulatory requirements. To mitigate the risk of non-compliance by an entity that does not have a corporate presence in Australia, provisions could be adopted to enable the Administrator of Vehicle Standards to suspend, cancel or refuse type approvals and associated import approvals for entities that fail to comply with penalties imposed under Australian fuel efficiency standards.

Regardless of which entity became ultimately responsible, both the entity holding the type approval and the local distributor managing the sale of vehicles in Australia would need to work together to ensure regulatory requirements were met.

Question

[40] It is recognised that this potential for CO_2 reductions from EVs and PHEVs is dependent on the "de-carbonisation" of the electricity generation system, but this is outside the scope of this RIS and there are other Australian Government policies in place designed to increase the proportion of electricity supplied from renewable and lower CO_2 emitting sources.

[41] See EU Regulation 443/2009 (Article 3) here

12. Which entities should be required to comply with a fuel efficiency standard, and why?

A10 Should all entities be subject to the same requirements?

Some entities supply a relatively small number of vehicles to Australia and offer a limited range of vehicle models globally, which could make it more difficult and expensive for these entities to comply with a sales weighted average standard. In recognition of these impacts, standards adopted in other markets often provide for alternative arrangements for low volume or niche manufacturers that are independent of larger global manufacturers.

If alternative arrangements were offered to low volume suppliers in Australia, a key issue that would need to be resolved would be which entities qualify as a low volume supplier. As Australia is a relatively small market by international standards, it would not be appropriate to adopt the same thresholds as larger markets. As the Australian market is roughly one-tenth of the EU market, ABMARC's research identified which manufacturers could be subject to the full or concession requirements, if thresholds were set at one-tenth of the EU thresholds. Table A5 shows the proportion of vehicles that may be eligible for a concessional arrangement if thresholds were set at one-tenth of the EU thresholds.

Table A5: Possible concessional arrangements based on EU approach

Possible threshold (sales per annum)	Possible Requirement	Proportion of vehicles affected (based on 2015 vehicle sales)
>30,000	Standard as defined by limit curve	83.96%
1,000 to 30,000	Alternative sales weighted average target, possibly based on an equivalent percentage reduction in average CO_2 emissions from 2020 to 2025.	15.63%
100 to 999	Alternative target, based on the entities economic and technological ability to improve efficiency.	0.38%
<100	Full exemption	0.03%

The Department notes that if this approach was adopted, the proportion of vehicles that would be subject to the standard (as defined by the limit curve) would be smaller than that in the EU, where the limit curve covers around 90 per cent of vehicle sales (ABMARC 2016). This proportion could also reduce further if the Australian market became more fragmented. To achieve an equivalent level of coverage to the EU, the threshold at which the limit curve applies could be made somewhere between 10,000 and 20,000, depending on how targets were applied to each vehicle segment.

Entities that supply less than 1,000 vehicles per annum, at an aggregate level, would make an insignificant contribution to total CO_2 emissions from the light vehicle fleet, relative to the regulatory burden a standard would impose on these manufacturers. However, from an equity or competitive neutrality perspective, it could be argued that all vehicles should be required to improve the efficiency of the vehicles they supply to Australia.

To determine an entity's liability and eligibility for any concession, all entities supplying vehicles to the Australian market could be required to report on the volume, efficiency and attributes of all vehicle supplied on a calendar year basis. The introduction of a Register of Approved Vehicles under proposed reforms to the *Motor Vehicle Standards Act 1989* could facilitate this at relatively low cost, if the information supplied to the register included the efficiency of the vehicle and vehicle attributes (such as mass or footprint), if an attribute based standard is adopted.

Question

13. **What concessional arrangements should be offered to low volume suppliers under an Australian fuel efficiency standard and why?**

A11 What penalties could be applied if entities failed to comply?

In other markets with standards, entities that fail to achieve their sale weighted targets are generally subject to a financial penalty. In the US, a US$5.50 fine applies for each 10th of a mile per gallon of each new vehicle sold above the target. In the EU, a €95 fine for every gram of emissions of each new vehicle sold above the target is charged. In Japan, a smaller financial penalty applies and firms must make a public announcement of their non-compliance (CCA 2014).

The principal objective of a fuel efficiency standard is to help achieve the abatement required to meet Australia's 2030 greenhouse gas reduction target by improving the efficiency of new light vehicles supplied to the Australian market. On this basis, a financial penalty could reflect the costs borne by the community through higher fuel costs and greenhouse gas emissions. However, a financial penalty would only be effective, if the cost of paying a financial penalty exceeded the cost to an entity of meeting regulatory requirements.

One possible option could be to apply a financial penalty to manufacturers that fail to meet their sales weighted average target, per unit of excess CO_2 that could be expected over the lifetime of the vehicles sold (that is excess gCO_2/km, multiplied by the number of vehicles sold, multiplied by average number of kilometres each vehicle could be expected to travel over its lifetime).

To ensure financial penalties could be enforced on all entities supplying vehicles to Australia, whether based in Australia or overseas, the *Motor Vehicle Standards Act 1989* could be amended to enable the Administrator of Vehicle Standards to suspend, cancel or refuse type approvals for entities that failed to pay a financial penalty in a timely manner. Suppliers could also be subject to other sanctions for non-compliance, such as exclusion from government fleet purchasing.

Question

14. **What penalties should be applied to entities that failed to comply with a fuel efficiency standard and why?**

Appendix B–BITRE Benefit–Cost Analysis

Executive Summary

This study assesses benefits and costs associated with the introduction of mandatory light vehicle efficiency (CO_2) standards. Three regulatory options are analysed reflecting variations on the proposed targets. Option 1 (S1) involves introducing a standard for new light vehicles commencing in 2020 with an approximate annual rate of improvement up to five times faster than anticipated under current policy settings to achieve a target of 105 grams of CO_2 emitted per kilometre travelled (g/km) in 2025. Option 2 (S2) involves introducing a standard for new light vehicles commencing in 2020 with an approximate annual rate of improvement up to four times faster than anticipated under current policy settings to achieve a target of 119g/km in 2025. Option 3 (S3) involves introducing a standard for new light vehicles commencing in 2020 with an approximate annual rate of improvement up to 2.5 times faster than anticipated under current policy settings to achieve a target of 135g/km in 2025.

The main benefit identified was fuel cost savings due to improvements in fuel efficiency required to meet the standards, and environmental benefits associated with a reduction in CO_2 emissions. The identified cost items mainly include additional capital costs required to meet the new standards.

The BCA results (Table B1) show that the three options considered are viable in economic terms with the strong standard S1 having the highest net benefit ($13.898m) and the mild standard 'S3' having the highest BCR (1.97). For all three main scenarios, some costs have been omitted (e.g. possible utility loss) due to lack of information and/or methodology to estimate them, resulting in the estimated BCR being biased slightly upward. Some assessments of such extra possible costs are conducted in sensitivity analyses.

Table B1: Economic comparison of regulatory options

Scenario	Present Value of Costs ($m)	Present Value of Benefits ($m)	Net Present Value ($m)	Benefit-Cost Ratio
S1	16,214.4	30,112.3	13,897.9	1.86
S2	11,157.7	21,587.9	10,430.3	1.93
S3	5,990.3	11,821.4	5,831.2	1.97

Introduction

This study assesses benefits and costs associated with the introduction of fuel efficiency (or equivalently CO_2) standards into the Australian light vehicle fleet.

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

Note that this analysis deals with new sales of all 'light' motor vehicles (i.e. all 4-wheeled road vehicles with a gross vehicle mass under 3.5 tonnes); encompassing the categories of cars, all-terrain wagons (ATWs) or sports utility vehicles (SUVs) and light commercial vehicles (LCVs). The sum of the 'cars' and 'SUVs' categories is equivalent to the standard Australian Bureau of Statistics (ABS) category of 'Passenger vehicles'. When new fleet values are quoted, they refer to sales-weighted averages across the entire *light vehicle* classification.

Three regulatory options are analysed reflecting variations on the proposed fleet average target for 2025. Option 1 (S1) involves introducing a standard for new light vehicles commencing in 2020 with an approximate annual rate of improvement up to five times faster than anticipated under current policy settings to achieve a target of 105 grams of CO_2 emitted per kilometre travelled (g/km) in 2025. Option 2 (S2) involves introducing a standard for new light vehicles commencing in 2020 with an approximate annual rate of improvement up to four times faster than anticipated under current policy settings to achieve a target of 119g/km in 2025. Option 3 (S3) involves introducing a standard for new light vehicles commencing in 2020 with an approximate annual rate of improvement up to 2.5 times faster than anticipated under currently policy settings to achieve a target of 135g/km in 2025. Table B2 presents a summary description of the three modelled options.

Table B2: Regulatory options

Scenario	Standard	Vehicle Group	Description of Scenario
S1	CO_2 standard commencing in 2020 with a fleet average target of 105g/km in 2025.	All new vehicles up to 3.5 tonnes	Standard requiring an annual rate of improvement up to five times faster than BAU from 2020 to 2025
S2	CO_2 standard commencing in 2020 with a fleet average target of 119g/km in 2025.	All new vehicles up to 3.5 tonnes	Standard requiring an annual rate of improvement up to four times faster than BAU from 2020 to 2025
S3	CO_2 standard commencing in 2020 with a fleet average target of 135g/km in 2025.	All new vehicles up to 3.5 tonnes	Standard requiring an annual rate of improvement up to 2.5 times faster than BAU from 2020 to 2025

Note that the values given in the table refer to *rated* or *test* fuel consumption levels, based on standard laboratory or dynamometer results over specified drive cycles, where such levels are typically lower than actual on-road fuel consumption. The table values refer to compliance results obtained over the NEDC (New European Driving Cycle) test, as specified in current United Nations Economic Commission for Europe (UNECE) regulations setting out procedures for determining fuel consumption and CO_2 emissions from light vehicles. The NEDC is a test driving cycle that attempts to better represent typical on-road driving conditions than previous regulatory test cycles (though will still typically underestimate on-road emission levels to some extent).

The main quantifiable benefit identified is the fuel cost avoided due to lower levels of fuel consumption as a result of such mandatory CO_2 emission standards. The identified costs mainly relate to additional capital involved in manufacturing vehicles for the Australian market with additional technology designed to meet the new standards.

The Benefit–Cost Analysis (BCA) results show that the three options considered are viable in economic terms with option S3 having the highest Benefit–Cost Ratio (BCR) at 1.97. Some of the cost and benefit items have been omitted due to data and methodological limitations and it is likely that they would offset each other to some extent. Overall, the results are heavily dependent on the underlying assumptions. Sensitivity tests are carried out to deal with uncertainties in the fuel, greenhouse gas and health cost values, implementation costs and discount rates.

Methodology for estimating fuel savings

The first step is to quantify the expected changes in fuel use for each of the scenarios under investigation and estimate fuel and CO_2 emission savings under each scenario of alternative vehicle emission standards (relative to the base case). The second step is to establish a value for a unit of fuel consumed ($ per unit, excluding taxes) and CO_2 emissions ($ per tonne of emissions). The final step is to calculate the total benefit (or cost avoided) by multiplying fuel use and tonnes of emissions saved by unit value(s) for these costs.

Fuel consumption and CO_2 emissions 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 rates 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 fuel consumption and CO_2 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 has been updated and revised for this BCA study, using:

- 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)[42];
- 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, 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) 2012a (*Discrepancies between type approval and "real-world" fuel consumption and CO_2 values*), ICCT 2013a (*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

[42] 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.

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 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 2015b (*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*), 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 2015c (*Real-world fuel consumption of popular European passenger car models*).

Fuel Cost

Unit cost values for each fuel type (in terms of resource costs, i.e. less taxes) were primarily based on pump price trend data collated by FuelTrac Pty Ltd–and published by the Australian Automobile Association; Australian Institute of Petroleum, Motormouth Pty Ltd, Viva Energy Australia, Caltex Australia and the NRMA; with projections using the basic assumption of a uniform annual increase of 1 per cent. These estimates are presented in Table B3. Sensitivity of the results to the fuel cost projections were also conducted (with the results presented in a later section).

Table B3: Resource Fuel Cost Estimates ($/unit in 2016 prices)

Financial Year	ULP ($/L)	PULP95 ($/L)	PULP98 and proprietary blends ($/L)	Diesel ($/L)	Other liquid/gas ($/L equivalent)	Electricity ($/kWh)
2016	0.70	0.79	0.82	0.70	0.70	0.20
2017	0.71	0.80	0.83	0.71	0.71	0.20
2018	0.71	0.81	0.84	0.71	0.71	0.20
2019	0.72	0.81	0.84	0.72	0.72	0.21
2020	0.73	0.82	0.85	0.73	0.73	0.21
2021	0.74	0.83	0.86	0.74	0.74	0.21
2022	0.74	0.84	0.87	0.74	0.74	0.21
2023	0.75	0.85	0.88	0.75	0.75	0.21
2024	0.76	0.86	0.89	0.76	0.76	0.22
2025	0.77	0.86	0.90	0.77	0.77	0.22
2026	0.77	0.87	0.91	0.77	0.77	0.22

Financial Year	ULP ($/L)	PULP95 ($/L)	PULP98 and proprietary blends ($/L)	Diesel ($/L)	Other liquid/gas ($/L equivalent)	Electricity ($/kWh)
2027	0.78	0.88	0.91	0.78	0.78	0.22
2028	0.79	0.89	0.92	0.79	0.79	0.23
2029	0.80	0.90	0.93	0.80	0.80	0.23
2030	0.80	0.91	0.94	0.80	0.80	0.23
2031	0.81	0.92	0.95	0.81	0.81	0.23
2032	0.82	0.93	0.96	0.82	0.82	0.23
2033	0.83	0.94	0.97	0.83	0.83	0.24
2034	0.84	0.94	0.98	0.84	0.84	0.24
2035	0.85	0.95	0.99	0.85	0.85	0.24
2036	0.85	0.96	1.00	0.85	0.85	0.24
2037	0.86	0.97	1.01	0.86	0.86	0.25
2038	0.87	0.98	1.02	0.87	0.87	0.25
2039	0.88	0.99	1.03	0.88	0.88	0.25
2040	0.89	1.00	1.04	0.89	0.89	0.25

ULP–unleaded petrol, PULP–Premium unleaded petrol.

Note: Costs are less taxes.

In estimating fuel saving benefits resulting from reductions in fuel consumption, a wide range of cost values has been used, across various scenarios, reflecting significant uncertainty as to the actual fuel costs that will be borne by consumers. Resulting cost uncertainty (e.g. net of possible utility losses or from changing fuel mixes and prices) is addressed via sensitivity tests.

Greenhouse Gas Costs

A conservative estimate of $35/per tonne of CO_2 abated, kept constant over the analysis period, has been used to estimate greenhouse benefits from a reduction in aggregate vehicle CO_2 emissions. This unit value has been based on appraisals conducted for the United States 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.

The SCC (see https://www3.epa.gov/climatechange/EPAactivities/economics/scc.html) is an estimate of the likely change in economic damages associated with a change in carbon dioxide emissions of one metric ton, in a given year. The value used here, for the BCA inputs, is sourced from the 2015 year value, of the median scenario, originally developed for US Government (see US Office of Management and Budget (OMB) 2010, *Social Cost of Carbon for Regulatory Impact Analysis*). The chosen valuation ($A35/per tonne over the full projection period) is conservative both due to being held constant (whereas the SCC values in OMB 2010 increase significantly over time) and to being lower than many literature values (where even the latest update to the US SCC values are somewhat higher–see OMB 2015).

A lower carbon cost value of $12.10 (based on the average cost of abatement from the first three auctions of the Emissions Reduction Fund) is also assessed as a sensitivity test.

Benefit–cost analysis

For the purpose of the benefit–cost analysis, the base and price year has been set to 2016 with the evaluation period extending to 2040. This allows for a 24-year analysis period after a mandatory standard commences in 2020. Following the recommendations in the *Australian Government*

Guide to Regulation (DPMC 2014), the discount rate used to estimate the net present value is 7%, with sensitivity tests at 3 and 11%.

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

Scenarios

Three regulatory options are analysed against the business-as-usual (BAU) case. These three options differ in the fleet average target and expected rate of improvement from 2020 to 2025.

BAU case

The 'base case' or reference scenario emission projections used herein are estimated using primarily business-as-usual assumptions for the coming years. It is 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 are made for the base case scenario.

- Oil prices are 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 1 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 Australian Bureau of Statistics (ABS), using values to 2050 from their mid-range Population Projections trend–'Series B' (ABS 2013b).
- 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 annum, remaining marginally above that passenger vehicles, at around 1.7% 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, the current popularity of diesel light vehicles–especially in the SUV and LCV markets–and the niche use of alternatives such as natural gas and electricity).
- There will be no change to current vehicle or fuel standards, though Australia will gain some benefits from a sub-set of imported vehicles meeting stricter overseas pollution or efficiency standards.
- 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.

In the base case scenario, the average rated[43] fuel intensity of the Australian new light vehicle fleet reaches a level of about 157 gCO_2/km by 2025 (down from a 2015 average of approximately 18 4 gCO_2/km, across all new light vehicle sales).

Scenario 1 (S1)

Scenario 1 is the same as the BAU case, except for a new standard commencing in 2020 requiring an average annual rate of improvement up to five times faster, to achieve a fleet average target, across all new light vehicle sales, of 105gCO_2/km in 2025.

Scenario 2 (S2)

[43] Over the NEDC test.

Scenario 2 is the same as for Scenario 1, except that the new standard commencing in 2020 requires an average annual rate of improvement up to four times faster, to achieve a new fleet average target of 119gCO_2/km in 2025.

Scenario 3 (S3)

Scenario 3 is the same as for Scenario 1, except that the new standard commencing in 2020 requires an average annual rate of improvement up to 2.5 times faster, to achieve a new fleet average target of 135gCO_2/km in 2025.

Benefits

Table B4 presents modelling results for fuel savings ($ million) for scenarios S1 to S3 compared with the BAU case. Tables B5 and B6 present modelling results for reductions in CO_2 emissions ('000 tonnes) and associated benefits ($ millions) for scenarios S1 to S3 compared with the BAU case.

Table B4: Fuel Cost savings ($ millions)

Financial Year	S1	S2	S3
2016	0	0	0
2017	0	0	0
2018	-31.0	-23.3	-9.2
2019	-123.0	-87.8	-37.0
2020	-274.7	-192.4	-82.7
2021	-481.0	-335.8	-148.7
2022	-741.3	-520.6	-241.8
2023	-1064.3	-754.1	-366.9
2024	-1449.8	-1035.9	-524.2
2025	-1909.5	-1373.3	-717.0
2026	-2375.4	-1714.7	-911.3
2027	-2831.2	-2048.2	-1100.7
2028	-3282.6	-2378.4	-1288.2
2029	-3727.5	-2703.8	-1472.8
2030	-4163.8	-2979.2	-1654.3
2031	-4591.8	-3288.2	-1832.3
2032	-5009.1	-3589.3	-2005.9
2033	-5415.1	-3882.2	-2175.1
2034	-5804.4	-4162.8	-2337.5
2035	-6177.5	-4431.9	-2493.5
2036	-6530.1	-4686.0	-2641.0
2037	-6864.6	-4927.1	-2781.1
2038	-7176.0	-5151.0	-2911.3
2039	-7466.1	-5359.5	-3032.6
2040	-7734.0	-5551.7	-3144.6

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

Source: BITRE estimates.

Table B5: Estimated reduction in CO_2 emissions (thousand tonnes)

Financial Year	S1	S2	S3
2016	0	0	0
2017	0	0	0
2018	-100	-67	-30
2019	-391	-261	-118
2020	-864	-577	-260
2021	-1,498	-1,005	-463
2022	-2,285	-1,552	-744
2023	-3,244	-2,232	-1,115
2024	-4,372	-3,042	-1,575
2025	-5,656	-3,971	-2,109
2026	-6,968	-4,919	-2,655
2027	-8,234	-5,829	-3,178
2028	-9,436	-6,698	-3,678
2029	-10,603	-7,538	-4,162
2030	-11,720	-8,342	-4,625
2031	-12,789	-9,111	-5,069
2032	-13,804	-9,841	-5,491
2033	-14,765	-10,532	-5,891
2034	-15,658	-11,174	-6,264
2035	-16,484	-11,769	-6,610
2036	-17,233	-12,308	-6,925
2037	-17,913	-12,796	-7,212
2038	-18,512	-13,227	-7,465
2039	-19,037	-13,603	-7,688
2040	-19,490	-13,927	-7,880

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

Source: BITRE estimates.

Table B6: Greenhouse gas reduction benefits ($ millions)

Financial Year	S1	S2	S3
2016	0	0	0
2017	0	0	0
2018	-3.5	-2.3	-1.1
2019	-13.7	-9.2	-4.1
2020	-30.2	-20.2	-9.1
2021	-52.4	-35.2	-16.2
2022	-80.0	-54.3	-26.0
2023	-113.5	-78.1	-39.0

Financial Year	S1	S2	S3
2024	-153.0	-106.5	-55.1
2025	-198.0	-139.0	-73.8
2026	-243.9	-172.2	-92.9
2027	-288.2	-204.0	-111.2
2028	-330.3	-234.4	-128.7
2029	-371.1	-263.8	-145.7
2030	-410.2	-292.0	-161.9
2031	-447.6	-318.9	-177.4
2032	-483.1	-344.4	-192.2
2033	-516.8	-368.6	-206.2
2034	-548.0	-391.1	-219.2
2035	-576.9	-411.9	-231.4
2036	-603.2	-430.8	-242.4
2037	-626.9	-447.9	-252.4
2038	-647.9	-462.9	-261.3
2039	-666.3	-476.1	-269.1
2040	-682.1	-487.4	-275.8

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

Source: BITRE estimates.

Implementation costs

There are a wide range of technologies that have been adopted by vehicle manufacturers to meet fuel efficiency/CO_2 standards in other countries, which vary by manufacturer and other market requirements. Obtaining reliable cost estimates for these technologies as a package and subsequent vehicle on-costs to users is problematic due to the sensitive nature of cost information and difficulty in apportioning costs. For the present study, the additional cost estimates for supplying vehicles with additional fuel saving technologies are primarily informed by US estimates for packages of various fuel-saving technologies (derived as part of the US Government's assessment of fuel intensity standards), which are applied progressively to achieve lower gCO_2/km values, and ICCT summary values for European studies (that have attempted estimating the additional manufacturing costs that would be required to meet various gCO_2/km target levels– where such European-based values have to be adjusted both: for the different make-up of the European fleet, with smaller vehicles in general, and lower proportions of SUVs and LCVs, making current levels of new fleet gCO_2/km averages substantially lower than Australia; and for the inclusion of indirect cost multipliers[44], to scale up extra manufacturing costs to final market-delivered levels). These extra costs (relative to the baseline improvement trend) typically increase as the standard becomes more stringent, and over time as the target year approaches, until 2025 after which the derived cost levels roughly stabilise (with some slow declines, depending on the particular modelling settings), since the chosen scenarios revert to the base case proportional decrease in annual gCO_2/km thereafter (i.e. do not impose further intensity reduction targets following 2025).

Basically an average cost versus fuel intensity function (extra dollars required to produce a new fleet with progressively lower gCO_2/km values) was derived by aggregating the various technology component studies, focusing on those technology options with the most relevance to the Australian light fleet composition. Various sources for such (fuel-saving) technology cost estimates included:

[44] e.g. see US EPA 2009, NRC 2015, BEUC 2013.

US EPA 2012a and 2012b (*Regulatory Impact Analysis: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards*), U.S. EPA and U.S. National Highway Traffic Safety Administration 2011 and 2012, ICCT 2012b (*Summary of the EU cost curve development methodology*), ICCT 2012c (*Estimated Cost of Emission Reduction Technologies for Light-Duty Vehicles*), ICCT 2013b (*Passenger car fuel-efficiency, 2020–2025*), Mock 2015a (*Vehicle technology costs: Estimates vs. reality*) and 2015b, IKA 2014 (*CO_2 Emission Reduction Potential for Passenger Cars and Light Commercial Vehicles Post* 2020), Citigroup 2011, AEA Technology 2012 (*A review of the efficiency and cost assumptions for road transport vehicles to 2050*), European Commission 2015, Ricardo-AEA 2014, and National Research Council 2015 (*Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles*).

Separate cost curves were fit, from the technology assessment data, for light passenger vehicles and commercial vehicles. There is considerable uncertainty in the determination of such CO_2 intensity cost curves–not only due to the exact mix of future technologies, that will be successfully marketed in Australia, yet to be decided, but also due to the many unknown factors that could bear on future technology component costs (such as economies of scale, technical advances or 'learning' enhancements). The ensuing modelled cost functions are non-linear (i.e. exhibit faster increases in net costs for larger improvements in fuel efficiency than for slight improvements) and could be regarded as roughly median results (i.e. are both higher than some literature results and lower than others, as well as being more non-linear than some and less than others). This level of additional vehicle cost uncertainty is addressed by sensitivity tests; noting that BEUC (2013) "emphasise that in ex-ante estimates, production costs are often largely overestimated", with Ricardo-AEA (2014) also observing that the "costs of deploying technologies for new vehicles have been lower than anticipated" when looking at the cost effectiveness of recent progress under European light vehicle CO_2 regulation (in a comparison of ex-ante impact assessments with ex-post evaluations). In fact, the recent US EPA (2016)[45] assessment of progress towards the US light vehicle CO_2 standards (*Midterm Evaluation of Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2022-2025*), finds that compared with earlier technical assessments of the technologies available to meet the standards (e.g. US EPA 2012a), "A wider range of technologies exist for manufacturers to use to meet the MY [Model Year] 2022-2025 standards, and at costs that are similar or lower, than those projected in the 2012 rule".

Table B7 shows the average additional cost per vehicle (for non-electric vehicles) under the three regulatory scenarios, resulting from the fleet fuel intensity modelling. These extra capital costs (averaged across all the different vehicle types/sizes composing the new light vehicle fleet) include allowance for extra compliance costs associated with additional reporting and record keeping arrangements under the proposed standards.

Table B7: Estimated additional capital and compliance costs, non-electric fleet average ($/vehicle)

Financial year	S1		S2		S3	
	Passenger	Light Commercial	Passenger	Light Commercial	Passenger	Light Commercial
2016	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
2018	238.3	231.9	167.8	105.6	77.0	36.7
2019	493.0	490.7	345.2	223.8	157.3	80.6
2020	763.9	776.4	532.4	354.5	241.0	131.3

[45] US EPA 2016b evaluation also expects that "advanced gasoline vehicle technologies will continue to be the predominant technologies, with modest levels of strong hybridization and very low levels of full electrification (plug-in vehicles) needed to meet the standards".

Financial year	S1		S2		S3	
	Passenger	Light Commercial	Passenger	Light Commercial	Passenger	Light Commercial
2021	956.8	1183.2	680.3	588.0	330.1	243.9
2022	1192.5	1622.7	868.6	837.9	456.7	364.1
2023	1437.8	2090.6	1064.2	1099.9	587.6	487.4
2024	1692.7	2590.1	1266.9	1377.1	722.8	617.0
2025	1921.8	3120.1	1441.3	1668.6	826.8	752.0
2026	1901.0	3120.6	1426.9	1671.3	819.4	754.1
2027	1886.6	3120.5	1416.8	1673.6	814.3	756.0
2028	1871.8	3119.7	1406.4	1675.6	808.9	757.7
2029	1856.7	3118.3	1395.7	1677.1	803.3	759.2
2030	1841.1	3116.4	1384.7	1678.3	797.5	760.6
2031	1830.8	3115.2	1377.4	1678.8	793.6	761.2
2032	1820.4	3113.9	1370.0	1679.1	789.7	761.7
2033	1810.0	3113.0	1362.6	1679.3	785.8	762.0
2034	1799.5	3112.1	1355.1	1679.4	781.8	762.3
2035	1789.0	3111.1	1347.5	1679.5	777.8	762.6
2036	1778.4	3110.1	1340.0	1679.6	773.7	762.9
2037	1767.8	3109.1	1332.3	1679.7	769.6	763.1
2038	1757.1	3108.0	1324.7	1679.7	765.5	763.3
2039	1746.5	3106.9	1317.0	1679.7	761.4	763.5
2040	1735.8	3105.7	1309.3	1679.6	757.2	763.7

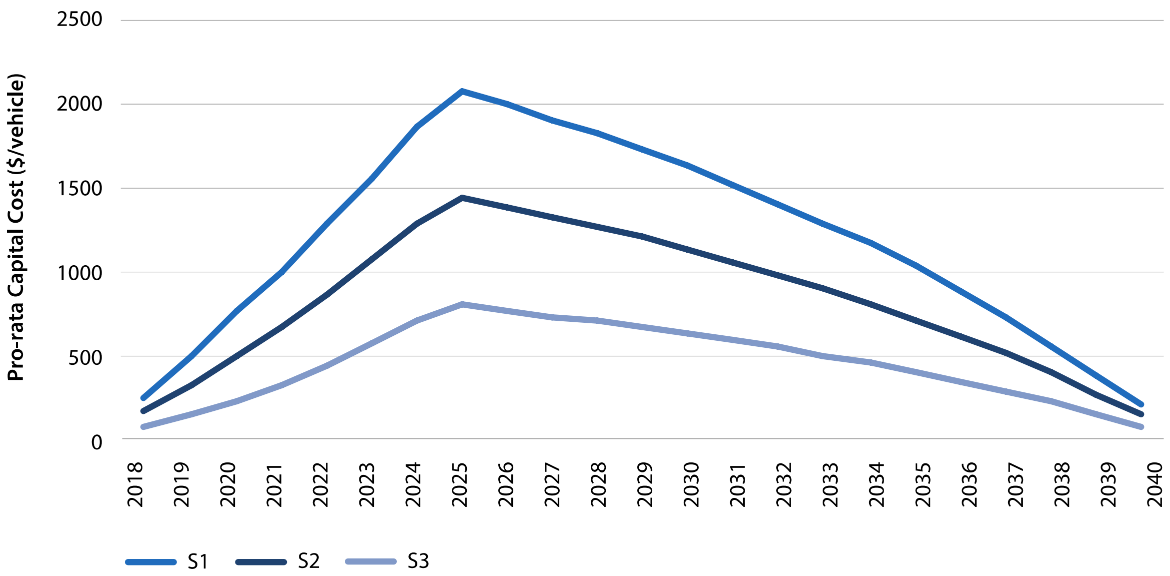
Note: These tabulated values are those derived for new vehicle averages before adding in the modelled effects of any further levels of electrification encouraged by the standards' setting; with full fleet averages (electric plus non-electric vehicles) typically a few per cent higher.

Sources: BITRE estimates based on US EPA (2012a, 2012b), US EPA & NHTSA (2011, 2012), Mock (2015a, 2015b), IKA 2014, Citigroup 2011, AEA Technology 2012, European Commission 2015, Ricardo-AEA 2014, NRC 2015 and ICCT (2012b, 2012c, 2013b).

Fuel saving technologies 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 vehicle fleet emission models simulate the fleet-wide impact of technology penetration over time, and separating out the continuing effects–after the end of the evaluation period–of pre-2040 vehicles from those bought after that date would be relatively imprecise and impractical for wide-ranging scenario analyses). Since the benefits from fuel saving technology are fairly constant over the lives of the vehicles, a good approximation is obtained by prorating the cost of the technology over the lives of the vehicles, then only counting costs attributed to years before 2040.

The average vehicle life was assumed to be 17 years. For vehicles purchased during the last 16 years of the evaluation period, the cost of the fuel saving technology was annuitised over 17 years at the discount rate of 7 per cent. Figure B1 shows the effects on costs per vehicle of excluding annualised costs after 2040 of fuel saving technology for vehicles purchased over the last 16 years of the evaluation period. The pro-rata curves approach zero by the end of the period, with vehicles purchased in 2039 having only one year of cost included, since only one year of their fuel saving benefit is captured by the fleet assessments.

Figure B1: Pro-rata capital costs under the three standards scenarios (BITRE estimates)



In estimating the total implementation costs for the main 3 scenarios, it was assumed that announcement of the standards (by 2017) would encourage some manufacturers to either start promoting their high-efficiency models more strongly or slightly bring forward planned technology enhancements; with the result that some vehicles sold in 2018 and 2019 would incorporate additional fuel saving technology (over the base case) in anticipation of the 2020-2025 requirements.

As a rough test into whether the pro-rata cost methodology might introduce some bias into the calculations (relative to the more usual 'residual value' method), a somewhat unrealistic scenario was run on the fleet emission models, that had S1 standards apply, and with fleet technology penetration following the same path as scenario S1 up to 2040, but with technology implementation reverting to the base case scenario after 2040. The modelled emission reductions over the next 10 years (2040-2050) were then used to approximate residual values for the continuing emission benefits of the pre-2040 vehicles. The result of this sensitivity test was that the pro-rata methodology did not greatly alter the derived outcome–with the estimated BCR of 1.84 very close to that of S1 (at 1.86).[46]

Net economic benefits and BCR

Table B8a reports the BCA results for S1. On the cost side, there are net cost savings for the total use of fuel and associated CO_2 emissions. Overall, benefits are higher than costs resulting in a positive net present value of $13,898m. The BCR is estimated to be 1.86.

Table B8b reports the BCA results for S2. The benefits are estimated to have a net present value of $10,430.3m and the BCR is estimated to be 1.93.

Table B8c reports the BCA results for S3. The benefits are estimated to have a net present value of $5,831.2m and the BCR is estimated to be 1.97.

It should be noted that, for all the three scenarios, some costs have been omitted here, often in order to maintain adequate precision (e.g. due to lack of information and/or a methodology to estimate some factors, such as possible utility losses, accurately), resulting in the estimated BCR

[46] The residual value scenario had a similar though somewhat higher net estimated benefit, at $17,879.3m (compared with the S1 result of $13,898m).

possibly being biased slightly upward. Some such cost possibilities are discussed within the sensitivity test sections.

Table B8a: Benefit-Cost Analysis for S1 (standard commencing in 2020, with a target of 105g/km by 2025)

Financial year	Undiscounted cash flow									Discounting factor @ 7%	Discounted cash flow @ 7%								
	Costs ($m)				Benefits ($m)				Net benefit ($m)		Costs ($m)				Benefits ($m)				Net benefit ($m)
	Capital	Maintenance	Utility loss	Total	Fuel savings	GHG emissions	Health costs avoided	Total			Capital	Maintenance	Utility loss	Total	Fuel savings	GHG emissions	Health costs avoided	Total	
2013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2014	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2016	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.000	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	0.935	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2018	272.4	0.0	0.0	272.4	31.0	3.5	0.0	34.5	-237.8	0.873	237.9	0.0	0.0	237.9	27.1	3.1	0.0	30.2	-207.7
2019	570.6	0.0	0.0	570.6	123.0	13.7	0.0	136.7	-433.9	0.816	465.8	0.0	0.0	465.8	100.4	11.2	0.0	111.6	-354.2
2020	900.2	0.0	0.0	900.2	274.7	30.2	0.0	305.0	-595.2	0.763	686.7	0.0	0.0	686.7	209.6	23.1	0.0	232.6	-454.1
2021	1,188.5	0.0	0.0	1,188.5	481.0	52.4	0.0	533.4	-655.1	0.713	847.4	0.0	0.0	847.4	342.9	37.4	0.0	380.3	-467.1
2022	1,535.3	0.0	0.0	1,535.3	741.3	80.0	0.0	821.3	-713.9	0.666	1,023.0	0.0	0.0	1,023.0	494.0	53.3	0.0	547.3	-475.7
2023	1,906.4	0.0	0.0	1,906.4	1,064.3	113.5	0.0	1,177.8	-728.6	0.623	1,187.2	0.0	0.0	1,187.2	662.8	70.7	0.0	733.5	-453.7
2024	2,304.2	0.0	0.0	2,304.2	1,449.8	153.0	0.0	1,602.8	-701.4	0.582	1,341.1	0.0	0.0	1,341.1	843.8	89.1	0.0	932.9	-408.2
2025	2,604.3	0.0	0.0	2,604.3	1,909.5	198.0	0.0	2,107.5	-496.8	0.544	1,416.6	0.0	0.0	1,416.6	1,038.7	107.7	0.0	1,146.3	-270.2
2026	2,529.1	0.0	0.0	2,529.1	2,375.4	243.9	0.0	2,619.3	90.2	0.508	1,285.6	0.0	0.0	1,285.6	1,207.5	124.0	0.0	1,331.5	45.9
2027	2,452.2	0.0	0.0	2,452.2	2,831.2	288.2	0.0	3,119.3	667.2	0.475	1,165.0	0.0	0.0	1,165.0	1,345.1	136.9	0.0	1,482.0	317.0
2028	2,366.8	0.0	0.0	2,366.8	3,282.6	330.3	0.0	3,612.8	1,246.1	0.444	1,050.9	0.0	0.0	1,050.9	1,457.5	146.6	0.0	1,604.1	553.3
2029	2,270.8	0.0	0.0	2,270.8	3,727.5	371.1	0.0	4,098.6	1,827.8	0.415	942.3	0.0	0.0	942.3	1,546.8	154.0	0.0	1,700.8	758.5
2030	2,164.1	0.0	0.0	2,164.1	4,163.8	410.2	0.0	4,574.0	2,409.9	0.388	839.3	0.0	0.0	839.3	1,614.8	159.1	0.0	1,773.9	934.6
2031	2,042.5	0.0	0.0	2,042.5	4,591.8	447.6	0.0	5,039.4	2,996.9	0.362	740.3	0.0	0.0	740.3	1,664.3	162.2	0.0	1,826.5	1,086.2
2032	1,908.8	0.0	0.0	1,908.8	5,009.1	483.1	0.0	5,492.3	3,583.4	0.339	646.6	0.0	0.0	646.6	1,696.8	163.7	0.0	1,860.4	1,213.8

Financial year	Undiscounted cash flow									Discounting factor @ 7%	Discounted cash flow @ 7%								
	Costs ($m)				Benefits ($m)				Net benefit ($m)		Costs ($m)				Benefits ($m)				Net benefit ($m)
	Capital	Maintenance	Utility loss	Total	Fuel savings	GHG emissions	Health costs avoided	Total			Capital	Maintenance	Utility loss	Total	Fuel savings	GHG emissions	Health costs avoided	Total	
2033	1,761.8	0.0	0.0	1,761.8	5,415.1	516.8	0.0	5,931.9	4,170.1	0.317	557.7	0.0	0.0	557.7	1,714.3	163.6	0.0	1,877.9	1,320.1
2034	1,598.8	0.0	0.0	1,598.8	5,804.4	548.0	0.0	6,352.4	4,753.5	0.296	473.0	0.0	0.0	473.0	1,717.3	162.1	0.0	1,879.4	1,406.4
2035	1,421.3	0.0	0.0	1,421.3	6,177.5	576.9	0.0	6,754.4	5,333.1	0.277	393.0	0.0	0.0	393.0	1,708.1	159.5	0.0	1,867.6	1,474.6
2036	1,228.7	0.0	0.0	1,228.7	6,530.1	603.2	0.0	7,133.2	5,904.5	0.258	317.5	0.0	0.0	317.5	1,687.5	155.9	0.0	1,843.4	1,525.8
2037	1,019.6	0.0	0.0	1,019.6	6,864.6	626.9	0.0	7,491.6	6,472.0	0.242	246.3	0.0	0.0	246.3	1,657.9	151.4	0.0	1,809.3	1,563.1
2038	793.6	0.0	0.0	793.6	7,176.0	647.9	0.0	7,823.9	7,030.2	0.226	179.1	0.0	0.0	179.1	1,619.7	146.2	0.0	1,766.0	1,586.8
2039	548.9	0.0	0.0	548.9	7,466.1	666.3	0.0	8,132.4	7,583.5	0.211	115.8	0.0	0.0	115.8	1,575.0	140.6	0.0	1,715.5	1,599.7
2040	284.9	0.0	0.0	284.9	7,734.0	682.1	0.0	8,416.2	8,131.3	0.197	56.2	0.0	0.0	56.2	1,524.7	134.5	0.0	1,659.2	1,603.1
Total	35,673.9	0.0	0.0	35,673.9	85,223.9	8,087.0	0.0	93,310.8	57,636.9		16,214.4	0.0	0.0	16,214.4	27,456.5	2,655.8	0.0	30,112.3	13,897.9
Benefit-Cost Ratio =1.86																			

Note: Change from the BAU scenario.
Source: BITRE estimates.

Table B8b: Benefit-Cost Analysis for S2 (standard commencing in 2020, with a target of 119g/km by 2025)

Financial year	Undiscounted cash flow									Discounting factor @ 7%	Discounted cash flow @ 7%								
	Costs ($m)				Benefits ($m)				Net benefit ($m)		Costs ($m)				Benefits ($m)				Net benefit ($m)
	Capital	Maintenance	Utility loss	Total	Fuel savings	GHG emissions	Health costs avoided	Total			Capital	Maintenance	Utility loss	Total	Fuel savings	GHG emissions	Health costs avoided	Total	
2013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2014	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Financial year	Undiscounted cash flow									Discounting factor @ 7%	Discounted cash flow @ 7%								
	Costs ($m)				Benefits ($m)				Net benefit ($m)		Costs ($m)				Benefits ($m)				Net benefit ($m)
	Capital	Maintenance	Utility loss	Total	Fuel savings	GHG emissions	Health costs avoided	Total			Capital	Maintenance	Utility loss	Total	Fuel savings	GHG emissions	Health costs avoided	Total	
2016	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.000	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	0.935	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2018	179.8	0.0	0.0	179.8	23.3	2.3	0.0	25.6	-154.2	0.873	157.1	0.0	0.0	157.1	20.3	2.1	0.0	22.4	-134.7
2019	374.5	0.0	0.0	374.5	87.8	9.2	0.0	96.9	-277.5	0.816	305.7	0.0	0.0	305.7	71.7	7.5	0.0	79.1	-226.6
2020	587.5	0.0	0.0	587.5	192.4	20.2	0.0	212.6	-374.9	0.763	448.2	0.0	0.0	448.2	146.8	15.4	0.0	162.2	-286.0
2021	790.2	0.0	0.0	790.2	335.8	35.2	0.0	370.9	-419.2	0.713	563.4	0.0	0.0	563.4	239.4	25.1	0.0	264.5	-298.9
2022	1,042.6	0.0	0.0	1,042.6	520.6	54.3	0.0	574.9	-467.7	0.666	694.8	0.0	0.0	694.8	346.9	36.2	0.0	383.1	-311.6
2023	1,311.2	0.0	0.0	1,311.2	754.1	78.1	0.0	832.3	-478.9	0.623	816.5	0.0	0.0	816.5	469.6	48.6	0.0	518.3	-298.2
2024	1,597.7	0.0	0.0	1,597.7	1,035.9	106.5	0.0	1,142.4	-455.4	0.582	929.9	0.0	0.0	929.9	602.9	62.0	0.0	664.9	-265.0
2025	1,805.3	0.0	0.0	1,805.3	1,373.3	139.0	0.0	1,512.3	-293.0	0.544	982.0	0.0	0.0	982.0	747.0	75.6	0.0	822.6	-159.4
2026	1,754.5	0.0	0.0	1,754.5	1,714.7	172.2	0.0	1,886.9	132.4	0.508	891.9	0.0	0.0	891.9	871.7	87.5	0.0	959.2	67.3
2027	1,702.4	0.0	0.0	1,702.4	2,048.2	204.0	0.0	2,252.3	549.9	0.475	808.8	0.0	0.0	808.8	973.1	96.9	0.0	1,070.0	261.3
2028	1,644.3	0.0	0.0	1,644.3	2,378.4	234.4	0.0	2,612.8	968.5	0.444	730.1	0.0	0.0	730.1	1,056.0	104.1	0.0	1,160.1	430.0
2029	1,578.6	0.0	0.0	1,578.6	2,703.8	263.8	0.0	2,967.7	1,389.0	0.415	655.1	0.0	0.0	655.1	1,122.0	109.5	0.0	1,231.5	576.4
2030	1,505.2	0.0	0.0	1,505.2	2,979.2	292.0	0.0	3,271.2	1,766.0	0.388	583.8	0.0	0.0	583.8	1,155.4	113.2	0.0	1,268.6	684.9
2031	1,420.9	0.0	0.0	1,420.9	3,288.2	318.9	0.0	3,607.1	2,186.2	0.362	515.0	0.0	0.0	515.0	1,191.8	115.6	0.0	1,307.4	792.4
2032	1,328.1	0.0	0.0	1,328.1	3,589.3	344.4	0.0	3,933.8	2,605.6	0.339	449.9	0.0	0.0	449.9	1,215.8	116.7	0.0	1,332.5	882.6
2033	1,225.7	0.0	0.0	1,225.7	3,882.2	368.6	0.0	4,250.8	3,025.1	0.317	388.0	0.0	0.0	388.0	1,229.0	116.7	0.0	1,345.7	957.7
2034	1,112.1	0.0	0.0	1,112.1	4,162.8	391.1	0.0	4,553.9	3,441.9	0.296	329.0	0.0	0.0	329.0	1,231.6	115.7	0.0	1,347.3	1,018.3
2035	988.2	0.0	0.0	988.2	4,431.9	411.9	0.0	4,843.8	3,855.6	0.277	273.2	0.0	0.0	273.2	1,225.5	113.9	0.0	1,339.3	1,066.1
2036	853.9	0.0	0.0	853.9	4,686.0	430.8	0.0	5,116.8	4,262.9	0.258	220.7	0.0	0.0	220.7	1,211.0	111.3	0.0	1,322.3	1,101.6
2037	708.3	0.0	0.0	708.3	4,927.1	447.9	0.0	5,375.0	4,666.7	0.242	171.1	0.0	0.0	171.1	1,190.0	108.2	0.0	1,298.1	1,127.1

Financial year	Undiscounted cash flow									Discounting factor @ 7%	Discounted cash flow @ 7%								
	Costs ($m)				Benefits ($m)				Net benefit ($m)		Costs ($m)				Benefits ($m)				Net benefit ($m)
	Capital	Maintenance	Utility loss	Total	Fuel savings	GHG emissions	Health costs avoided	Total			Capital	Maintenance	Utility loss	Total	Fuel savings	GHG emissions	Health costs avoided	Total	
2038	551.1	0.0	0.0	551.1	5,151.0	462.9	0.0	5,613.9	5,062.9	0.226	124.4	0.0	0.0	124.4	1,162.7	104.5	0.0	1,267.1	1,142.8
2039	380.9	0.0	0.0	380.9	5,359.5	476.1	0.0	5,835.6	5,454.7	0.211	80.3	0.0	0.0	80.3	1,130.6	100.4	0.0	1,231.0	1,150.7
2040	197.6	0.0	0.0	197.6	5,551.7	487.4	0.0	6,039.1	5,841.6	0.197	38.9	0.0	0.0	38.9	1,094.5	96.1	0.0	1,190.6	1,151.6
Total	24,640.6	0.0	0.0	24,640.6	61,177.4	5,751.3	0.0	66,928.7	42,288.1		11,157.7	0.0	0.0	11,157.7	19,705.2	1,882.7	0.0	21,587.9	10,430.3
Benefit-Cost Ratio =1.93																			

Note: Change from the BAU scenario.
Source: BITRE estimates.

Table B8c: Benefit-Cost Analysis for S3 (standard commencing in 2020, with a target of 135g/km by 2025)

Financial year	Undiscounted cash flow									Discounting factor @ 7%	Discounted cash flow @ 7%								
	Costs ($m)				Benefits ($m)				Net benefit ($m)		Costs ($m)				Benefits ($m)				Net benefit ($m)
	Capital	Maintenance	Utility loss	Total	Fuel savings	GHG emissions	Health costs avoided	Total			Capital	Maintenance	Utility loss	Total	Fuel savings	GHG emissions	Health costs avoided	Total	
2013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2014	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2015	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2016	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.000	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	0.935	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2018	80.4	0.0	0.0	80.4	9.2	1.1	0.0	10.3	-70.1	0.873	70.2	0.0	0.0	70.2	8.0	0.9	0.0	9.0	-61.2
2019	166.6	0.0	0.0	166.6	37.0	4.1	0.0	41.1	-125.5	0.816	136.0	0.0	0.0	136.0	30.2	3.4	0.0	33.5	-102.4
2020	260.3	0.0	0.0	260.3	82.7	9.1	0.0	91.8	-168.5	0.763	198.6	0.0	0.0	198.6	63.1	6.9	0.0	70.0	-128.6

Financial year	Undiscounted cash flow									Discounting factor @ 7%	Discounted cash flow @ 7%								
	Costs ($m)				Benefits ($m)				Net benefit ($m)		Costs ($m)				Benefits ($m)				Net benefit ($m)
	Capital	Maintenance	Utility loss	Total	Fuel savings	GHG emissions	Health costs avoided	Total			Capital	Maintenance	Utility loss	Total	Fuel savings	GHG emissions	Health costs avoided	Total	
2021	374.9	0.0	0.0	374.9	148.7	16.2	0.0	165.0	-210.0	0.713	267.3	0.0	0.0	267.3	106.1	11.6	0.0	117.6	-149.7
2022	532.1	0.0	0.0	532.1	241.8	26.0	0.0	267.8	-264.3	0.666	354.6	0.0	0.0	354.6	161.1	17.4	0.0	178.5	-176.1
2023	698.4	0.0	0.0	698.4	366.9	39.0	0.0	406.0	-292.4	0.623	434.9	0.0	0.0	434.9	228.5	24.3	0.0	252.8	-182.1
2024	875.3	0.0	0.0	875.3	524.2	55.1	0.0	579.4	-295.9	0.582	509.4	0.0	0.0	509.4	305.1	32.1	0.0	337.2	-172.2
2025	993.1	0.0	0.0	993.1	717.0	73.8	0.0	790.8	-202.3	0.544	540.2	0.0	0.0	540.2	390.0	40.1	0.0	430.1	-110.0
2026	967.4	0.0	0.0	967.4	911.3	92.9	0.0	1,004.2	36.9	0.508	491.8	0.0	0.0	491.8	463.3	47.2	0.0	510.5	18.7
2027	940.7	0.0	0.0	940.7	1,100.7	111.2	0.0	1,212.0	271.3	0.475	446.9	0.0	0.0	446.9	523.0	52.8	0.0	575.8	128.9
2028	910.8	0.0	0.0	910.8	1,288.2	128.7	0.0	1,417.0	506.2	0.444	404.4	0.0	0.0	404.4	572.0	57.2	0.0	629.1	224.8
2029	876.3	0.0	0.0	876.3	1,472.8	145.7	0.0	1,618.5	742.2	0.415	363.6	0.0	0.0	363.6	611.2	60.5	0.0	671.6	308.0
2030	837.3	0.0	0.0	837.3	1,654.3	161.9	0.0	1,816.1	978.9	0.388	324.7	0.0	0.0	324.7	641.6	62.8	0.0	704.3	379.6
2031	791.8	0.0	0.0	791.8	1,832.3	177.4	0.0	2,009.7	1,217.9	0.362	287.0	0.0	0.0	287.0	664.1	64.3	0.0	728.4	441.4
2032	741.2	0.0	0.0	741.2	2,005.9	192.2	0.0	2,198.1	1,456.9	0.339	251.1	0.0	0.0	251.1	679.5	65.1	0.0	744.6	493.5
2033	684.9	0.0	0.0	684.9	2,175.1	206.2	0.0	2,381.2	1,696.4	0.317	216.8	0.0	0.0	216.8	688.6	65.3	0.0	753.8	537.0
2034	622.0	0.0	0.0	622.0	2,337.5	219.2	0.0	2,556.7	1,934.7	0.296	184.0	0.0	0.0	184.0	691.6	64.9	0.0	756.4	572.4
2035	553.1	0.0	0.0	553.1	2,493.5	231.4	0.0	2,724.8	2,171.7	0.277	152.9	0.0	0.0	152.9	689.5	64.0	0.0	753.4	600.5
2036	478.2	0.0	0.0	478.2	2,641.0	242.4	0.0	2,883.4	2,405.2	0.258	123.6	0.0	0.0	123.6	682.5	62.6	0.0	745.1	621.6
2037	396.8	0.0	0.0	396.8	2,781.1	252.4	0.0	3,033.5	2,636.8	0.242	95.8	0.0	0.0	95.8	671.7	61.0	0.0	732.6	636.8
2038	308.9	0.0	0.0	308.9	2,911.3	261.3	0.0	3,172.6	2,863.7	0.226	69.7	0.0	0.0	69.7	657.1	59.0	0.0	716.1	646.4
2039	213.4	0.0	0.0	213.4	3,032.6	269.1	0.0	3,301.6	3,088.2	0.211	45.0	0.0	0.0	45.0	639.7	56.8	0.0	696.5	651.4
2040	110.7	0.0	0.0	110.7	3,144.6	275.8	0.0	3,420.4	3,309.7	0.197	21.8	0.0	0.0	21.8	619.9	54.4	0.0	674.3	652.5
Total	13,414.2	0.0	0.0	13,414.2	33,909.6	3,192.2	0.0	37,101.9	23,687.7		5,990.3	0.0	0.0	5,990.3	10,787.1	1,034.4	0.0	11,821.4	5,831.2

Financial year	Undiscounted cash flow									Discounting factor @ 7%	Discounted cash flow @ 7%								
	Costs ($m)				Benefits ($m)				Net benefit ($m)		Costs ($m)				Benefits ($m)				Net benefit ($m)
	Capital	Maintenance	Utility loss	Total	Fuel savings	GHG emissions	Health costs avoided	Total			Capital	Maintenance	Utility loss	Total	Fuel savings	GHG emissions	Health costs avoided	Total	
Benefit-Cost Ratio =1.97																			

Note: Change from the BAU scenario.
Source: BITRE estimates.

Sensitivity tests

Given that the option S1 generates the highest net benefits, sensitivity testing was based on S1 modelling.

Changes to discount rates

The results of sensitivity testing in relation to the discount rates are shown in Table B9. With a discount rate of 3%, BCR reaches a value of 2.4.

Table B9: Changes to discount rates

	Net Present Values ($m)	Benefit–Cost Ratio
Mean (7%)	13,898	1.86
Low (3%)	31,732	2.40
High (11%)	5,692	1.50

Changes to fuel cost values

Sensitivity tests were undertaken of a range of fuel cost values. For the main scenarios, oil prices are 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 ULP is set to increase around 1 per cent per annum, from current levels of about 70c/litre, reaching a level close to 90c/litre over the projection assessment period (to 2040). For simplicity, the same proportional rate of increase is applied to each main fuel product, with the analysis allowing for the growing market share of premium gasoline blends (especially where fostered by growing numbers of vehicles with manufacturers' recommendations for higher octane or lower-sulfur fuel operation).

This increasing share for higher-price premium gasoline means that the average petroleum fuel cost rises faster than that of ULP in the main scenarios, reaching around 94c/litre (averaged across all marketed products) by 2040. High and Low fuel price sensitivity tests were performed–with the high price scenario (under option S1) assuming a higher annual rate of increase of 2 per cent (reaching an average petroleum fuel resource cost of around $1.20/litre by 2040) and the low price scenario assuming an annual cost *decrease* of 1 per cent (reaching an average petroleum cost of around 60c/litre by 2040).

Though the fleet projections allow for an increasing proportion of vehicles to use PULP (gasoline blends of 95 or higher RON) both over time and with increasing stringency of the CO_2 standards, in the main standards scenarios 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 desulfurisation are included. Current average levels of sulfur in Australian gasolines are substantially below the legislated cap levels (of 150ppm for ULP and 50ppm for PULP). A further sensitivity test was also undertaken to allow for a marginal increase in petrol prices, in the event that having to meet this extra demand for low or ultra-low (less than 10ppm) sulfur petrol adds around 1-2 cents per litre to average gasoline prices (for each product type, either through extra costs for further desulfurisation or costlier imports).

Table B10 summarises the implications of different fuel cost values.

Table B10: Changes to fuel cost values

	Net Present Values ($m)	Benefit–Cost Ratio
Mean–petroleum resource cost 94c/L (excluding taxes) in 2040	13,898	1.86
Mean petroleum resource cost scenario with a 1-2c/L further increase in average petrol prices as a result of high demand for low sulfur petrol	12,119	1.75

	Net Present Values ($m)	Benefit–Cost Ratio
Low–petroleum resource cost of 60c/L (excluding taxes) in 2040	6,547	1.40
High–petroleum resource cost of $1.20/L (excluding taxes) in 2040	17,809	2.10

Changes to unit value for CO_2 emissions

As mentioned earlier, the unit value of carbon (for discounted climate change damages) is still very uncertain, and a conservative valuation (relative to most of the literature) has been chosen (constant at $A35/tonne CO_2). A sensitivity test was undertaken to examine the impact of using the average price of abatement from the first three auctions of the Emissions Reduction Fund (ERF) as the unit value of carbon, which is also similar to the high discount rate scenario results from OMB 2010 and 2015.

If the ERF value of $12.10 per tonne is used, the net present value under S1 is $12,160.3 million, with a BCR of 1.75.

If the greenhouse gas abatement benefits are left out of the BCA totals altogether, the net present value under S1 is $11,242.1 million, with a BCR of 1.69.

Table B11 summarises the implications of different unit cost values for CO_2.

Table B11: Changes to unit cost for CO_2 emissions

	Net Present Values ($m)	Benefit–Cost Ratio
At $35/tonne CO_2	13,898	1.86
At $12.10/tonne CO_2	12,160.3	1.75
If CO_2 benefits are excluded	11,242.1	1.69

Changes to implementation costs for all vehicles

There are considerable uncertainties in the assumed capital cost estimates. A range of sensitivity tests were undertaken to assess possible lower and upper bounds for the additional capital costs, as set out in Table B12. The ‘Low’ cost scenario uses a more highly non-linear cost function than for S1, that has similar cost levels to the main scenarios for larger average efficiency gains (in terms of dollars required per extra gCO_2/km reduction) yet lower costs for smaller gains. The ‘High’ cost scenario assumes that average incremental vehicle costs are 1.3 times than for S1, as could apply if indirect cost multipliers are higher than allowed for within the main scenarios–e.g. if various compliance requirements, such as from introducing/conducting ‘Real Driving Emissions’ (RDE) or new cycle tests, incur significant unforeseen overheads or if technical cost improvements are less rapid than currently expected. The results show that the BCA for these vehicle cost possibilities retain a BCR of well above 1.

Table B12: Changes to capital and compliance cost values

	Net Present Values ($m)	Benefit–Cost Ratio
Mean	13,898	1.86
Low incremental cost	15,859	2.11
High incremental cost (per unit of CO_2 reduction)	9,034	1.43

Higher implementation cost for SUVs

There are additional uncertainties regarding the capital cost estimates for SUVs relative to passenger cars.Though the derivation of the functional forms for estimating average incremental costs (across all new light passenger vehicles) makes allowances for the high SUV proportions within the Australian new light fleet, the main scenario estimates could still underestimate total cost impacts if maintaining the desired performance characteristics of such vehicles (while reducing future SUV fuel consumption) ends up substantially more difficult than for sedans. Table B13 shows the results of a sensitivity test undertaken using a higher incremental capital cost (per gCO_2/km reduction) for SUV models than in scenario S1, employing the average cost relationship derived for light commercial vehicles in the main scenarios.

Table B13: Changes in implementation costs for SUVs

	Net Present Values ($m)	Benefit–Cost Ratio
Mean	13,898	1.86
Higher capital cost for SUVs	10,661	1.55

Possible utility costs

It is assumed that market forces will limit the ability of manufacturers to reduce CO_2 emission rates by sacrificing performance attributes valued by consumers. However, a sensitivity test was undertaken to allow for a loss of utility in the event manufacturers were forced to partially offset performance attributes highly valued by consumers to meet a mandatory fuel intensity standard. Possible utility losses to new car buyers form one of the most uncertain parts of these BCA results–with such losses potentially, under certain conditions, being able to negate a large part of the estimated net benefits. The Table B14 values present the result of a speculative scenario that attempts to roughly quantify such potential losses–by considering the prospect of meeting a strong fuel intensity standard causing more restriction on the range of new vehicle choices/features than consumers would have otherwise preferred (and here assuming that to have maintained levels of preferred performance characteristics–such as power, accessories or interior space–would have incurred 50% higher incremental vehicle costs than for the S1 scenario).

Table B14: Impact of a possible loss of utility for consumers

	Net Present Values ($m)	Benefit–Cost Ratio
Mean	13,898	1.86
With higher utility costs	5,791	1.24

Changes in vehicle turnover

For the main scenarios, it is assumed that a standard will have minimal impact on consumer utility and vehicle turnover rates. Table B15 shows the results of a sensitivity test undertaken to allow for the possibility that turnover in the vehicle fleet is reduced as a result of a standard impacting on the range of vehicles available to Australian consumers (e.g. if the higher average price of vehicles under the action of a CO_2 standard causes some consumers to postpone their new purchases).

Table B15: Changes in vehicle turnover

	Net Present Values ($m)	Benefit–Cost Ratio
Mean	13,898	1.86
Lower vehicle turnover	12,409	1.83

Baseline differences

The business as usual scenario assumes that Australia would receive some of the benefits of standards adopted in other markets. Table B16 shows the results of sensitivity tests undertaken to allow for the possibility that Australia receives minimal benefits from standards adopted in other markets and the possibility Australia receives a higher ‘free rider effect’ from standards adopted in other markets.

Table B16: Changes in the ‘business as usual’ scenario

	Net Present Values ($m)	Benefit–Cost Ratio
Mean	13,898	1.86
Low free rider effect	20,177	1.95
High free rider effect	9,100	1.77

Changes in correlation between tested and on-road emissions

It is assumed that the difference between tested and on-road fuel efficiency levels will remain unchanged under a mandatory standard, especially if the World-harmonized Light-duty Vehicles Test Procedure (WLTP) is adopted as the basis of measurement. Table B17 shows the results of a sensitivity test undertaken to consider the implications of a reduction in the correlation between tested and on-road emissions. The main scenarios assume the gap between rated (i.e. dynamometer cycle test) fuel intensity and actual on-road fuel consumption remains roughly constant over time (at current levels typically around 5-10%). However, Europe has seen this gap widen substantially over recent years (ICCT 2015b). This sensitivity scenario simulates emission levels for an Australian new vehicle fleet undergoing the same ‘testing gap’ widening as experienced in Europe (e.g. if CO_2 standards encounter some enforcement problems, such as transition to new cycle tests proving not adequate to ensure full standards compliance or a lack of suitable RDE tests to complement the cycle results).

Table B17: Changes in correlation between ‘tested’ vs ‘on-road’ emission levels

	Net Present Values ($m)	Benefit–Cost Ratio
Mean	13,898	1.86
Higher gap between tested and on road emission levels	10,563	1.65

Possible rebound effect

The rebound effect of a fuel efficiency/CO_2 standard is assumed to be minimal, especially since average Australian per capita daily travel volumes are reasonably close to saturation levels. Much of the reduction in fuel savings from any rebound driving effect will also be countered by the gain in consumer utility from the extra travel. However, for completeness, a sensitivity test was undertaken to allow for the possibility of an increase in vehicle kilometres associated with a rebound elasticity of 0.1, and attempting rough estimates of possible net social costs arising from this amount of induced travel. Table B18 shows the results of a sensitivity test allowing for an induced increase in travel.

Table B18: Impact of a possible rebound effect

	Net Present Values ($m)	Benefit–Cost Ratio
Mean	13,898	1.86
With rebound elasticity of 0.1	11,031	1.64

Increases in health costs

The proportion of new vehicle models employing Gasoline Direct Injection (GDI) is 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 happen to increase this substantially, the cost-benefit position will tend to be reliant on the accompanying passage of Euro 6 standards for pollutant emissions from light vehicles–otherwise the health impacts of rising particulate emissions levels, from GDI vehicles compliant only with Euro 5, will counteract some of the fuel efficiency benefits.

Furthermore, a sensitivity test was undertaken to allow for the proportion of new vehicle models employing GDI to increase even more markedly than BAU (with GDI variants approaching most of new petrol-vehicle sales by 2030 in this scenario) and for higher than BAU diesel sales (with less future replacement of their market share by petrol-hybrids than in the BAU scenario), causing higher than BAU emission rates of nitrogen oxides (NO_x) and fine particulate matter (PM), as might result from an increase in Euro 5 diesel and GDI vehicle sales in the event that Euro 6 standards are not adopted in Australia. Table B19 summarises the results of a sensitivity test allowing for an increased utilisation of diesel and GDI technology.

Table B19: Possible impact of a high Euro 5 diesel and GDI scenario

	Net Present Values ($m)	**Benefit–Cost Ratio**
Mean	13,898	1.86
High Euro 5 diesel and GDI	9,915	1.47

Slower short term improvements in vehicle efficiency

The modelling assumes a fairly consistent rate of improvement in vehicle efficiency from 2018, with manufacturers introducing improvements in the lead up to a mandatory standard and additional improvements with model year updates.

The Department notes that some submissions to the Vehicle Emissions Discussion Paper suggested that manufacturers may be unable to make significant improvements in the short term as product plans are determined several years in advance, with major changes only possible when a new model cycle commences. Table B20 shows the result of a sensitivity test conducted to allow for the possibility that manufacturers are unable to make significant changes to their existing model range, with more substantial improvements realised in later years, as new model cycles commence. That is, this sensitivity scenario sets the same strong fuel efficiency standard for light vehicles as S1 (for an average new fleet target of 105 gCO_2/km by 2025), but with a later phase-in of intensity reductions than S1 (to allow for already committed manufacturer product plans limiting scope for fleet changes until around a 2022-23 timeframe).

Table B20: Reduced capacity to improve efficiency of existing models

	Net Present Values ($m)	**Benefit–Cost Ratio**
Mean	13,898	1.86
Reduced potential for improvement over the short term	11,501	1.85

Appendix C–Consumer fuel savings

C1 Fuel savings for consumers include fuel taxes

The fuel savings quantified in the benefit-cost analysis were calculated on an economy wide basis. In an economy wide analysis, taxes represent a transfer between consumers and government. As a result, the economy wide effect of reduction in fuel taxes paid by consumers to government as a result of reduced fuel use is zero, as this is offset by a reduction in government fuel tax revenue. As result, fuel savings realised by consumers could be higher than the economy wide savings estimated in the benefit-cost analysis, as they will also pay less in fuel taxes to government.

Passenger Vehicles

Table C1 provides an estimate of the potential fuel savings that could be realised by consumers for an average performing petrol passenger vehicle under the three possible targets analysed relative to current policy settings.[47]

Table C1: Possible consumer fuel savings for an average performing petrol passenger vehicle

Possible consumer outcome in 2025 for an average performing petrol passenger vehicle	Projection under current settings	Target A (Overall fleet average of 105g/km)	Target B (Overall fleet average of 119g/km)	Target C (Overall fleet average of 135g/km)
Projected average test efficiency (gCO_2/km)	145.6	95	106.7	122.5
With an on-road adjustment factor of 10 per cent	160.2	104.5	117.4	134.8
Difference in adjusted g/km (relative to BAU)	-	55.7	44.9	25.4
Difference converted to litres per km[48]	-	0.024	0.019	0.011
Annual litres of petrol saved for a vehicle travelling 16,100km per annum[49]	-	388.8	298.9	177.5
Possible annual consumer fuel cost saving in 2025 at a retail petrol price of $1.30 per litre	-	$519	$399	$237

Light Commercial Vehicles

The modelling used in the benefit-cost analysis anticipates a different magnitude of improvement in the efficiency of light commercial vehicles relative to passenger vehicles.

47 These estimates assume no changes to consumer behaviour resulting from a fuel efficiency standard (i.e. motorists travel the same distance, and purchase an average performing vehicle utilising the same fuel type and grade). Improvements in the efficiency of individual vehicle models and variants will vary depending on the level of improvement required by the manufacturer to meet a sales weighted average target.

48 Based on energy content and emission factors for petrol from the National Greenhouse Accounts.

49 Average annual km for passenger vehicles less than five years old reported in the 2014 ABS Survey of Motor Vehicle Use.

Table C2 provides an estimate of the potential fuel savings that could be realised by consumers for an average performing diesel light commercial vehicle under the three possible targets analysed relative to current policy settings.[50]

Table C2: Possible consumer fuel savings for an average performing diesel light commercial vehicle travelling average km for a new vehicle.

Possible consumer outcome in 2025 for an average performing diesel light commercial vehicle	Projection under current settings	Target A (Overall fleet average of 105g/km)	Target B (Overall fleet average of 119g/km)	Target C (Overall fleet average of 135g/km)
Projected average test efficiency (gCO_2/km)	205.4	149	173	190
With an on-road adjustment factor of 10 per cent	225.9	163.9	190.3	209
Difference in adjusted g/km (relative to BAU)	-	62	35.6	16.9
Difference converted to litres per km[51]	-	0.023	0.013	0.006
Annual litres of diesel saved for a vehicle travelling 21,700km per annum[52]	-	499	286.6	136.2
Possible annual consumer fuel cost saving in 2025 at a retail diesel price of $1.30 per litre	-	$666	$383	$182

C2 Fuel savings will depend on distances travelled and fuel prices

The fuel cost savings realised by consumers will be strongly influenced by the prevailing retail fuel prices at the time and kilometres travelled by consumers. Table C3, C4 and C5 provides an estimate of potential consumer fuel savings for a range of distances and fuel prices for an average performing passenger vehicle under the three possible fleet average targets. Tables C6, C7 and C8 provide estimates for an average performing diesel light commercial vehicle.

Passenger Vehicles

Table C3: Possible consumer fuel savings for an average performing petrol passenger vehicle under Target A.

Target A–Fuel saving of 0.024L/km					
Fuel Price Scenario	**10,000km per annum**	**15,000km per annum**	**20,000km per annum**	**25,000km per annum**	**30,000 km per annum**
$1.00/L	$242	$362	$483	$604	$724
$1.10/L	$266	$398	$531	$664	$797

50 These estimates assume no changes to consumer behaviour resulting from a fuel efficiency standard (i.e. motorists travel the same distance, and purchase an average performing vehicle utilising the same fuel type and grade). Improvements in the efficiency of individual vehicle models and variants will vary depending on the level of improvement required by the manufacturer to meet a sales weighted average target.

51 Based on energy content and emission factors for diesel from the National Greenhouse Accounts

52 Average annual km for light commercial vehicles less than five years old reported in the 2014 ABS Survey of Motor Vehicle Use.

Target A–Fuel saving of 0.024L/km					
Fuel Price Scenario	**10,000km per annum**	**15,000km per annum**	**20,000km per annum**	**25,000km per annum**	**30,000 km per annum**
$1.20/L	$290	$435	$580	$724	$869
$1.30/L	$314	$471	$628	$785	$942
$1.40/L	$338	$507	$676	$845	$1,014
$1.50/L	$362	$543	$724	$906	$1,087

Table C4: Possible consumer fuel savings for an average performing petrol passenger vehicle under Target B.

Target B–Fuel saving of 0.019L/km					
Fuel Price Scenario	**10,000km per annum**	**15,000km per annum**	**20,000km per annum**	**25,000km per annum**	**30,000 km per annum**
$1.00/L	$186	$278	$371	$464	$557
$1.10/L	$204	$306	$408	$510	$613
$1.20/L	$223	$334	$446	$557	$668
$1.30/L	$241	$362	$483	$603	$724
$1.40/L	$260	$390	$520	$650	$780
$1.50/L	$278	$418	$557	$696	$835

Table C5: Possible consumer fuel savings for an average performing petrol passenger vehicle under Target C.

Target C–Fuel saving of 0.011L/km					
Fuel Price Scenario	**10,000km per annum**	**15,000km per annum**	**20,000km per annum**	**25,000km per annum**	**30,000 km per annum**
$1.00/L	$110	$165	$220	$276	$331
$1.10/L	$121	$182	$243	$303	$364
$1.20/L	$132	$198	$265	$331	$397
$1.30/L	$143	$215	$287	$358	$430
$1.40/L	$154	$231	$309	$386	$463
$1.50/L	$165	$248	$331	$413	$496

Light Commercial Vehicles

Table C6: Possible consumer fuel savings for an average performing diesel light commercial vehicle under Target A.

Target A–Fuel saving of 0.023L/km					
Fuel Price Scenario	**10,000km per annum**	**15,000km per annum**	**20,000km per annum**	**25,000km per annum**	**30,000 km per annum**
$1.00/L	$230	$345	$460	$575	$690
$1.10/L	$253	$380	$506	$632	$759
$1.20/L	$276	$414	$552	$690	$828

Target A–Fuel saving of 0.023L/km					
Fuel Price Scenario	**10,000km per annum**	**15,000km per annum**	**20,000km per annum**	**25,000km per annum**	**30,000 km per annum**
$1.30/L	$299	$449	$598	$747	$897
$1.40/L	$322	$483	$644	$805	$966
$1.50/L	$345	$517	$690	$862	$1035

Table C7: Possible consumer fuel savings for an average performing diesel light commercial vehicle under Target B.

Target B–Fuel saving of 0.013L/km					
Fuel Price Scenario	**10,000km per annum**	**15,000km per annum**	**20,000km per annum**	**25,000km per annum**	**30,000 km per annum**
$1.00/L	$132	$198	$264	$330	$396
$1.10/L	$145	$218	$291	$363	$436
$1.20/L	$159	$238	$317	$396	$476
$1.30/L	$172	$258	$343	$429	$515
$1.40/L	$185	$277	$370	$462	$555
$1.50/L	$198	$297	$397	$495	$595

Table C8: Possible consumer fuel savings for an average performing diesel light commercial vehicle under Target C.

Target C–Fuel saving of 0.006L/km					
Fuel Price Scenario	**10,000km per annum**	**15,000km per annum**	**20,000km per annum**	**25,000km per annum**	**30,000 km per annum**
$1.00/L	$63	$94	$126	$157	$188
$1.10/L	$69	$104	$138	$173	$207
$1.20/L	$75	$113	$151	$188	$226
$1.30/L	$82	$122	$163	$204	$245
$1.40/L	$88	$132	$176	$220	$264
$1.50/L	$94	$141	$188	$235	$282

C3 Additional production costs may be passed on to consumers

As vehicle manufacturers will incur additional costs to supply a range of vehicles to meet a sales weighted average target, it is possible these costs may be passed on to consumers through higher retail prices. The extent to which these costs may be passed on to consumers will depend on factors such as competition, pricing strategies adopted by manufacturers to ensure they meet a sales weighted average target and other changes to vehicle specifications, as part of any model updates.

Table C9 provides an estimate of potential average change in retail vehicle prices in the event the estimated average change in production cost was passed on in full to consumers.

Table C9: Possible average change in retail vehicle prices (rounded to nearest dollar)

Possible impact on retail vehicle prices in 2025	Target A (Overall fleet average of 105g/km)	Target B (Overall fleet average of 119g/km)	Target C (Overall fleet average of 135g/km)
For an average performing petrol passenger vehicle	$1922	$1441	$827
For an average performing diesel light commercial vehicle	$3120	$1669	$752

C4 Payback periods will depend on a range of factors

The timeframe in which a consumer could be expected to recoup any additional purchase costs via fuel cost savings will depend on the prevailing fuel prices and distances travelled. Table C10 provides estimates for an average performing petrol passenger vehicle, while Table C11 provide estimates for an average performing diesel light commercial vehicle.

Table C10: Estimated travel required for an average performing petrol passenger vehicle to recoup additional costs, if passed on in full

Fuel Price Scenario	Target A Price increase of $1922 Fuel saving of 0.024L/km	Target B Price increase of $1441 Fuel saving of 0.019L/km	Target C Price increase of $827 Fuel saving of 0.011L/km
$1.00/L	79589 km	77642 km	75004 km
$1.10/L	72353 km	70584 km	68185 km
$1.20/L	66324 km	64702 km	62503 km
$1.30/L	61222 km	59725 km	57695 km
$1.40/L	56849 km	55459 km	53574 km
$1.50/L	53059 km	51761 km	50002 km

At a retail fuel price of $1.30 per litre, an average motorist[53] could recoup additional purchase costs for an average performing passenger vehicle within four years.

Table C11: Estimated travel required an average performing diesel light commercial vehicle, to recoup additional costs, if passed on in full

Fuel Price Scenario	Target A Price increase of $3120 Fuel saving of 0.023L/km	Target B Price increase of $1669 Fuel saving of 0.013L/km	Target C Price increase of $752 Fuel saving of 0.006L/km
$1.00/L	135694 km	126322 km	119776 km
$1.10/L	123358 km	114838 km	108887 km
$1.20/L	113078 km	105268 km	99813 km
$1.30/L	104380 km	97171 km	92135 km
$1.40/L	96924 km	90230 km	85554 km
$1.50/L	90463 km	84215 km	79851 km

At a retail fuel price of $1.30 per litre, an average motorist[54] could recoup additional purchase costs for an average performing light commercial vehicle within five years.

[53] Travelling average annual km for passenger vehicles less than five years old (16,100km) reported in the 2014 ABS Survey of Motor Vehicle Use.

[54] Travelling average annual km for light commercial vehicles less than five years old (21,700km) reported in

the the 2014 ABS Survey of Motor Vehicle Use.

References

Australian Automobile Association (AAA) 2016, *Submission to the Vehicle Emissions Discussion Paper*, April 2016

ABMARC 2016, Analysis of the Australian 2015 New Light Vehicle Fleet and Review of Technology to Improve Light Vehicle Efficiency, Study for the Department of Infrastructure & Regional Development

Australian Bureau of Statistics (ABS) 2013a, Programme for the International Assessment of Adult Competencies, Australia, 2011–12, ABS CAT No 4228.0, ABS, Canberra

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

ABS 2015a, Survey of Motor Vehicle Use, Australia, 12 months ended 31 October 2014, Cat no. 9208.0, ABS, Canberra

ABS 2015b, Motor Vehicle Census, Australia, 31 Jan 2015, Cat no. 9309.0, ABS, Canberra

ABS 2016a, Motor Vehicle Census, Australia, 31 Jan 2016, Cat no. 9309.0, ABS, Canberra

ABS 2016b, *Sales of New Motor Vehicles, Australia,* Cat no. 9314.0, ABS, Canberra

Advisory Committee on Tunnel Air Quality (ATCAQ) 2006, Advisory Committee on Tunnel Air Quality comment on Australian Government Vehicle Emissions Discussion Paper, NSW Government

AEA Technology 2012, *A review of the efficiency and cost assumptions for road transport vehicles to 2050*, Report for the Committee on Climate Change (CCC), Project AEA/R/ED57444, CCC, UK

BEUC 2013, CO_2 emissions target for passenger cars for 2025: delivering value to consumers, The European Consumer Organisation

BTRE 2003, *Urban Pollutant Emissions from Motor Vehicles: Australian Trends to 2020*, Commissioned report available on the DIRD website.

BITRE 2009, Greenhouse Gas Emissions from Australian Transport: Projections to 2020, Working Paper 73

BITRE & CSIRO 2008, Modelling the Road Transport Sector, appendix to Treasury (2008), Australia's Low Pollution Future: The Economics of Climate Change Mitigation

BITRE 2010, *Long-term Projections of Australian Transport Emissions: Base Case 2010*

BITRE 2012, *Traffic Growth in Australia*, Report 127, Bureau of Infrastructure, Transport and Regional Economics, Canberra, Australia.
http://www.bitre.gov.au/publications/2012/report_127.aspx

BITRE 2014a, *Saturating Daily Travel*, Information Sheet 61, BITRE, Canberra

BITRE 2014b, New Passenger Vehicle Fuel Consumption Trends, 1979 to 2013, Information Sheet 66, BITRE, Canberra.

BITRE 2015, Traffic and congestion cost trends for Australian capital cities, Information Sheet 74, BITRE, Canberra

Center for Alternative Fuels, Engines & Emissions West Virginia University (CAFEE) 2014, *Final Report: In-Use Emissions Testing of Light-Duty Diesel Vehicles in the United States*, ICCT contracted study, West Virginia University, US

Citigroup 2011, U.S. Autos & Auto Parts, Fuel Economy Focus: Perspectives on 2020 Industry Implications,
Citi Investment Research & Analysis, Citigroup Global Markets Inc

Climate Change Authority 2014, *Light Vehicle Emissions Standards for Australia*, Research Report, June 2014

ClimateWorks Australia 2013, *Tracking Progress to a Low Carbon Economy,* Special Report 6 on factors influencing large industrial energy efficiency, Melbourne

ClimateWorks Australia 2014, *Improving Australia's Light Vehicle Fuel Efficiency*, Briefing Paper February 2014

ClimateWorks Australia, ANU, CSIRO and CoPS 2014, *Pathways to Deep Decarbonisation in 2050: How Australia can prosper in a low carbon world*, Technical report, ClimateWorks Australia, Published by ClimateWorks Australia, Melbourne, Victoria, September 2014

Cosgrove, D., Gargett, D., Evans, C., Graham, P., Ritzinger, A., 2012, Greenhouse gas abatement potential of the Australian transport sector: Technical report from the Australian Low Carbon Transport Forum, CSIRO, Australia

Cosgrove, D. 2008, *Long-term emission trends for Australian transport*. Paper for 31st Australasian Transport Research Forum, October 2–3 October 2008, Gold Coast. Bureau of Infrastructure, Transport and Regional Economics, Canberra

Department of the Environment, Heritage, Water and the Arts (DEHWA) 2009, *The Second National In-Service Emissions Study: Technical Summary*, Commonwealth of Australia

Department of the Environment (2015) Transport emissions projections 2014–15

Department of the Environment and Energy (2016a) Quarterly Update of Australia's National Greenhouse Gas Inventory: December 2015

Department of the Environment and Energy (2016b) Australian National Greenhouse Accounts National Inventory Report 2014 (revised) Volume 1

Department of Industry, Innovation and Science (2016) *Australian Energy Statistics*: Table F1, Australian Energy Consumption

Department of Prime Minister and Cabinet 2014, The Australian Government Guide to Regulation, March 2014

European Commission (EC) 2015, "Evaluation of Regulations 443/2009 and 510/2011 on CO_2 emissions from light-duty vehicles", Final Report, 8th April 2015, Study contract no. 071201/2013/664487/ETU/CLIMA.C.2, Authors: Gena Gibson, Sujith Kollamthodi, Felix Kirsch, Elisabeth Windisch, Charlotte Brannigan, Ben White, Eugenia Bonifazi, Outi Korkeala (Ricardo-AEA), Ian Skinner (Transport and Environmental Policy Research, TEPR), EC

European Environment Agency (EEA) 2016, 'Reported CO_2 emissions from new cars continue to fall' media release 14 April 2016, and Reduction of CO_2 emissions from new vans slowed in 2015, media release 11 May 2015

Federal Chamber of Automotive Industries (FCAI) 2016, VFACTS, various issues

FCAI 2015, *Annual Report 2014*, FCAI, Canberra

FCAI 2016, FCAI Response to Vehicle Emissions Discussion Paper, submitted 8 April 2016

Green, D 2010, Why the Market for New Passenger Cars Generally Undervalues Fuel Economy, Joint Transport Research Centre Discussion Paper No.2010-6, Oak Ridge, United States.

Franco, V., Posada Sánchez, F., German, J., & Mock, P. 2014, *White paper: Real-World Exhaust Emissions from Modern Diesel Cars, Part 2: Detailed results*, Washington, DC: The International Council on Clean Transportation

H-D Systems 2012, Technology and CO_2 Data Analysis of the Australian Light Vehicle Fleet Consolidated Report Prepared for Australian Department of Infrastructure and Transport, June 2012

H-D Systems 2015, *New Light-Duty Vehicle Technology and Impact on Fuel Efficiency*, presentation by K.G. Duleep, Canberra, October 2015

IHS Consulting 2016, Global Automotive Regulatory Requirements: Regulatory Environment and Technology Roadmaps, presentation by Paul Haelterman, Canberra, February 2016

International Council on Clean Transportation (ICCT) 2012a, *Discrepancies between type approval and "real-world" fuel consumption and CO_2 values*, Authors: Peter Mock, John German, Anup Bandivadekar, Iddo Riemersma

ICCT 2012b, *Summary of the EU cost curve development methodology*, Authors: Dan Meszler, John German, Peter Mock, Anup Bandivadekar, ICCT Working Paper 2012-5

ICCT 2012c, Estimated Cost of Emission Reduction Technologies for Light-Duty Vehicles

ICCT 2012d, Comments in Response to the Proposed Rulemaking Issued by the National Highway Traffic Safety Administration and the Environmental Protection Agency on 2017 and Later

Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards on The International Council on Clean Transportation website

ICCT 2013, *Measuring in-use fuel economy in Europe and the US: Summary of pilot studies*, Authors: Francisco Posada and John German, ICCT Working Paper 2013-5

ICCT 2013b, Passenger car fuel-efficiency, 2020–2025: Comparing stringency and technology feasibility of the Chinese and US standards, Authors: Hui He, Anup Bandivadekar, ICCT Working Paper 2013-3

ICCT 2014a, Development of Test Cycle Conversion Factors among Worldwide Light-Duty Vehicle CO_2 Emission Standards, Authors: Jörg Kühlwein, John German, Anup Bandivadekar

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, Authors: Peter Mock, Uwe Tietge, Vicente Franco, John German, Anup Bandivadekar, Norbert Ligterink (TNO), Udo Lambrecht (IFEU), Jörg Kühlwein (KISU), Iddo Riemersma

ICCT 2014c, Press Release: Gap between reported and actual fuel economy higher than ever before, ICCT, September 28, 2014

ICCT 2014d, *The WLTP: How a new test procedure for cars will affect fuel consumption values in the EU*, Authors: Peter Mock, Jörg Kühlwein, Uwe Tietge, Vicente Franco, Anup Bandivadekar, John German, ICCT Working Paper 2014-9

ICCT 2014e, EU CO_2 Emission Standards for Passenger Cars and Light-Commercial Vehicles, ICCT Policy Update

ICCT 2014f, Real-World Exhaust Emissions from Modern Diesel Cars, A Meta-analysis of PEMS Emissions Data from EU (Euro 6) and US (Tier 2 Bin 5/ULEV II) Diesel Passenger Cars, Part 1: Aggregated Results, Authors: Vicente Franco, Francisco Posada Sánchez, John German, and Peter Mock, ICCT White Paper

ICCT 2015a, *Global PV standards chart library*

ICCT 2015b, From Laboratory to Road: A 2015 update of official and “real-world” fuel consumption and CO_2 values for passenger cars in Europe, Authors: Uwe Tietge, Nikiforos Zacharof, Peter Mock, Vicente Franco, John German, Anup Bandivadekar (ICCT), Norbert Ligterink (TNO), Udo Lambrecht (IFEU), ICCT White Paper, September 2015

ICCT 2015c, *Real-world fuel consumption of popular European passenger car models*, Authors: Uwe Tietge, Peter Mock, Nikiforos Zacharof, Vicente Franco, ICCT Working Paper 2015–8

IEA (International Energy Agency) 2012, Technology Roadmap, Fuel Economy of Road Vehicles, OECD/IEA, Paris

IKA 2014, *Management Summary: CO_2 Emission Reduction Potential for Passenger Cars and Light Commercial Vehicles Post 2020*, Institut fur Kraftfahrzeuge, Strategy and Consulting, Project Number 123320, Study commissioned by the German Federal Ministry for Economic Affairs and Energy (Bundesministerium fur Wirtschaft und Energie–BMWi), Service Project 59/12, RWTH Aachen University.

KPMG International 2015, *KPMG’s Global Automotive Executive Survey 2016*

KPMG International 2014, KPMG’s Global Automotive Executive Survey 2014.

Marsden Jacob Associates 2016, Final Report, Review of the Fuel Quality Standards Act 2000, Report prepared for the Department of the Environment, April 2016

Meszler, D et al (2013) *Summary of mass reduction impacts on EU cost curves*, ICCT

Mock, P. (2011) Evaluation of parameter-based vehicle emissions targets in the EU

Mock, P. 2015a, *Vehicle technology costs: Estimates vs. reality*.

Mock, P. 2015b, “Estimating the costs of vehicle efficiency: Will the European Commission incorporate lessons from experience?”, Published Wed, 2015.09.02, ICCT

Mock, P. & German J. 2015, The future of vehicle emissions testing and compliance: How to align regulatory requirements, customer expectations, and environmental performance in the European Union, ICCT White Paper

Mock, P., German, J., Bandivadekar, A., Riemersma, I., Ligterink, N., & Lambrecht, U. 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, International Council on Clean Transportation (ICCT)

National Research Council (NRC) 2015, *Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles*, Committee on the Assessment of Technologies for Improving Fuel Economy of Light-Duty Vehicles, Phase 2; Board on Energy and Environmental Systems; Division on Engineering and Physical Sciences; National Research Council; National Academy of Sciences (NAS); The National Academies Press (NAP), Washington, DC, US

National Transport Commission (NTC), *Carbon Dioxide Emissions Intensity for New Australian Light Vehicles* Information paper, various issues

Nesbit, K., & Sperling, D. 2001, Fleet purchase behaviour: decision processes and implications for new vehicle technologies and fuels. Transportation Research, Part C, Vol 9, pp. 297-318

Office of the Chief Economist 2016 (and various earlier issues), *Australian Petroleum Statistics*, Office of the Chief Economist, Department of Industry and Science, Commonwealth of Australia, Canberra

Onoda, T. 2008, *Review of International Polices for Vehicle Fuel Efficiency*, IEA Information Paper in support of the G8 Plan of Action, OECD/IEA, Paris, August

Productivity Commission (PC) 2005, *The Private Cost Effectiveness of Improving Energy Efficiency,* Productivity Commission Inquiry Report, No. 36, 31 August 2005, Melbourne

Rare Consulting 2012, Light vehicle emission standards in Australia–The case for action, Prepared for ClimateWorks Australia

Reedman, Luke J. and Graham, Paul W. 2013a, *Transport Sector Greenhouse Gas Emissions Projections 2013-2050*, Report No. EP139979, CSIRO, Australia

Reedman, Luke J. and Graham, Paul W. 2013b, *Sensitivity analysis of modelling of light vehicle emission standards in Australia*, Report No. EP1312837, CSIRO, Australia

Ricardo-AEA 2014, “Improving understanding of technology and costs for CO_2 reductions from cars and vans in the period to 2030”, study for the European Commission’s DG Climate Action LDV Framework

Scoular, R. (2004), Voluntary Fuel Consumption and CO_2 Emission Targets for New Light Vehicles: The Australian Experience, 6th APEC Automotive Dialogue, Beijing

Smit, R., Ntziachristos, L, Boulter, P., 2010, *Validation of road vehicle and traffic emission models–a review and meta-analysis*, Atmospheric Environment, 44 (25), 2943-2953

Smit 2014, Australian Motor Vehicle Emission Inventory for the National Pollutant Inventory (NPI), Prepared for Department of the Environment, UniQuest Project No: C01772

Smit, Kingston, Tooker, Neale, Torr, Harper, O’Brien, Harvest, Wainwright 2015, A Brisbane tunnel study to assess the accuracy of Australian motor vehicle emission models and examine the main factors affecting prediction errors, Air Quality and Climate Change Volume 49, No 3, August 2015

Smit, R. & Kingston, P., 2015a, A Brisbane tunnel study to validate Australian motor vehicle emission models, SAE Technical Paper 2015-01-0058

Smit, R. & Kingston, P., 2015b, *A tunnel study to validate Australian motor vehicle emission software*, CASANZ 2015 Conference, Melbourne, 20-23 September 2015

The Society of Motor Manufacturers and Traders Limited (SMMT) 2016, *New Car CO_2 Report 2016*, SMMT, London

TNO, AEA, CE Delft, Okopol, TML, Ricardo, IHS Global Insight 2011, *Support for the revision of Regulation (EC) No 443/2009 on CO_2 emissions from cars*, Final Report

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*, European Federation for Transport and Environment (T&E), Belgium

Transport and Environment 2015, *How clean are Europe's cars? An analysis of carmaker progress towards EU CO_2 targets in 2014*, European Federation for Transport and Environment (T&E), Belgium

Transport for London (TfL) 2015, In-service emissions performance of Euro 6/VI vehicles: A summary of testing using London drive cycles, Transport for London, UK

Treasury 2015, *2015 Intergenerational Report: Australia in 2055*, Circulated March 2015, Commonwealth of Australia and *2015-16 Mid-Year Economic and Fiscal Outlook*, Circulated December 2015

US EPA 2009, *Automobile Industry Retail Price Equivalent and Indirect Cost Multipliers*, Assessment and Standards Division, Office of Transportation and Air Quality, US Environmental Protection Agency, Prepared by RTI International and Transportation Research Institute, University of Michigan; RTI Project Number 0211577.002.004, US EPA

United States Environmental Protection Agency (US EPA) 2012a, Regulatory Impact Analysis: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, EPA Office of Transportation and Air Quality EPA-420-R-12-016

US EPA 2012b, EPA and NHTSA Set Standards to Reduce Greenhouse Gases and Improve Fuel Economy for Model Years 2017-2025 Cars and Light Trucks, EPA Office of Transportation and Air Quality, EPA-420-F-12-051

US EPA 2014, Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2014, EPA Office of Transportation and Air Quality, EPA-420-R-14-023a, October 2014

US EPA 2016a, Greenhouse Gas Emission Standards for Light-Duty Vehicles–Manufacturer Performance Report for the 2015 Model Year, EPA-420-R-16-014, November 2016

US EPA 2016b, Draft Technical Assessment Report: Midterm Evaluation of Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2022-2025, Office of Transportation and Air Quality–US Environmental Protection Agency, National Highway Traffic Safety Administration–US Department of Transportation and California Air Resources Board, EPA-420-D-16-900, July 2016

US EPA and US National Highway Traffic Safety Administration (NHTSA) 2011, "Draft Joint Technical Support Document: Rulemaking for 2017-2025, Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards," EPA-420-D-11-901, November 2011

US EPA and NHTSA 2012, Joint Final Technical Support Document: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards

US Office of Management and Budget (OMB) 2010, *Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis–Under Executive Order 12866*, Interagency Working Group on Social Cost of Carbon, United States Government

US Office of Management and Budget (OMB) 2015, Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis–Under Executive Order 12866, Interagency Working Group on Social Cost of Carbon, United States Government