

# Greenhouse gas abatement potential of the Australian transport sector

Summary report from the Australian Low Carbon Transport Forum

An initiative of the ARRB Group, Bureau of Infrastructure Transport and Regional Economics and CSIRO

**SEPTEMBER 2012** 

#### Acknowledgements

This report would not have been possible without the expert input and co-funding of the participants in the Australian Low Carbon Transport Forum (see below). ARRB Group, BITRE and CSIRO extend their sincere thanks to the individuals from all of the organisations that provided their expertise to the group in workshops and other informal discussions.

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#### CITATION

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

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## **Executive summary**

In recognition of both the progress of climate science and the need to manage the risks faced by future generations, the majority of the world's governments are implementing programs for the long term reduction of greenhouse gas emissions. Accordingly, the Australian government has adopted a target of an 80 per cent reduction on the 2000 levels of emissions for the Australian economy by 2050.

As a major greenhouse gas emission contributing sector in the economy at 16 per cent of national emissions, transport will need to make a significant contribution to the abatement target. The question then arises as to the potential greenhouse gas abatement options available to the sector.

The Australian transport industry, researchers and government have in many cases deep knowledge about the issues of environmental sustainability, and individual transport sector greenhouse gas abatement options. However, that knowledge is fragmented due to the diversity and complexity of transport. There are existing studies of transport abatement options but they are limited to a narrow subset of the available options. As a consequence no single document is available to provide an overview of the options and potential for abatement in the transport sector.

With this background the ARRB Group, BITRE and CSIRO formed the Australian Low Carbon Transport Forum (ALCTF) in July 2011 to bring together knowledge on the options for greenhouse gas abatement in transport and explore how deeply emissions could be cut in the sector.

The overall aims of the ALCTF are to:

- generate a list of options that would reduce emissions from transport
- identify the potential magnitude of the contribution to greenhouse gas reduction of each option both individually and combined
- examine challenges to these options achieving full potential and what drivers might overcome these challenges
- examine the potential for increasing the effectiveness of each option, including identification of uncertainties, and how these might be addressed.

A diverse range of participants were recruited to contribute their expertise to the Forum and to provide an opportunity for them to exchange information outside of their usual domain, mode or industry grouping. These included representatives from national and state government, industry, universities and not-for-profit organisations. This was to ensure that the study could cover a broad and inclusive range of options from the many diverse sub-sectors that make up Australian transport. Over three workshops the expert participants contributed information and provided feedback on the analysis developed by the project team in an iterative process.

The amount of abatement an option will achieve is dependent on 1) its level of adoption in a given segment of the transport sector, 2) the existing emissions in that segment and 3) how effective it is in reducing emissions relative to what has gone before. The impact of an abatement option individually is not the same as when acting with other options because the existing emissions in the given transport sector segment are changed.

The current report collates and calculates all of the relevant factors as a resource for transport industry stakeholders and decision-makers. The authors have also sought to make the assumptions used in the calculations of abatement potential transparent, so that transport industry stakeholders may continue to review and develop the material. To this end, a more in-depth technical discussion of how the estimated levels of abatement were reached is published in *Greenhouse gas abatement potential of the Australian transport sector: Technical report.* 

The report does not specifically assess the impact of the introduction of a carbon price on greenhouse gas abatement in the transport sector. The report assesses the potential of a wide variety of abatement options which in many cases would be activated and enhanced by a carbon price but may also be supported by other complementary policies or drivers in oil prices or technological development.



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#### KEY CONCLUSIONS OF THE REPORT.

The transport sector has a very large number of abatement options available to it	Based on input from transport experts this report examines 47 individual transport sector abatement options including a large number of fuel and vehicle technologies, urban transport measures, new and alternative infrastructure and options to modify behaviour via regulation and price signals. The large number of options available confirms how complex and diverse the transport sector is.
If able to be implemented, the transport sector abatement options examined could achieve a 64 per cent reduction on 2000 level emissions by 2050	Government policy is to achieve an 80 per cent reduction on 2000 level national greenhouse gas emissions by 2050. There is no requirement, and indeed it is not economically efficient, for all sectors of the economy to make an equal contribution to that target. However, since the emission reduction target is challenging, the major emitting sectors such as transport will need to make a significant contribution. This report establishes that it is technically feasible for transport to achieve that goal.
There are social and economic barriers which limit the ability to access the full abatement available from the options	While the maximum <sup>1</sup> potential of transport sector abatement options is large, there are significant challenges. These include reluctance to modify lifestyle choices, NIMBYism, established work practices, established land uses, higher costs and limited capital budgets. The existence of these challenges means that while technically feasible, the likely achievable abatement from some options will be lower.
The largest abatement achieving options come from fuel and vehicle technologies and a diverse range of other actions	The options that could achieve the greatest abatement in the long term are the fuel and vehicle technology options of fuel efficiency improvements, vehicle electrification, and use of second-generation biofuels. The benefits of both electrification and the use of biofuels are dependent on several conditions being met. Electric vehicles must be efficient and/or be fed from a de-carbonised grid. Biofuels will require an adequate supply of affordable second-generation fuels. This is subject to technological development and to competing needs for biomass possibly limiting transport sector availability.
	The next largest abatement options arise from a variety of areas including, the introduction of congestion and other pricing, improved freight logistics and changing transport modes in freight and passenger transport.
Transport sector abatement options which achieve a lower level of abatement may still be equally or more attractive to implement because of the co-benefits	In many cases there are substantial co-benefits that arise from each transport sector abatement option. These include for example reduced net oil imports, improved air quality, lower transport costs, improved urban amenity, improvements to infrastructure process and design, improvements to road safety, improved health and safety, and more competitive businesses.
they deliver	The existence of these co-benefits means that options that were assessed as having a smaller contribution to make to greenhouse gas abatement should not necessarily be dismissed. When their total net benefit is assessed by policy makers, businesses, and individuals engaging in the transport sector, they may rank equal to or higher than options that appeared more attractive on their abatement impact alone.
Disbenefits also need to be considered	Change always brings disruptions to the status quo which may be harmful to broad or specific parts of society. While there are co- benefits to greenhouse gas abatement actions there may also be disbenefits.
	Some specific disbenefits that might arise if implementation of low carbon transport options is not managed well include, displacement of communities, loss of vehicle amenity, negative land use changes such as reduced biodiversity and reduced soil quality, and higher taxes or transport costs.

<sup>1</sup> By 'maximum' it is meant the amount judged through discussions of the participating organisations to be approaching the limits of social and economic constraints but remaining technically feasible.

The main uncertainty is the extent to which society would be prepared to adopt the available options	Not surprisingly, there is significant uncertainty surrounding the abatement potential of the options explored. We cannot reliably predict how users will respond to new infrastructure. There are several data gaps and technical performance limits which are yet to be fully addressed. However, in many cases the greater uncertainty is the extent to which individuals, industry and government would be prepared to adopt the option. Market forces (particularly the oil price), cultural norms, public policy, social attitudes and the limits to coordinated governance all contribute to the high level of uncertainty. High levels of uncertainty tend to encourage delay.
A combination of a rising oil price together with policy that addresses social constraints will likely be required in order to realise transport sector abatement potential	The required technology and knowhow to reduce transport sector greenhouse gas emissions is already available. However, ongoing global research, development and deployment is required to reduce the cost of some options delaying their adoption. On the other hand, if oil prices rise significantly many options will more rapidly switch from being considered as a cost burden to a means of cost saving.
	Consumers have already responded to past oil price increases by purchasing lighter, more efficient vehicles. However, increased population and economic growth have offset the emission benefits of reduced average vehicle emission intensity.
	To realise the full potential of some options, an expected rising oil price will provide a strong incentive but not be sufficient in all cases. There is a wide range of policies governments could consider to complement new and existing drivers of change including investment, information, urban and regional transport planning and policies, tax reform and regulation.

The report commences with an overview of transport sector emissions and fuel use, projected growth to 2050, and emission reduction targets for Australia and the transport sector's implied contribution. The report then provides a discussion of the abatement options examined and the framework used to calculate potential abatement.

The estimated abatement potential of each of the options is discussed first on their own, then combined together. The report outlines the challenges that will need to be overcome in order to achieve maximum abatement, such as public policy, social and cultural, economic and biophysical considerations. The various co-benefits and disbenefits associated with each options are also discussed. implementation of the options will likely be cost saving in the long run. Whilst no specific recommendations are made, the report concludes by discussing what actions, drivers and strategies could be implemented in order to realise the potential of the options. In understanding these shapers and drivers, there are significant risks and uncertainties that would need to be addressed. After a general discussion we focus on three specific issues: road safety, demand management and price signals.

There are many issues that deserve greater exploration. However, it is hoped that this report provides a broad and robust foundation for characterising the potential and challenges for achieving substantial greenhouse gas abatement in the transport sector.



We do not estimate costs in detail. However we provide some examples which indicate that



# The imperative for transport sector abatement

#### Transport sector emissions

The transport sector is a major contributor to Australia's greenhouse gas emissions with a share of 16 per cent in 2010 (Figure 1). The source of these emissions is the use of predominantly petroleumderived transport fuels which produce carbon dioxide and other greenhouse gas emissions when combusted.

Within the transport sector, road transport is far and away the largest source of transport greenhouse gas emissions at approximately 87 per cent. This indicates that any efforts to substantially reduce emissions in the transport sector must be biased towards the road sector.

In 1990 marine, rail and air transport emissions were of a similar magnitude, each contributing around 3-4 per cent of transport sector emissions. However, in the past two decades aviation's share of emissions has increased more rapidly than other transport modes reflecting strong growth in aviation transport demand. Consequently aviation now contributes around 8 per cent of transport sector emissions. Rail and marine transport's contribution has reduced to 2-3 per cent. These transport mode shares are expected to remain fairly stable out to 2020 (BITRE, 2009).

In terms of fuel type, petrol and diesel are the two most common transport fuels followed by aviation jet fuel and liquefied petroleum gas (LPG) (Figure 2). Around 3 billion litres of petrol is currently blended with ethanol and sold as E10, particularly in New South Wales where mandated ethanol blending targets have been introduced. Whilst the majority of the transport sector uses liquid fuel, the rail sector also uses approximately 9 petajoules of electricity nationally each year, mainly for urban passenger transport.

FIGURE 1: SHARES OF MAJOR GREENHOUSE GAS





### FIGURE 2: TRANSPORT FUEL CONSUMPTION BY FUEL, 2010-11. SOURCES: DEPARTMENT OF RESOURCES, ENERGY AND TOURISM (2011); BITRE (2010)

FIGURE 3: PROJECTED TRANSPORT SECTOR GREENHOUSE GAS EMISSIONS BY MODE. SOURCE: BITRE (2010); COSGROVE AT AL. (2012)



#### Projected growth to 2050

Figure 3 shows the projected growth in transport sector greenhouse gas emissions to 2050. This projection is a reference case based on BITRE (2010). The rate of growth in population is expected to be declining in the next 40 years such that the trend in the total level of population will be approximately a straight line. Road vehicle use *per person* is expected to exhibit a slight upward trend to 2020, as the negative effects of the Global Financial Crisis wear off. However past 2020, road vehicle kilometres per person should saturate. This leaves the decreasing fossil fuel intensity of the vehicles as the factor responsible for the peaking and then downward trend of aggregate base-case transport emissions evident in Figure 3.

Part of this decrease in fossil fuel intensity will come from assumed efficiency gains in vehicle and engine technology, and partly from fuel switching to lower emission intensive fuels (assumed increases in electricity and bio-fuels). This reference case differs slightly from the original developed in BITRE (2010) in that it assumes the electricity sector decarbonises over time consistent with the electricity sector modelling outcomes that are projected to occur following introduction of a carbon price (Commonwealth of Australia, 2011a,b). This reduces the emission intensity of electricity as a transport fuel.

However, other more direct impacts of a carbon price have not been included as this study required a reference case that was closer to 'business as usual' to highlight the abatement effects of each option.

About two-thirds of projected road vehicle emissions occur in urban areas. Marine and rail emission trends follow that of road transport, but aviation emissions continue to grow to 2050 in this projection.

### Emission reduction targets and strategies

There is no government target for the reduction of emissions in the transport sector. There is, however, a target for national greenhouse gas reduction of 80 per cent below 2000 levels by 2050 (Commonwealth of Australia, 2011a, b). To meet this target at lowest cost, each sector's contribution to this abatement target is flexible and indeed the intention is that up to half of the required emission permits may be purchased not only from other sectors but from other countries if the cost of domestic abatement activities becomes too high.

However, the larger emission sectors, such as transport, must make a significant contribution. If emissions were allowed to grow unchecked as in the reference case, the transport sector's emissions alone would exceed the 2050 target for the whole economy, which in physical terms allows for 111 Mt  $CO_2e$ .

There are four general strategies available to reduce greenhouse gas emissions in transport. They are:

- reduce the emission intensity of transport fuels
- improve the fuel efficiency of transport so that less fuel is required
- reduce the amount of transport required to meet society's needs
- remove and store the emissions after they have been created.

This report focuses on the first three options, since actions to remove and store carbon are not unique to transport. They include reafforestation and chemical absorption of carbon dioxide for underground storage.



## **Transport sector abatement options**

#### Assembling the options

A total of 47 abatement options were examined, based on input from experts, availability of data and uniqueness of the option. This large number of options confirms the value of collating them in this study but is by no means an exhaustive list. There are many options not explored and some options could have been further disaggregated into greater detail. However, there is sufficient diversity and breadth to meet the goal of presenting an unfragmented view of the options for reducing transport sector emissions.

The options were examined for their potential contribution to abatement in 2020 and 2050. The focus on 2020 highlights the challenges that must be overcome while a focus on 2050 helps to free up the thinking around what may be possible, since this is long enough that it might be possible for behaviours to change, and to overcome most of the delays associated with constructing and renewing transport infrastructure.

Whilst we discussed with the expert group what the *likely* adoption of each abatement option was, based on a subjective assessment of all potential barriers, we were primarily focussed on understanding the *maximum* abatement potential of each option. By 'maximum' it is meant the amount judged through discussions of the participating organisations to be approaching the limits of social and economic constraints but remaining technically feasible. The focus on the maximum case reflects the strong imperative to understand how the transport sector emissions can make a substantial contribution to emissions reduction.

Further examination of the likely case is of less value because various projections of the likely level of emissions in the transport sector are already available (Commonwealth of Australia, 2011a,b; Graham and Reedman, 2011; Reedman and Graham, 2011).

#### Assessing the options

The assembled options were assessed using a simple framework shown in Table 1.

The first two columns identify first the options category (Trucks) and then the specific option being considered from within that category (Regenerative braking). The third column shows the adoption fraction is 0.9 which means that we estimate that 90 per cent of the reference case urban rigid truck fleet by 2050 could employ regenerative braking. The next column shows the relevant market affected is urban rigids which determines the size of the 'market emissions' in the next cell – 9.1 Mt CO<sub>2</sub>e. The 0.2 value in the 'savings fraction' column is the estimated emissions savings (i.e. about 20 per cent of the reference case emissions would be

saved). Finally, the last column shows the result of the abatement potential calculation – in this case 1.6 Mt  $CO_2e$  per annum. The number in this column is the result of multiplying the numbers in three other columns –i.e. the 'adoption fraction' times the 'market emissions' times the abatement 'savings fraction'. Therefore, 0.9 times 9.1 times 0.2 equals the 1.6 Mt estimated 2050 abatement potential.

This abatement assessment framework is applied to all the 47 options considered here. More detail about the abatement calculation methodology is provided in *Greenhouse gas abatement potential of the Australian transport sector: Technical report.* 

#### TABLE 1: OPTION ASSESSMENT FRAMEWORK

CATEGORY	OPTION	ADOPTION FRACTION	MARKET AFFECTED	MARKET EMISSIONS	SAVINGS FRACTION	2050 ABATEMENT
Trucks	Regenerative braking	0.9	Urban rigids	9.1	0.2	1.6

#### **Emissions scope**

The abatement achieved by each option is calculated on a fuel life cycle basis. This means that when any alternative fuels are considered, all emissions associated with their production are taken into account. This is important because some alternative fuels have considerable upstream emissions, but very low or zero emissions during their use. For example, the carbon dioxide emissions for use of biofuels are assigned a zero level reflecting that this amount of carbon dioxide will be reabsorbed when the biofuel feedstock is regrown. However, emissions associated with growing, transporting, processing and converting the biomass into biofuel are counted.

The upstream emissions of alternative fuels are not constant but are rather expected to improve. For example, it is assumed that electricity generation becomes increasingly less carbon intensive, and that biofuels are sourced from non-crop feedstocks which require less fertilisation and use a greater portion of the plant.

Some previous studies have included a wider scope such as 'well to wheel'. Well to wheel refers to the

emissions associated with not only the fuel, but also the production of the vehicle that uses the fuel. There might be some concern, for example, about whether manufacturing radically different vehicles such as electric vehicles with batteries produces more emissions. However, it is difficult to predict at this early stage which battery materials will be used in the long run, the carbon intensity of their production and how amenable they will be to recycling.

In conventional vehicles, vehicle fuel combustion in use represents around 80 per cent of emissions, depending on how far it is driven over its life, and will likely remain the largest source of lifecycle transport emissions for some time. As such we confine vehicle emissions to use only.

However, one novel extension to the emission scope that has been carried out in this study is to include transport infrastructure, particularly road pavement, in the options for transport sector abatement. These emissions would normally be assigned to the industry sector.

#### The influence of the reference case

A calculation of abatement achieved must be relative to a projected future, usually referred to as a reference or base case. The choice of a reference case can significantly distort the analysis if not chosen carefully. For example, if we constructed a reference case that was a future where there was no change in either the types of transport we used or the cities we lived in, all of the abatement options would appear to have a strong impact, because the reference case would represent a world where transport sector emissions are very high and therefore any action would deliver a big reduction.

However, this sort of no action reference case would be an unrealistic future. Even if it were desirable it will be impossible to preserve our current transport sector. The pressure of higher oil prices (IEA, 2011a) and competition amongst vehicle suppliers to provide more innovative products will deliver future emission reductions.

On the other hand if we build too much emission abatement into the reference case some abatement options will appear to be less effective than they are in reality because their impact is already built in.

The reference case used in this report seeks to strike a balance between these options. The reference case represents a future where many abatement options are partially adopted, in most cases to a small degree, recognising that without a strong driver, infrastructure and culture are slow to change.





# Impact of the options considered in isolation

The study initially calculated the individual impact of options in isolation. By that we mean the abatement impact that the option would have if all else stayed the same. This approach allows us to see each option's potential without the operation of other options. Other options can substantially reduce the impact of an option when they are acting together. For example the abatement impact of making your house more energy efficient is less if you are already using renewable energy. Of course, it is more realistic that abatement options will act together in real life, and so in the next section we relax the assumption of 'all else constant' and explore combinations of options.

In slightly less than 40 years it will be technically feasible to transform much of our existing transport infrastructure. However, there will still be some aspects where the life of assets is longer than 40 years or the difficulty of changing them is almost insurmountable. For example, some transport modes simply do not deliver the same services as others.Road networks and city form that took hundreds of years to establish cannot be completely changed in this time frame. Nevertheless, the potential for change is substantial.

Figure 4 shows the maximum abatement expected from the 47 options considered in isolation from each other. In order of impact, the top five individual greenhouse gas abatement options considered in isolation are light vehicle electrification, light vehicle use of biofuels, light vehicle fuel efficiency, light vehicle downsizing and trucks using biodiesel. These are all road vehicle options reflecting the fact that this is the largest emission producing sector of transport (so there are more emissions to reduce) and this sector's major infrastructure (vehicles) can be completely replaced by 2050 allowing the options to have their full effect.

The next five largest individual greenhouse gas abatement options generally deliver a 5-10 Mt CO<sub>2</sub>e reduction. These are aviation biofuels, moderate road vehicle fuel efficiency standards, congestion pricing, light vehicle registration based on distance, and truck engine efficiency. In this second top five we again see measures addressing the road vehicle sector, but this time including two policy measures that change vehicle purchase and travel behaviour.

An aviation sector option, biofuels, is the sixth largest individual abatement option. This is not surprising since the aviation sector is the next largest greenhouse gas emitting transport sector after road and it is growing fast. It is also interesting to note that biofuels are the largest individual option for the rail and marine sectors as well. The second largest individual option for aviation is aircraft technology, which is the 11th largest individual abatement option overall.

The remainder of individual transport sector greenhouse gas abatement options generally deliver less than 5 Mt CO<sub>2</sub>e. However, there are a great many of them, and as we will discuss in more detail below, they may deliver additional co-benefits. This means they should not be wholly discounted relative to larger abatement options.



FIGURE 4: ESTIMATED MAXIMUM GREENHOUSE GAS REDUCTION THAT COULD BE ACHIEVED BY SELECTED TRANSPORT ABATEMENT OPTIONS CONSIDERED IN ISOLATION AND IN SEQUENCE, 2050. SOURCE: COSGROVE ET AL. (2012)



# Impact of options when combined in sequence

# How combining all options in sequence affects the interpretation of results

It was noted in the previous section that the individual impact of abatement can be significantly overstated because in reality abatement options will co-exist and these options can substantially reduce the impact of each other when acting together.

The obvious solution is to examine them when combined so we get a more realistic indication of their potential impact. However, combining the options introduces another analytical complexity in that whatever order is chosen to combine the options, those options that are chosen to be implemented first will appear to have a greater impact and those that appear later will have their impact reduced.

This occurs because after any preceding abatement options have been implemented, there are fewer emissions left to be abated. To provide a specific example, if a vehicle is converted to biofuel any vehicle efficiency improvements thereafter will have a small impact because emissions from use of that fuel are very low. However, if we take a conventional petroleum fuelled vehicle and made it substantially more efficient first and then add biofuel second, vehicle efficiency improvements would appear to provide a large amount of abatement and biofuels relatively less. In order to address this issue we have sequenced the options. First we designated option categories and sequenced these. The categories and their order were: vehicle and fuel technologies, price signals, regulation, urban transport, infrastructure, freight, and 'others'.

Secondly, within each category, we specified the order in which the individual options would be implemented.

The first sequencing of categories is the most important. Comparing 'in isolation' with 'in sequence' (Figure 4), it can be seen that the assessed abatement potentials of all categories below the first category 'Vehicle and fuel technologies' are substantially reduced.

However, in some categories, the sequencing of the individual options is also important. The most important example of this is the placing of light vehicle biofuels after electrics, super-efficiency and downsizing. The assessed abatement potential of biofuels falls from 28 Mt CO<sub>2</sub>e in isolation to 12 Mt CO<sub>2</sub>e in sequence. In other words, switching half of the light vehicle fleet to electric, and making it all super-efficient and light weight, leaves much less scope (what is termed 'residual market' in the technical analysis) for biofuels to have an effect.

The diminished abatement effect of measures further down the sequencing list can in some cases be overstated. This arises if the measures are 'enablers'<sup>2</sup> of measures further up the list. The pricing signals category is a prime example of this.

<sup>2</sup> Enablers are actions which do not lead to greenhouse gas abatement on their own but provide incentives and frameworks that activate other options.

In the right hand side of Figure 4 we have combined all of the abatement options sequentially for the 2050 maximum case. That is we introduce each option in the order shown from top to bottom, one by one. As discussed, this can disadvantage those options listed lower down in terms of showing what abatement they could achieve. However ultimately, in order to calculate the combined effect of all of the options, an ordering must be chosen.

In order of impact, the top four greenhouse gas abatement options considered in sequence are light vehicle electrification, fuel super efficiency, truck biodiesel and light vehicle bio-fuels. These are all road vehicle options reflecting the fact that this is the largest emission producing sector of transport (so there are more emissions to reduce) and this sector's major infrastructure (vehicles) can be completely replaced by 2050 allowing the options to have their full effect. The magnitude of reduction varies from 12 to 23 Mt CO<sub>2</sub>e per year.

The next four largest individual greenhouse gas abatement options generally deliver a 5-7 Mt CO<sub>2</sub>e reduction. These are aviation biofuels, truck engine efficiency, aviation technology and light vehicle downsizing. In this second top four we again see measures addressing the road vehicle sector, but this time including two policy measures that affect aviation emissions. The total abatement achieved according to the sequential analysis by 2050 is 108 Mt  $CO_2e$  against reference case emissions in that year of 140 Mt  $CO_2e - a$  77 per cent reduction. To express this another way, relative to the year 2000, if all of these abatement options were implemented they would achieve an emission reduction of 64 per cent by 2050.

As expected this amount of abatement is less than the 220 Mt  $CO_2e$  which is the sum of all individual measures shown previously in Figure 4. As has been discussed, this is due to the offsetting effects when the measures are combined.

### Maximum transport sector abatement pathway

If we take the 2020 and 2050 projected maximum abatement levels we can construct a pathway that diverges from the reference case and leads to a decrease in transport sector emissions (Figure 5). The interpolation between 2020 and 2050 is nonlinear and takes into account slower adoption rates in the first two decades to 2030 and accelerated adoption from 2030 to 2050.

FIGURE 5: PROJECTED MAXIMUM POTENTIAL TRANSPORT SECTOR ABATEMENT PATH AND REFERENCE CASE. SOURCE: COSGROVE ET AL. (2012)





## **Impact of categories of options**

Ideally we want to be able to conclude which of the broad categories of abatement options has the greatest potential to provide transport sector greenhouse gas abatement. However, the preceding analysis has demonstrated that when combining options, a sequence must be chosen and that sequence affects how each option is ranked. Those options included early in the sequence will have an advantage in their total abatement achieved because there are more emissions available to be abated. The reverse is true for those included later in the sequence.

To overcome this issue when grouping the options into their categories we have calculated the impact of the category in the order chosen by the study (Figure 4) and then recalculated the abatement if each category's options were sequenced first. This second calculation removes any sequencing bias in the way categories are evaluated against each other.

The results in Figure 6 highlight two outcomes. The first is that vehicle technologies do offer the largest category of abatement opportunities, at 95 Mt CO<sub>2</sub>e. It remains the largest abatement category even if the other categories were implemented first in sequence. This reflects the fact that there is a greater number of options available in this category which deliver savings to a broad set of activities.

The second outcome is that leaving aside vehicle technology the abatement achievable in the other categories is of a fairly similar order of magnitude, ranging between 6 and 15 Mt  $CO_2e$  or up to 4 Mt  $CO_2e$  if implemented in the sequence used in this study.

Given the dominance of the fuel and vehicle technology category abatement options, a more balanced comparison of the major options available may be to disaggregate that category into specific options and to aggregate some elements of the other categories into a common theme. The common theme in the categories of price signals, urban transport and freight is demand management.

Taking this approach Figure 7 shows the abatement potential of the three largest individual options and a combined demand management option. This comparison indicates that demand management measures, when combined can deliver abatement equal to the magnitude achievable via each of the fuel and technology options alone.

The biofuels option is the largest reflecting its broad applicability to all transport modes whereas electrification and efficiency relate primarily to road transport. Its contribution would be even larger if assumed supply constraints had not been imposed. In reality it would be unlikely that sustainable resources of biomass would be sufficient to supply all transport modes so some caution must be applied when interpreting this result. A more likely outcome is that biofuels would be used in modes where electrification is less suitable since they each achieve a similar reduction in emission intensity.



### FIGURE 6: PROJECTED MAXIMUM ABATEMENT BY 2050 BY COMBINED BROAD CATEGORIES. SOURCE: COSGROVE ET AL. (2012)

FIGURE 7: PROJECTED ABATEMENT BY 2050 BY SELECTED INDIVIDUAL AND COMBINED CATEGORIES. SOURCE: COSGROVE ET AL. (2012)





## Challenges

The analysis in this report focuses on the maximum amount of abatement by 2050 – a period of just under 40 years from the present. The history of urban passenger transport in Australia provides a mixed message about how much change we can expect in that type of timeframe.

On the one hand, in the early part of last century, rail and then the passenger car completely transformed our mode of transport. However, the 30 years between 1980 and 2010 demonstrate that sometimes no change happens at all. The timeframe of 2050 broadens the range of possible outcomes but does not guarantee significant change. There are still many challenges that may need to be overcome in order for the abatement options included in this report to reach their full potential. The challenges to be overcome are not fixed and could change as society changes. However, from our present knowledge, the main challenges are discussed below and summarised graphically in Table 2.





### TABLE 2: SUMMARY OF THE MAIN CONSTRAINTS TO THE ADOPTION OF TRANSPORT SECTOR ABATEMENT OPTIONS

Public policy	<ul> <li>NIMBY response to change</li> <li>Limits to public finance</li> <li>The size of the changes required</li> </ul>
Social and cultural	<ul> <li>Expectations about housing, access and mobility</li> <li>Technology familiarity and acceptance</li> <li>Other types of utility derived from road vehicles</li> </ul>
Economic	<ul> <li>The general aversion to additional up-front costs that are required when adopting some low emission options</li> <li>Costs of necessary infrastructure changes</li> </ul>
Biophysical	<ul> <li>The quality and expected life of transport vehicles and other infrastructure</li> <li>The amount of land that is available for biofuel production</li> </ul>

#### Public policy challenges

Transport infrastructure is embedded into all of our public spaces and represents a significant proportion of government expenditure. It is one of the 'public goods' that government is tasked for planning, building and maintaining on behalf of society. Transport infrastructure is an essential service in constant use. When public or private transport assets are damaged or lost it causes great concern and inconvenience.

The provision of transport infrastructure cannot be separated from the design of our towns and cities in which they operate and whose needs they meet. Citizens are naturally more concerned about changes to transport infrastructure in their local area. Motorways, freeways and train lines improve the efficiency and convenience of transport infrastructure, but they can bring negative externalities such as noise and air pollution to local residents giving rise to NIMBY (Not In My Back Yard) responses. Economic stability and quality of life is therefore intimately tied to the transport network.

As a consequence, governments must find a difficult balance between the welfare of society at large and the amenity of those more directly affected. Governments must also manage the mixed messages of society which lobbies for more services but at the same time for more fiscal responsibility.

The outcome of these considerations is that incremental change will tend to have the most public policy support. Larger changes will affect many local stakeholders and put pressure on other government services or raise debt. Best practice stakeholder engagement processes and alternative financial arrangements such as public-private partnerships can assist but are not a panacea.

#### Social and cultural challenges

Public expectations do vary by location and are in some cases changing rapidly. Increased oil prices, the decreasing affordability of housing, and congestion within our larger capital cities has marginally increased demand for public transport and higher density living (ABS, 2010; ABS, 2011) (Figure 9). However, in general the expectations of car, house and land ownership are not easily changed.

A significant unknown factor at this point in time is whether Australians will embrace alternative fuel and vehicle technologies. For example, electric vehicles will require the driver to drive and refuel in a different manner from the present. On the other hand there are always segments of the community who embrace new technology. It is difficult to predict the timing and limits to mainstream acceptance. We can say with some confidence that higher vehicle costs will constrain uptake if not reduced over time relative to conventional vehicles.

Road vehicles are, of course, more than just a means to mobility and accessibility. If the adoption of abatement options such as alternative fuels, downsizing and energy efficiency cannot fulfil other aspects of utility such as safety, power, space, reliability and towing capacity, then adoption rates may be limited.

Working life culture has evolved so that employees generally need to present themselves at work and be observed to be working and interacting with their colleagues in order to be renumerated. However, the expansion of computer and knowledge based employment and information technology has led to two important outcomes. The first is the blurring of work and non-work time and the second is the increasing ability to work effectively and efficiently from non-work locations. Some amount of telecommuting is already a norm in white collar workplaces. However, the extent to which it evolves from a sometime convenience to a dominant system of working is unknown. The planned expansion of telecommunication infrastructure in Australia is a potential enabler. The lack of interconnectivity of some platforms, such as video conferencing between businesses, is a limit.

#### Economic challenges

Many of the abatement options in this report, such as vehicle efficiency, do not impose additional costs on the user but rather return savings relative to the status quo. Some alternative fuel vehicles may initially come at a higher cost but that would be expected to decline over time.

Transport infrastructure costs are more difficult to evaluate on a cost-benefit basis because their impacts are so widespread in terms of benefits received by the community (e.g. health, fuel consumption, congestion, aesthetics, etc.), but at the same time each expenditure is specific to a location. As such, we cannot generalise on whether transport infrastructure delivers a net benefit or cost. However, even if we were to assume that all abatement options are cost neutral over their lifetime, an important economic barrier remains and that is the general aversion to up-front investment costs. Whether we are an individual, business or government, there is a limit to how much we are prepared to spend, either from our existing cash or by raising debt, to win a payback in the long term. Our cash and tolerance for debt are limited and so we prioritise, even if that means not investing in something that would clearly save us money in the long term.

There are business models such as leasing which can alleviate the effects of this hurdle. However, they cannot always overcome the issue if there are many other perceived higher priority expenditure items in the budget.

Higher costs of transport from increases in oil prices or changes in government policy and regulation can raise the priority for accessing energy and greenhouse saving transport infrastructure investments. For example, the higher oil prices since 2004 have shifted purchases of new vehicles towards low size ranges (Figure 10).



#### FIGURE 9: SHARE OF PUBLIC TRANSPORT USE IN AUSTRALIA BY CAPITAL CITY. SOURCE: BITRE (FORTHCOMING)

#### **Bio-physical challenges**

Biophysical challenges are those generally defined by physical laws and so cannot be easily overcome. As such, in most cases they have been included in the analyses. However, there are some cases where the biophysical challenges are partly set by human behaviour and values.

One example is the rate of depreciation of transport infrastructure. How much we use our roads, how we care for our vehicles and how well we build our housing all determine for how long we would assume the current transport infrastructure and urban form to remain. On average, road vehicles remain in the fleet for 20 years. Aircraft, rail and marine vehicles are designed for longer lives so that their fleets are mostly renewed in 30-40 years. There are of course losses to accidents which are more common in the road sector. Vehicle regulation, the quality of roads, driving training and many more factors influence the accident rate.

How often we renew our hard transport infrastructure depends on the public policy challenges we have already discussed. Soft infrastructure such as traffic management systems and logistics can be implemented somewhat faster, although it does require enabling hard infrastructure. Another example of human interaction with biophysical limits is the physical amount of land we might consider available for biofuel production. The sensitivity of consumers to food prices means that it will likely not be acceptable to expand biofuel production at the expense of food production. This does not rule out the use of biofuels because there are feedstocks which are by-products of agriculture and forestry and some biofuel production can co-exist with agricultural production (Farine et al., 2011). Some feedstocks such as algae do not require fertile land at the production site. However, this social constraint to biofuel production does mean it is not likely that biofuels will completely replace fossil fuels, even if it were possible based on unconstrained access to land.

One final potential biophysical challenge is limits to the supply of materials for batteries for vehicle electrification. There is not enough evidence to understand how significant this problem will be, particularly given the infancy of the electric vehicle industry means that we cannot say for certain exactly which materials will be used in future evolutions of vehicle batteries. However, this will be an issue that will need to be considered given the current tendency towards less abundant materials than traditional batteries and the potential quantities needed at a global scale.



FIGURE 10: CHANGES IN PREFERENCES FOR PURCHASES OF ROAD VEHICLE TYPES AND SIZES. SOURCE: FCAI (2011).

![](_page_23_Picture_0.jpeg)

## **Co-benefits and Disbenefits**

The previous sections have highlighted the relative size of transport sector greenhouse gas abatement options. We have taken care to emphasise that the amount of abatement that can be achieved depends very much on how the options interact when implemented together.

Another very obvious but important point is that each abatement option will not just affect transport emissions. They will have many other co-benefits as well as some disbenefits.

#### **Co-benefits**

Some co-benefits include improved public health, urban amenity, safety and reduced transport costs but there are many others. Urban amenity is somewhat subjective and could include a broad range of indicators such as accessibility of services, urban aesthetics, noise, commuting times, sense of community, living space and affordability of housing.

We do not seek to be definitive or comprehensive in Table 3 but merely highlight the relationship between the selected co-benefits and the 47 abatement options. Some options are ambiguous because they have different impacts at an individual and social level. For example, parking fees can improve urban amenity at a social level by freeing up parking spaces but on an individual level are regarded as a negative outcome.

Other outcomes depend on an individual's lifestyle. For example a switch to distance based registration and insurance costs would benefit someone who has lower than average travel rates or conversely be disadvantageous for a high kilometre traveller. Finally, we are uncertain of some outcomes. Biofuels and electrics, for example, could be lower cost transport options at some time in the future given appropriate technological developments. But exactly when is not known and depends very much on the future oil price, and the rate of technological improvement in refining and vehicle manufacture.

#### Disbenefits

There may be some disbenefits associated with abatement measures. For instance, low-emission vehicles may not supply desired amenity in terms of acceleration, towing capacity or 4WD capability. Pricing mechanisms may increase the cost of transport. Infrastructure-related options may require increased government expenditure with a greater call on tax revenue.

But if managed properly, some of these disbenefits could be reduced. For example, reduced fuel costs associated with new vehicle technologies will help offset amenity losses. Congestion pricing would add to commuter costs, but to the extent that travel times improved relative to the case without the charges, the drivers and their passengers would benefit. Any increases in taxes for infrastructurerelated options would be balanced against the benefits derived from the improvements.

Biofuels have at times received significant negative sentiment due to concerns their production might lead to land use changes which usurp food production driving up food prices.

However, arrangements to develop a certification process that would assist in ensuring biofuel production is sustainable (taking into account food security and other issues) have commenced<sup>3</sup> (Biofuels Association of Australia, 2011). The expected outcome of a fully developed certification process is that biofuel production will be confined to selected feedstocks which have minimal land use impact. This would reduce the potential volume available, but remaining volumes would still be significant (Farine et al., 2011). Other abatement options could similarly have their disbenefits reduced with careful planning and management of their implementation (Table 4).

### TABLE 3: SELECTED CO-BENEFITS AND THE TRANSPORT SECTOR ABATEMENT OPTIONS WHICH MAY CONTRIBUTE TO ACHIEVING THE OUTCOME

RELEVANT ABATEMENT OPTIONS
Telecommuting, mode shift car-walk, mode shift car-cycle, traffic management, congestion pricing
Electric vehicles, congestion pricing, urban form/design, telecommuting, mode shift car-walk, mode shift car-cycle, traffic management, gross polluter regulation
Congestion pricing, urban form/design, telecommuting, traffic management
Vehicle downsizing, mode shift car - UPT, telecommuting
Electric vehicles (noise reduction), congestion pricing, urban form/design, telecommuting, mode shift car-walk, mode shift car-cycle, traffic management
Fuel super-efficiency, improved logistics, traffic management, telecommuting, ecodriving, downsizing, low rolling resistance, regenerative braking, B-triples, PBS trucks, other mode technology
Electric vehicles, biofuels, telecommuting, ecodriving, Fuel super-efficiency, downsizing, low rolling resistance, regenerative braking, B-triples, PBS trucks, other mode technology
Selection of low carbon pavement materials, improved processes and pavement design for road maintenance, construction and climate change resilience

### TABLE 4: SELECTED DISBENEFITS AND THE TRANSPORT SECTOR ABATEMENT OPTIONS WHICH MAY CONTRIBUTE TO ACHIEVING THE OUTCOME

DISBENEFIT	RELEVANT ABATEMENT OPTIONS
Loss of vehicle amenity	Ecodriving, downsizing, fuel super efficiency (acceleration, towing capacity, 4WD capability), B-triples
Increased cost of transport	Congestion pricing, parking charges
Increased government expenditure and subsequent opportunity cost of tax revenue	Urban form/design, mode shift car - UPT, mode shift car-walk, mode shift car-cycle, traffic management, improved logistics
Change in existing land use	Urban form/design (NIMBY impacts), biofuels (if sustainability certification not implemented well)
Reduced safety	Mode shift car-cycle

<sup>3</sup> Standards Australia, industry and the Commonwealth Government will participate in the International Organization for Standardization (ISO) Technical Committee (TC) 248 Sustainability Criteria for Bioenergy.

![](_page_25_Picture_0.jpeg)

## **Cost of transport abatement**

This report has not sought to quantify the costs of each individual transport sector abatement option. However, we can generally conclude that investment of some \$A5-10 billion per annum, whether public or private, would be required to implement the transport sector abatement options identified with the major component of costs being new vehicle technologies. Over time this investment delivers financial benefits in the form of fuel savings which would be expected to eventually more than offset the costs. The following sections explore the issues in more detail.

#### Improved vehicle efficiency costs

Most energy efficiency improvement options are negative cost abatement options. The simple reason is because they usually have little or no extra cost. In some cases, like downsizing, the vehicle costs less because it has fewer materials. If there are extra costs, the fuel savings usually recover the cost within a few years. However, while most fuel efficiency options deliver reduced transport costs and negative cost abatement, they may not be taken up in practice because:

- Vehicle stock purchasers have an aversion to high up-front costs.
- The disbenefit of a loss of vehicle amenity associated with higher efficiency may be viewed as outweighing the benefit of lower transport costs.
- The efficiency improvement may not be allowed at this present time (e.g. B-triples).
- The uptake of technology may be largely driven from overseas.

#### Alternative fuel vehicle costs

The main alternative fuel vehicle abatement options considered included vehicle electrification and biofuels. They could also include more speculative options not included in this study, such as hydrogen vehicles.

Electric vehicles currently cost around \$25,000 more than the equivalent size vehicle they are competing with (Drive, 2011). They do reduce annual fuel costs by almost 90 per cent but that is not sufficient to completely offset the additional capital costs (Graham and Reedman, 2011).

If we conservatively assume that the gap between electric and conventional vehicles narrows to \$5000 by 2030 then it will be approximately at that point that the cost of abatement for electric vehicles switches from positive to negative (Figure 11). Apart from the reduced up-front costs on electric vehicles, this result reflects the expected increases in the price of electricity and petroleum fuels that contribute to the total cost of travel.

Vehicles that use biofuels in low or high blends do not generally have a significant additional cost. However, large volumes of biofuel could not be produced at present at reasonable cost until refining and production technologies for advanced generation biofuels are fully developed and demonstrated. Graham et al. (2011) estimated that a wide range of biofuels from different feedstocks are expected to be cost competitive with petroleum by 2020. FIGURE 11: POSSIBLE TIME PATH FOR THE ABATEMENT COST OF ELECTRIC VEHICLES UNDER AN ASSUMED RATE OF DECREASE IN ELECTRIC VEHICLE COSTS. SOURCE: AUTHOR CALCULATION. FUEL PRICES BASED ON IEA (2011A). ELECTRICITY EMISSION INTENSITY AND AVERAGE RETAIL ELECTRICITY PRICES BASED ON COMMONWEALTH OF AUSTRALIA (2011B) AND AN ASSUMED 40 PER CENT DISCOUNT FOR CHARGING THE VEHICLE DURING OFF-PEAK TIMES. OTHER ASSUMPTIONS FROM GRAHAM AND REEDMAN (2011).

![](_page_26_Figure_1.jpeg)

Therefore, in both of these cases implementation of these abatement options in the short term would represent a positive cost of abatement. However, the cost of the relevant fuel and vehicle technologies are expected to decline over time (Electrification Coalition, 2009; IEA, 2009; IEA, 2011b; King, 2007) and move below parity with conventional petroleum-based vehicles, so that in the longer term they are expected to be negativecost abatement options.

#### Infrastructure costs

The difficulty with assigning costs to abatement for infrastructure related options is that the infrastructure has so many co-benefits that evaluating such projects on their cost of abatement alone is misleading. These co-benefits relate to urban amenity which is a subjective and often intangible benefit that is difficult to value. The benefit falls to society at large or to communities using that infrastructure, and there will not be a uniform view as to the level of benefit received.

#### Infrastructure materials

The price of oil is an important factor in determining the cost of conventional road infrastructure materials, such as bitumen. An upward trend in oil prices from 2005 to 2011 (VicRoads data obtained from ABS) has resulted in an increase in the price of bitumen (Figure 12).

Lower greenhouse gas intensive alternatives to conventional bitumen include biomass-sourced bitumen surfaced pavements such as vegetable-oilbased bitumen mixes and molasses-based bitumen products. Other alternatives include geopolymer concrete (rigid pavements); in situ cold recycling and; warm mix asphalt (Austroads, 2010a; 2010b). The costs of these are still largely unknown in practice, and further investment and research is required into<sup>4</sup>:

- long-term performance and lifetime of biomasssourced bitumen (or equivalent) pavements and how the performance of these alternative sources of bitumen (or equivalent) in pavements can be evaluated
- estimation of the investment needed for new equipment and the required re-training
- estimation of the cost of using biomass-sourced bitumen pavements in the field

<sup>&</sup>lt;sup>4</sup> There are also performance and occupational health and safety issues, with regard to the sources of bitumen i.e. until recently Australia used Middle East crude and refining was conducted in Australia. Now, the crude is refined overseas and the bitumen imported. There is uncertainty as to the source of the bitumen and hence its likely field performance and its effect on road workers (fumes, etc.).

![](_page_27_Figure_0.jpeg)

FIGURE 12: INCREASE IN THE PRICE OF BITUMEN IN RECENT YEARS. SOURCE: VICROADS (2011), DERIVED FROM ABS DATA

 estimation of the exact scale of available raw material, i.e. the extent to which suitable plant waste from the agriculture industry can allow biomass-sourced bitumen (or equivalent) to replace fossil-oil-based bitumen.

Unlike bitumen, concrete for the construction of roads does not depend directly on the price of oil/bitumen. Geopolymer concrete which is an alternative to conventional concrete uses fly ash, a low cost by-product from coal-fired power stations which is reported to reduce greenhouse gas emissions by 40% compared to Portland Cement (Austroads, 2010a). However, commercial production of geopolymer concrete in Australia is still developing. Whilst geopolymer concrete has been tested under a variety of conditions, further research is required into its suitability and longterm performance for pavement construction and maintenance (Austroads, 2010a).

The use of recycled aggregates and reclaimed asphalt pavement (RAP) can also result in environmental benefits if there is an efficient collection and reuse supply chain. In situ cold emulsion recycling may provide nearly 50% energy savings compared to conventional hot mix asphalt (Austroads, 2010a). Finally, the use of warm mix asphalt (WMA) appears to be increasing throughout the developed world in place of conventional hot mix asphalt (HMA).

Whilst there is potential to use WMA to ultimately replace HMA, long-term performance monitoring needs to be undertaken as well as confirmation of the cost and stated reduction in greenhouse gas emissions (Austroads, 2010a; Evans and Martin 2010).

### Cost of intelligent transport system assets

The reductions in energy consumption in operating intelligent transport system (ITS) assets depend greatly on individual applications, and the localities they are servicing. In order to improve energy efficiency many ITS assets require further research, and the implementation and operation of these assets also requires a high level of skill, information and understanding from asset managers to be fully effective (Austroads, 2002).

As an example, at the international level, and within Australia, incandescent and halogen lamps in traffic signals are progressively being replaced by LED array lamps. According to the Californian Department of Transportation (Iwasaki, 2003), the primary benefits of retrofitting their signal lamps include:

- up to 85% reduction in energy consumption
- replacement of signal lamps are improved to a five year cycle for red modules and a 10 year cycle for others (incandescent/halogen lamps often need to be replaced every one to two years)
- increased reliability ('burn-out' repairs are reduced by up to 90%, meaning less overtime and a lower chance of a signal failing in operation)
- ability to use a battery backup system economically (Austroads, 2010a).

It has been found that the initial investment in LED modules is paid off through energy savings in approximately three years, depending on energy prices (US EPA, 2000; Austroads, 2010a).

#### Marginal costs of road wear

Another consideration for infrastructure costs is the marginal cost of road wear. In Australia improvements to road freight productivity have arisen mainly by increasing freight vehicle payloads and allowing access to vehicles with longer, wider and taller configurations in a way that continues to ensure safety. The higher axle group loads associated with increased payloads can however, in some cases, significantly increase the marginal cost of road wear.

Two significant challenges exist. Firstly, can the current road network be used more efficiently and productively and, secondly, can the road network access be expanded in a way that enables the additional cost of this improved access to be recovered?

Recently, ARRB research commissioned by Austroads and the National Transport Commission (NTC) has developed tools to estimate the marginal cost of road wear. This work focused on higher loads of a vehicle on a range of road types, and the provision of potential pricing signals based on the marginal cost, for effective management of road networks in regard to the availability of targeted funds for maintaining road freight routes (Martin et al. 2010; Michel and Toole, 2006).

![](_page_28_Picture_5.jpeg)

![](_page_29_Picture_0.jpeg)

# Realising the potential of the abatement options

### Drivers of change: fuel prices and technology

The required technology and knowhow to reduce transport sector greenhouse gas emissions is already available. However, ongoing global research and development is required to reduce the cost of some of these options, delaying their adoption. On the other hand oil prices have increased substantially in the last decade and are projected to continue rising over time (IEA, 2011a). If oil prices rise significantly many options will more rapidly switch from being considered as a cost burden to a means of cost saving.

Consumers have already responded to past oil price increases by purchasing lighter more efficient vehicles. However, increased population and economic growth have offset the benefits of reduced average vehicle emission intensity.

To realise the full potential of some options, an expected rising oil price will provide a strong incentive but not be sufficient in all cases. There is a wide range of policies governments could consider to complement new and existing drivers of change including investment, information, urban and regional transport planning and policies, tax reform and regulation.

## Shaping the future through government policy

This report includes an assessment of the impact on greenhouse gas emissions of a limited set of possible 'policy' abatement options, such as efficiency standards, truck size regulations, congestion pricing, parking charges and distance based registration and insurance charges. There are a number of existing policies that already provide signals to reduce greenhouse gas emissions in transport.

Fuel excise rates on private light vehicles already makes the use of some lower emission fuels more economically attractive than they would be in the absence of such charges. Registration, insurance, stamp duty and other government charges are often lower for smaller, more fuel efficient vehicles.

The introduction of a carbon price in July 2012 will provide a very targeted signal to reduce greenhouse gas emissions. However, it will not apply to light duty road vehicle transport. Heavy duty road transport will participate from 2014 (Commonwealth of Australia, 2011a,b). The electricity sector will participate, and as such the transport sector may benefit if vehicle electrification proves to be cost effective.

Other possible transport policies that could also contribute to transport sector abatement are included in Table 5. These were derived

Urban transport policy	Designated lanes for low emission road vehicles Expanded rail networks
Tax reform	Align registration and stamp duty charges to emission intensity
Regulation	Emission labelling vehicles Amend selection criteria for government procurement of transport infrastructure
Investment	Investment in low carbon fuel production Investment in broadband infrastructure
Information	Raise awareness of transport's carbon footprint Raise awareness of oil price vulnerability
Regional transport policy	National freight strategy Designate regional distribution centres

#### TABLE 5: SUMMARY OF POTENTIAL POLICIES AND EXAMPLES OF SPECIFIC MEASURES

from suggestions by workshop participants. As can be seen there are a substantial number of potential urban transport policy levers. Some other categories are also very rich in the options available. None of these policies are evaluated or advocated. However, they serve to demonstrate the complexity of transport sector policy options.

#### Uncertainties

The largest uncertainty is society's likely level of adoption of each of the abatement options considered over time. It is difficult to predict how society will respond to and adopt new products, technologies, infrastructure and policies. Whilst some abatement options (particularly, some of the new fuel and vehicle technologies) are presently available, consumer demand and acceptance has been varied.

The assumed rate of adoption of each abatement option has been developed based on a combination of input from ALCTF participants, a literature review and research by the authors. The adoption assumptions remain the most subjective aspect of the analysis and will continue to require further research. The assumed adoption rates and discussion of their derivation are included in *Greenhouse gas abatement potential of the Australian transport sector: Technical report.* 

In an effort to identify as many uncertainties as possible, ALCTF participants were asked to

provide an indication of where they believe there are knowledge gaps which could be addressed to improve our understanding of the potential impacts of transport sector greenhouse gas abatement options. Their input is summarised in Table 6.

Within this list, the main uncertainties relate to how future users of transport infrastructure and services will behave, how more inter-connected government policies can be developed, more detailed data on the task our current freight system is carrying out, the viability and performance of new processes and technologies for scaled-up demands, the social and political appetite for changing our transport infrastructure and pricing regimes, and the nature and sustainability of new 'abatement-enabling' infrastructure materials and concepts adapted to the Australian context.

This list is by no means comprehensive but may serve as a useful guide for transport sector researchers to consider. Uncertainties are important to address because ongoing uncertainty can mean that there is not sufficient confidence to support investment or investment decisions may only be supported after considerable delay.

In the following three sections we expand on three uncertainties which illustrate a broad range of issues: road safety, responses to price signals, and demand management.

ABATEMENT OPTION / CATEGORY	IDENTIFIED UNCERTAINTY
Urban form/design	Predicting user behaviour after implementation of various options Consideration of social and economic constraints in urban planning/ design/densification
Electrification & biofuels	Australian-specific 'well to wheel' analysis of lifecycle greenhouse gas emissions Fuel distribution infrastructure requirements
Biofuels	Land use impacts and supply constraints Further advances in production processes and feedstock Continued research into advanced biofuels Optimisation and harmonisation of different policy levers
Eco-driving	How to embed and maintain changed behaviour in individuals, employees and fleet operators
Truck efficiency (engines, B-triples, low rolling	How to improve the coherence of multiple policy objectives How to manage influencing factors Requirements for adapted / specialised infrastructure Specific requirements of the future freight task
Improved logistics	How to integrate freight and land use planning more efficiently How to manage the complexity of evaluating alternatives Lack of data on destinations, route corridors and cargo How to improve data collection and analysis methods How to design effective regulation and economic incentives Scope for more rationalised / centralised freight and supply chain management e.g. inter-company collaboration, greater facility sharing and warehouse energy conservation
Mode shift road to rail and road/rail to sea	The likely timing of investment Reform to enable power-assist technologies Road to rail freight – improving transit times, how much investment is required, and required regulatory reform
Hard and soft infrastructure	Many alternative materials and processes are untrialled Design and standards required for alternative materials Procurement arrangements and investment required Social and political appetite for investment Social assessment of the non-greenhouse gas related impacts and trade-offs Research into long term field performance and laboratory characterisation Ability of current network to withstand increasing traffic demands (size, weight etc.) and scope for 'sweating the assets' approaches Consideration of the effects of climate change on pavements e.g. saturation, cracking/rutting
Price signals (congestion pricing, parking charges, etc.)	Public response to strong price signals How to select different pricing options and technologies Social appetite for implementation

TABLE 6: SPECIFIC UNCERTAINTIES IDENTIFIED BY ALCTF PARTICIPANTS BY ABATEMENT OPTION OR CATEGORY

### Uncertainty in the impact on road safety

The implementation of the abatement options could have either positive or negative impacts on road safety. The extent of these impacts is difficult to predict in part because not all of the safety issues that might arise with each option are known. Possible impacts on road safety can be grouped into four broad categories:

- impact of the introduction of new technologies (e.g. electric vehicles, low rolling resistance tyres, PBS-designed heavy vehicles), new infrastructure materials/designs
- impacts related to mode shift (e.g. shift from passenger vehicles to public transport, shift from passenger vehicles to cycling and walking)
- impacts related to characteristics of certain modes (e.g. driver behaviour and travel speed)
- impacts related to changes in urban design.

One example is PBS-based vehicles. These vehicles, despite being longer and heavier than conventional vehicles, are designed to offer inherently better levels of active safety (in terms of vehicle dynamic behaviour) than other vehicles, and are often fitted with advanced safety systems such as electronic stability control and other driver aids. In this regard, it is expected that the replacement of conventional vehicles with PBS vehicles would yield road safety benefits, although the extent is again difficult to quantify. However, concerns remain about the effects of larger PBS-based road freight vehicles on other road users' behaviour and thus on overall road safety.

The difficulty in determining the potential safety impacts relating to mode shift are compounded because some mode shifts may result in positive road safety outcomes, while others may result in negative road safety outcomes. As an example, if passenger vehicle kilometres are reduced, and the resulting demand is met by public transport, there could be a substantial reduction in road accidents through reduced traffic levels. However, if the resulting demand is addressed by an increase in cycling and walking (the most vulnerable types of road users), there could be an increase in the numbers of incidents involving these road users, thereby negating at least part of the safety benefits of a reduction in passenger vehicle kilometres.

'Eco-driving', while primarily aimed at delivering reductions in greenhouse gas emissions, may also yield safety benefits. The term 'eco-driving' is used to describe the concept of a modified driving style which is aimed at achieving a reduction in fuel usage when compared to conventional driving styles. Eco-driving encompasses a number of specific techniques which are each aimed at operating the vehicle's engine as efficiently as possible. It has been reported that eco-driving may also deliver road safety benefits. Specifically, less gear changes may reduce fatigue, adopting a smooth driving style with respect to acceleration could potentially prevent some loss-of-control events, and may reduce the risk of rear-end collisions with respect to reductions in sharp, or sudden braking.

The implementation of some abatement options may result in both higher and lower average travel speeds depending on the measure. This could increase the time at which vehicles operate at speeds which yield the lowest emissions per kilometre travelled. Fuel consumption decreases with increasing speed, up to a speed of about 80 km/h, and then increases by roughly 50% up to 120 km/h. In the context of these results, travel speeds around 80 km/h appear to be the most optimal in terms of emission reduction. Road safety research indicates that crash risk and severity increases with increasing speed.

This discussion highlights the impacts of the abatement options on road safety are likely to be mixed depending on the option. As it is anticipated that there is considerable existing research regarding the potential impacts individually, the required research will most likely be in the form of reviews to collate, summarise, and integrate the existing material to achieve better understanding of likely compound effects and outcomes.

### Uncertainty in the scope and impact of price signals

There are a number of existing drivers that provide price signals to reduce greenhouse gas emissions in transport. These include drivers such as the introduction of a carbon price to some parts of the transport sector, rising oil prices, and other pricing measures that affect transport decision making.

In terms of future projections, a number of agencies have forecast the price of oil. In addition to the International Energy Agency (IEA), the U.S. Department of Energy's Energy Information Administration (EIA) provides both short and long-term oil forecasts together with numerous international agencies including Altos, GII, PEL, PIRA, NRC and, DBAB (Austroads, 2010c). Figure 15 shows the range of long-term oil price projections from the EIA and IEA. The IEA's range is based on the level of global commitment to greenhouse gas reduction policy implementation which would tend to reduce the price of oil and other fossil fuels in the long term. The EIA's projected range is the widest with its 'high' and 'low' cases based on general oil market uncertainty.

![](_page_33_Figure_1.jpeg)

FIGURE 13: THE PROJECTED RANGE OF LONG TERM OIL PRICES FROM THE EIA AND IEA. SOURCE: EIA (2011); IEA (2011A)

Oil market uncertainty is due to differing opinions about: (1) how much oil is yet to be discovered; (2) how much technology will improve to allow oil extraction from non-conventional sources; (3) the effect of price on the viability of oil extraction from non-conventional sources; (4) the impact of alternative transport fuels; (5) how much oil consumption will change in the future; and (6) how global geopolitics will influence the supply and distribution of oil (Austroads, 2010b).

There are many other scenarios for oil prices, both higher and lower than the bounds outlined in Figure 13 (CSIRO, 2008; Graham and Reedman, 2010). All of these different oil price scenarios imply different scenarios for Australian petrol prices (Gargett, 2010; BITRE, 2012).

Apart from oil prices, there are a number of other costs that can impact on transport decisions and hence greenhouse gas emissions. For example, various cities internationally have introduced congestion charges that have encouraged motorists to switch to public transport. Pricing measures adopted in Australia that affect decision-making include the tolling of certain major roads, increases in parking charges in the centres of certain cities, and Australia's system of heavy vehicle charging. There are uncertainties as to the extent to which such charges/prices currently impact on greenhouse gas emissions, and the extent to which they may play a role in the future.

These uncertainties include the relative effects of different types of pricing signals, underpinning regulatory frameworks and technologies required, and the level of public acceptance. For example, there are uncertainties over how much extra abatement could be generated by increased levels of urban parking charges and the political appetite for their implementation. While the transport sector is generally understood to be price inelastic, the potential scale of future price increases and relatively recent technology options (e.g. telecommuting) could see behaviours emerge that are different from the past.

#### Uncertainties in demand management

The aim of demand management in the context of low carbon emissions is to reduce the amount of travel in passenger and freight, urban and inter-city transport. After taking into account population and economic growth factors the amount of demand for transport is strongly influenced by lifestyles. In the long term, the mobility and transport preferences of society in general can change, along with their choice of dwelling, selection of mode, employment/ societal locations and liveability standards. Whether Australians maintain a preference for low density detached living is one possible change that, if reversed, would significantly impact the effectiveness of certain abatement options. Another possible change might be with respect to how households carry out their shopping i.e. online versus travelling to the shopping centre, reducing passenger travel but increasing freight.

The major uncertainties in regard to the success of demand management measures are:

- the extent to which public and industry perceive some measures as constraining mobility or personal choice
- whether logistics systems will continue to favour frequent and smaller shipments
- the extent to which high density development in Australian cities is allowed
- whether Australian towns and cities will centralise or rural and regional centres expand
- whether expanded public transport system services will be perceived as an acceptable trade-off for personal vehicle travel for a greater portion of the population.

![](_page_34_Picture_8.jpeg)

### Acronyms

ABS	Australian Bureau of Statistics
ALCTF	Australian Low Carbon Transport Forum
B-triple	A prime mover towing three trailers
BITRE	Bureau of Infrastructure, Transport and Regional Economics
CSIRO	Commonwealth Scientific Industrial Research Organisation
DBAB	Deutsche Bank Alex. Brown
EIA	Energy Information Administration
F	Freight
FCAI	Federal Chamber of Automotive Industries
GII	Geophysical Institute of Israel
HMA	Hot mix asphalt
IEA	International Energy Agency
ITS	Intelligent transport system
LED	Light-emitting diode
LPG	Liquefied petroluem gas
LV	Light vehicle
Mt CO <sub>2</sub> e	Million tonnes of carbon dioxide equivalent
NRC	Natural Resources Canada
NTC	National Transport Commission
PBS	Performance-based standard
PEL	Petroleum Economic Limited
RAP	Reclaimed asphalt pavement
t	Tonne
TDM	Transport demand management
UPT	Urban public transport
US EPA	United States Environment Protection Agency
WMA	Warm mix asphalt

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