

Road Transport and Climate Change: Stepping off the Greenhouse Gas

Report prepared by John Stanley and Chris Loader,
BusVic, for the Bus Industry Confederation

April, 2008



Contents

Executive Summary	3
1 Context	5
2 Transport greenhouse gas emissions and emission reduction targets	7
2.1 Road transport greenhouse gas emissions	7
2.2 Interim emission reduction target for 2020	9
2.3 Forecasting transport emissions to 2050.....	9
2.4 An emissions reduction target for 2050	10
A tale of two cities – Melbourne and London	11
3 Meeting 2020 interim emission reduction targets	12
3.1 Six ways to achieve emission reductions	12
3.1.1 Increase the share of urban trips by walking and cycling	13
3.1.2 Reduce forecast total urban vehicle kilometres	14
3.1.3 Increase public transport’s mode share of urban travel.....	14
3.1.4 Increase urban car occupancy rates	15
3.1.5 Reduce forecast fuel use for road freight	15
3.1.6 Improve vehicle efficiency	17
3.2 Overall impact.....	20
3.3 Emissions trading/carbon pricing	21
3.4 Urban structure and transport greenhouse gas emissions	22
3.5 Equity implications.....	22
4 Meeting 2050 reduction targets	24
5 Conclusions	27
5.1 Pathways to emission reduction.....	27
5.2 Three key drivers.....	27
5.2.1 Vehicle emissions technology	28
5.2.2 Urban structure and infrastructure planning.....	28
5.2.3 Road pricing	28
5.3 Wider benefits	29
References	30

Executive Summary

Transport is Australia’s third largest and second fastest growing source of greenhouse gas (GHG) emissions. The road transport sector makes up 88% of total transport emissions, and the projected emissions increase from 1990 to 2020 is 64% (with projected total emissions of 88.9Mt CO₂-e). This is indefensible in a warming world. Major behavioural and technological changes will be needed to deliver a more acceptable outcome.

This submission investigates the following two targets, and what they might mean for the Australian road transport sector:

1. Emissions in 2020 being 20% below 2000 levels
2. Emissions in 2050 being 80% below 2000 levels

BIC sees six key ways by which road transport GHG emissions can be reduced to achieve these targets, and the six could be utilised in many different ways to achieve targets, as illustrated in the following table (options A, B and C all meet the 2020 target):

Measure	Target	2007	2020 (A)	2020 (B)	2020 (C)
1. Fewer/short car trips (kms)	Less car kms	-	10%	20%	25%
2. Shift car to walking/cycling	Active transport mode share (urban)	16%	26%	34%	39%
3. Increase public transport mode share	PT share or trips (all urban trips)	8%	15%	20%	21%
4. Increase car occupancy	Passengers/car	1.4	1.6	1.8	1.9
5. Freight efficiency	Less fuel than forecast	-	30%	30%	30%
6. Car emissions intensity	Less than 2007	-	30%	18%	13%
Truck emissions intensity	Less than 2007		18%	13%	8%

All the sets of measures set out in the table will require major behavioural and technological changes, particularly early action to redress the lack of progress over the nearly two decades since 1990 – which reflects badly on transport policy and planning skills and processes in Australia.

The required changes can be summarised in the following 9 key actions:

1. Comprehensive road pricing
2. Increased investment in public transport
3. Major investment in walking and cycling
4. More compact, walkable urban settlements
5. Significantly improved fuel efficiency (mandatory targets)
6. Invest in rail freight and intermodal hubs
7. Freight efficiency improvement (e.g. more productive vehicles; changed delivery times)
8. Reallocate road space to prioritise low emission modes
9. Behaviour change programs

BIC believes that these are all quite feasible within the 2020 timeframe, provided we act quickly.

The 2050 targets are far more problematic and BIC doubts whether road transport GHG emission reductions of about 80% on 2000 levels by 2050 are achievable, unless there are major break-

throughs on vehicle fuel economy (delivering reductions of about 90% on current vehicular GHG emission rates).

The upcoming emissions trading scheme is unlikely to deliver substantial emissions reductions from road transport, given low fuel price elasticities and strong underlying growth in transport demand. Complementary substantial investments and policy interventions will also be required to change the very nature of our cities, transport systems and travel behaviour to make significant road transport emission reductions.

Our research indicates that achieving very substantial reductions in vehicle emission intensity is absolutely vital to making major inroads in road transport GHG emissions. We believe that this will require mandatory GHG emission standards and a focus on changing consumer behaviour towards purchase of less emission intensive vehicles.

Many of the emission reduction initiatives considered in this report will benefit from urban development policies and plans that facilitate more compact urban settlement patterns. Such urban design will help to reduce travel distances (e.g. because of closer proximity of trip origins and destinations), make walking and cycling easier and improve the economics of public transport service provision.

Analysis of the equity implications of carbon pricing/emissions trading suggests that this will have regressive distributional impacts. By carefully framing the complementary emission reduction measures outlined in this report, the travel needs of disadvantaged people can be given high priority, to help to mitigate these regressive impacts. Bus service improvements in outer suburbs of Australian cities and regional areas will be central to this approach.

1 Context

Professor Ross Garnaut has warned Australians that (Garnaut 2008, p.4)

...the world is moving towards high risks of dangerous climate change more rapidly than has generally been understood. This makes mitigation more urgent...

Recognising that greenhouse gas (GHG) emissions have been growing more quickly than was anticipated in the Intergovernmental Panel on Climate Change’s Fourth Assessment Report (IPCC 2007), Garnaut has argued that Australian emissions reductions of 70 to 90% on 2000 levels are needed by 2050 under global emission stabilisation scenarios of 550ppm and 450ppm of CO₂-e respectively. He also argues that Australia should adopt interim emission reduction targets for 2020.

Transport is Australia’s third largest and second fastest growing source of greenhouse gas (GHG) emissions. The Australian Greenhouse Office (AGO 2006), for example, forecast that Australian transport emissions will grow by a huge 62% between 1990 and 2020, even with a range of emission-reducing measures in place. The new Australian Government Department of Climate Change has recently increased this growth rate projection from 62% to 67%.

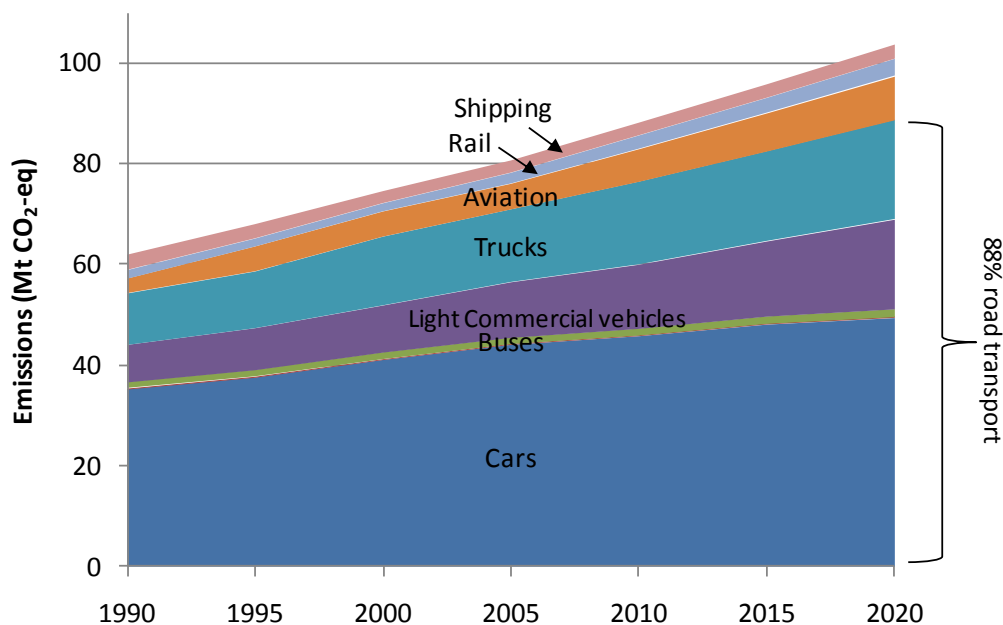


Figure 1.1 - Australian Transport Emissions - actual and forecast

The road transport sector makes up 88% of total transport emissions and its projected emissions increase from 1990 to 2020 is 64% (with projected total emissions of 88.9Mt CO₂-e) as shown in Figure 1.1. This is indefensible in a warming world. Major behavioural and technological changes will be needed to deliver a more acceptable outcome.

While the most efficient national path to emission reduction might involve some sectors cutting their emissions more than others, emission reductions on the scale indicated by Garnaut will require all sectors to contribute substantially. The larger and faster growing emissions sectors will need to be prominent, otherwise the maths will simply not add up.

We investigate the following two targets, and what they might mean for the Australian road transport sector:

- Emissions in 2020 being 20% below 2000 levels
- Emissions in 2050 being 80% below 2000 levels

Investigating such indicative sectoral targets is not implying that the transport sector need necessarily be required to deliver on changes of the magnitude canvassed solely by behavioural and technological changes that directly reduce transport emissions. For example, emission credits might be cost-effectively obtained by the transport sector from other sectors and/or other countries, in an international emissions trading regime. However, by confronting the possibility that the sector may need to be accountable for reductions of the order of magnitude under consideration, this report focuses attention on some of the strategic thinking that must start today to plan for the future.

Section 2 of this report presents data on road transport GHG emissions and projections of future emissions, to provide a basis for estimating the scale of reductions that will be needed to achieve the reduction targets indicated. Section 3 discusses the interim 2020 target and outlines the type of changes that will be required to achieve this result from the road transport sector. Section 4 considers the much tougher 2050 target. Section 5 outlines the conclusions from the work, drawing out some key policy implications.

2 Transport greenhouse gas emissions and emission reduction targets

2.1 Road transport greenhouse gas emissions

The Australia Department of Climate Change (DCC 2008) reports that Australian transport sector greenhouse gas emissions in 2005 totalled 80.8Mt CO₂-e, some 30% higher than the 1990 level of 62.1 Mt CO₂-e and 8.5% above the 2000 emission level. Table 2.1 sets out emission projections from that report, showing 2020 emissions 45.0% higher than 2000 levels under a “business-as-usual” scenario and still a huge 38.5% above 2000 levels under a “with measures” scenario. The latter scenario allows for a number of initiatives that are being implemented to cut emissions.¹

Table 2.1: Transport sector emission projections (Mt CO₂-eq)

	2000	2020	2020 increase on 2000
“Business as usual”	74.9	108.6	+45.0%
“With measures”	74.9	103.7	+38.5%

(Source: DCC (2008), Tables ES.1 and 1.2)

These numbers show the urgency of very substantial emissions reduction measures over the coming decade if the suggested 2020 target (emissions to be 20% below 2000 levels) is to be approached at a transport sectoral level, to say nothing of the changes required to deliver cuts of 70-90% on 2000 levels by 2050.

The road transport sector contributes 88% of total transport sector GHG emissions, some 71.0Mt CO₂-eq in 2005. Road transport emissions in 2005 were 11.9% higher than in 2000, a faster rate of increase than that for the transport sector as a whole (at 8.5%). To consider how emission reduction targets might impact on the transport sector, this report focuses on the road transport part of the sector, because of its dominance of the total.

Figure 2.1 shows that passenger cars are the largest single contributor to road transport greenhouse gas emissions, followed by trucks and light commercial vehicles (LCVs).

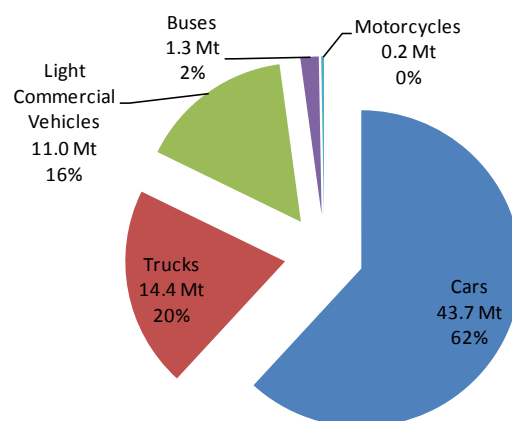


Figure 2.1 – Breakdown of Australian road transport emissions in 2005

(Source: DCC 2007)

¹ The “measures” included under this scenario are voluntary fuel consumption targets that have been agreed, government biofuels measures, the alternative fuels conversion program, various state measures (e.g. to increase public transport use), travel demand measures, a range of aviation initiatives and some energy efficiency opportunities.

Figure 2.2 shows that while car emissions have increased 25% between 1990 and 2005, emissions from LCVs have increased 48% and emissions from trucks have increased 41%. However, given the absolute scale of these various components, the total increase in emissions from cars accounted for more than the total increase from LCVs, trucks and buses over the 15 year period. Looking forward to 2020, both trucks and LCV emissions are forecast to increase to around double 1990 levels. Cars, LCVs and trucks must all therefore contribute significantly if substantial cuts in GHG emissions are to be achieved.

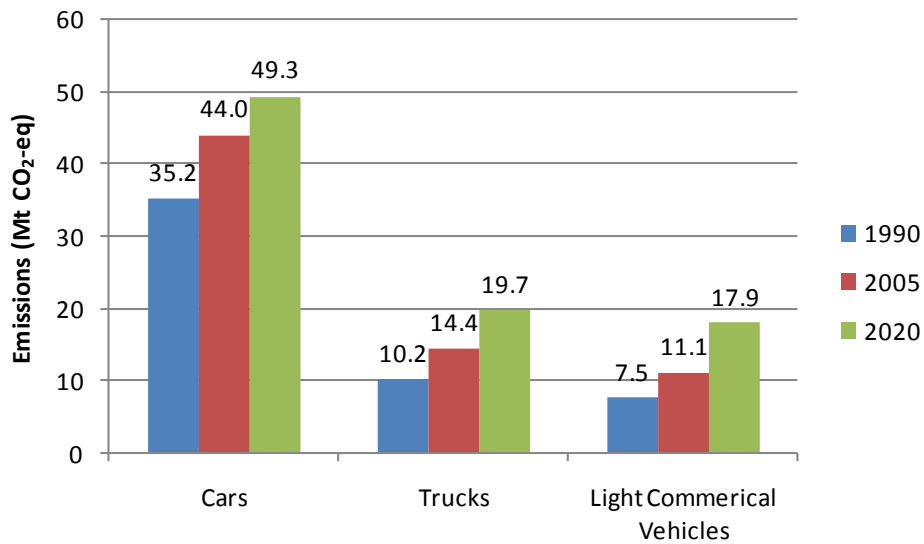


Figure 2.2 - Growth in Australian road transport emissions (actual to 2005, forecast to 2020)
(Source: DCC 2008, Table 2.3)

Buses accounted for 1.3 Mt CO₂-e in 2005 (1.7% of road transport emissions), and have grown only 8% since 1990.

Table 2.2 sets out road transport greenhouse gas emission forecasts, as presented by the Department of Climate Change (DCC 2008) for 2020. Ignoring motor cycles, which are insignificant in total road transport emissions, Table 2.2 shows that emissions are forecast to increase by 22.7 Mt CO₂-e over the 2000 to 2020 period, with car emissions increasing by 8 Mt, LCVs by 8.4 Mt and trucks and buses by 6.3 Mt (almost all trucks).

Table 2.2: Emission Forecasts for the Road Transport Sector (Mt CO₂-eq)

Vehicle Type	1990	2000	2020	Reduction on forecast to achieve 2020 = 20% less than 2000
Cars	35.2	41.3	49.3	
LCVs	7.5	9.5	17.9	
Trucks and Buses	11.3	15.0	21.3	
Total of the above (1)	54.0	65.8	88.5	35.9

Sources: DCC (2008), Tables 1.2 and 2.3; Note: (1) Excludes motor cycles.

2.2 Interim emission reduction target for 2020

At the recent Bali Climate Change conference, emissions targets of 25-40% below 2000 levels in 2020 for industrialised countries were canvassed by scientists and many nations. If we were to accept that it might be a little easier to achieve reductions in other sectors (Stern 2006), a target of 20% below 2000 levels in 2020 might be a modest target for road transport. This translates to a reduction in road transport emissions of around 36 Mt below forecast for the year 2020 (Table 2.2).

2.3 Forecasting transport emissions to 2050

There are no published projections of road transport greenhouse gas emissions to 2050 of which we are aware. We have projected 2050 emissions by extrapolating modal emissions growth trends in the BTRE (2007b) “with measures” case beyond 2020 (with very modest allowance for further reduction initiatives). Our approach has been to take the typical annual traffic growth rate for each category of road transport vehicle over the forecast period to 2020 and extrapolate this to 2050, generally with a slower growth rate, to produce “indicative” traffic volumes (refer Table 2.3). Emission rates have been derived from these traffic flows by assuming emissions grow at around 80% the rate of traffic growth. These assumptions are coarse but at least explicit!

Table 2.3 -Vehicle kms and emissions growth assumptions to 2050

Mode	Average annual growth rate 2010-2020 (BTRE 2007b)	Annual growth rate 2030-2050	Emissions growth rate 2030-2050
Cars (metropolitan)	1.3%	1.0%	0.7%
Cars (non-metropolitan)	1.0%	0.6%	
Light Commercial Vehicles	3.1%	2.7%	2.2%
Rigid trucks	0.9%	0.7%	0.6%
Articulated Trucks	2.8%	2.2%	1.8%
Buses	1.9%	2.0%	1.6%
Motorcycles	2.1%	2.0%	1.6%

While growing congestion over time might lead to emissions growth faster than traffic growth, the emission reduction scenarios suggests that this is probably a second-order complication in this “indicative” analysis. Our scenarios (detailed below) suggest that road traffic volumes may need to decline in absolute terms if 2050 reductions targets of more than 50-60% are to be achieved, unless there is a radical transformation in energy sources to very low GHG emission free alternatives .

It is highly likely that global oil supply constraints will significantly impact growth in traffic volumes before 2050, even according to conservative commentators (BTRE 2005). However, in modelling future emissions we assume oil supply will be less constraining than strong greenhouse gas emission targets, which enables us to focus on the behavioural and technological changes necessary to meet the emissions reductions targets alone.

Figure 2.3 sets out an indicative projection of road transport GHG emissions to 2050, on these crude assumptions. With traffic growth on a “business as usual” basis, road transport emissions of 131 Mt CO₂-eq are projected for 2050.

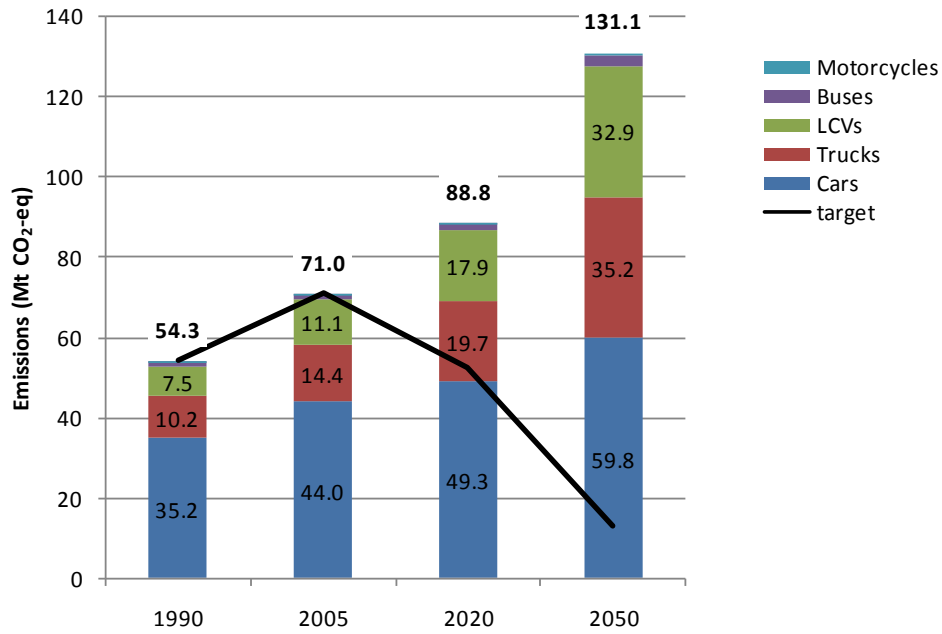


Figure 2.3 - Actual and projected road transport emission compared to targets (2020=20% below 2000 and 2050=80% below 2000, totals shown in bold).
 (Source: DCC (2008), BIC projections for 2050)

2.4 An emissions reduction target for 2050

To achieve a 2050 target of emissions 80% below 2000 levels would require around a massive reduction of about 120 Mt CO₂-e below projected 2050 emissions. Figure 2.3 shows the reduction against the projections for 2050. Section 4 considers what might be needed to meet such a target.

A tale of two cities – Melbourne and London

Cities are the main originating area for road transport greenhouse gas emissions. To shed some light on road transport emission performance in Australian cities, we have compared the transport greenhouse emissions of Melbourne and London. For Melbourne we have estimated 2006 emissions using the national greenhouse emissions inventory for 2005, with adjustments made to reflect available data on traffic and emissions growth post 2005.

Figure 2.4 shows that Melbourne’s emissions of around 11.0 Mt CO₂-e exceed those of London at 8.5 Mt CO₂-e, despite Melbourne having around half the population of London. Per capita transport emissions in Melbourne are 3.1 tonnes compared to London at 1.2 tonnes. This is a stark comparison.

The figures clearly reflect the significantly different transport systems and land use patterns. While London is a relatively compact and high density city, Melbourne is characterised by sprawling low density suburban areas (covering a larger geographic area than London). London has a very large network of overground and underground rail lines, several light rail lines and very high frequency bus services. In contrast, Melbourne has extensive, though almost entirely radial, train and tram networks, and generally low frequency bus routes in the outer suburbs. In Melbourne it is not uncommon for outer metropolitan bus routes to operate hourly on weekdays, and have limited evening and Saturday services, and no Sunday service at all.

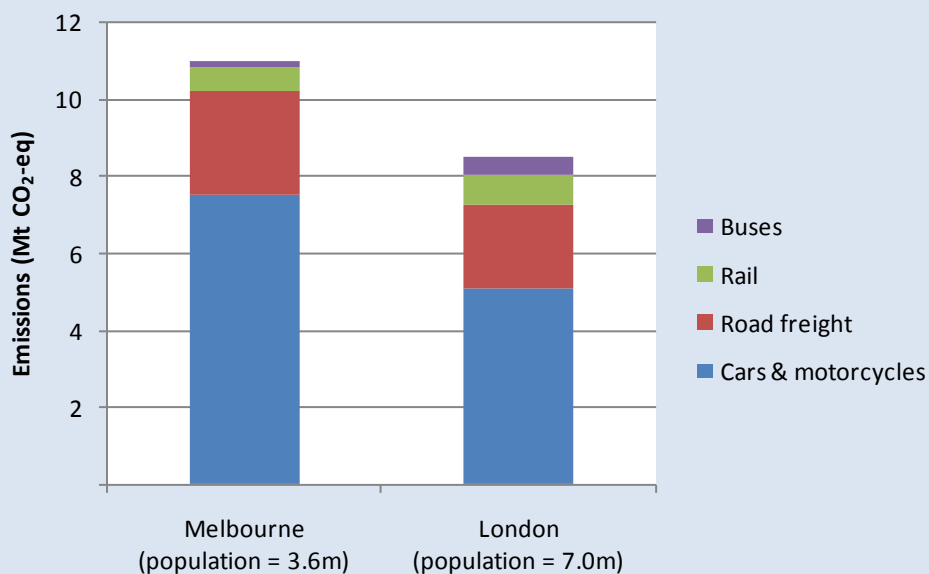


Figure 2.4: Comparing Land Transport Greenhouse Gas Emissions in Melbourne and London

These results reflect strongly on the transport mode shares in each city. In Melbourne around 9% of motorised trips are made by public transport, while in London this figure is around 48%.

3 Meeting 2020 interim emission reduction targets

Figure 3.1 shows the emission reductions needed from the road transport sector as a whole if it is to achieve a 2020 target that is 20% lower than the 2000 emission level. Table 2.2 pointed out that the reduction represents 36 Mt CO₂-e.

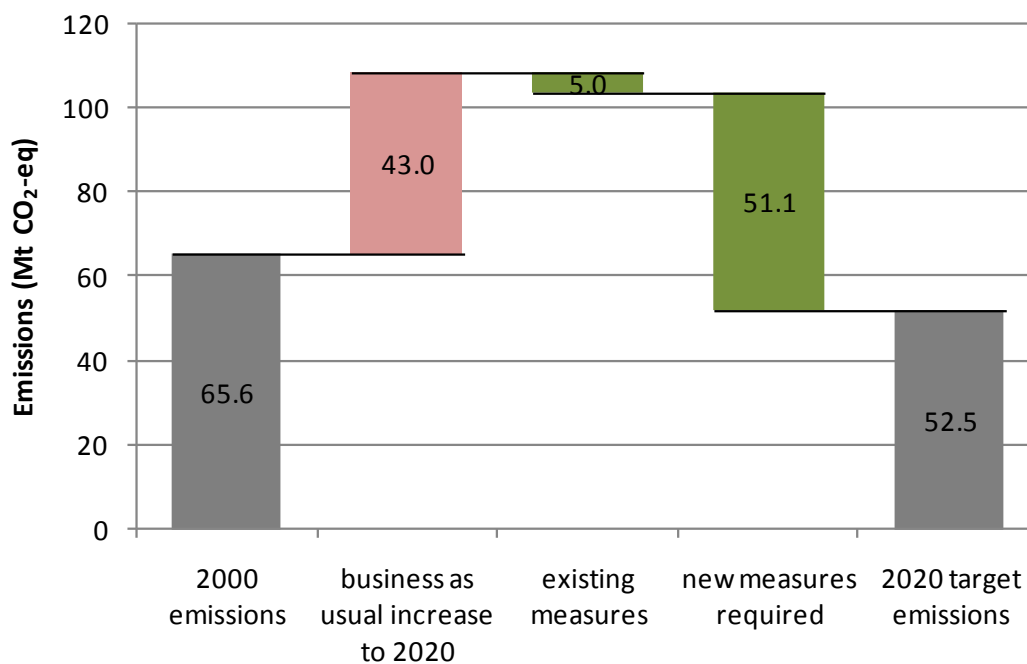


Figure 3.1. Australian Road Transport emissions – projections to 2020 and additional measures required to deliver a 20% cut on 2000 levels.

3.1 Six ways to achieve emission reductions

BIC sees six key ways by which road transport GHG emissions can be reduced to achieve this target.

- 1) Increase the share of trips performed by walking and cycling
- 2) Reduce urban vehicle kilometres (especially by cutting trip lengths and increasing trip chaining)
- 3) Increase public transport's mode share of urban motorised trips
- 4) Increase urban car occupancy rates
- 5) Reduce forecast fuel use for road freight
- 6) Improve vehicle efficiency

The following sections show feasible sub-targets for each of these actions, which will deliver the total emission reductions needed by 2020.

3.1.1 Increase the share of urban trips by walking and cycling

A general strategy for reducing transport GHG emissions is to increase the relative task performed by low emission modes. There are no lower GHG emission modes than walking and cycling. Most Australian cities are well suited to cycling, with relatively friendly terrain. However, conflict with other road users, particularly cars and trucks, raises safety issues for cyclists. Provision of dedicated cycle paths increases the safety of this form of travel.

Concerns about safety have contributed to a substantial shift in some forms of personal travel away from cycling to motor vehicles in recent decades, the trip to and from school being notable, as shown in Figure 3.2.

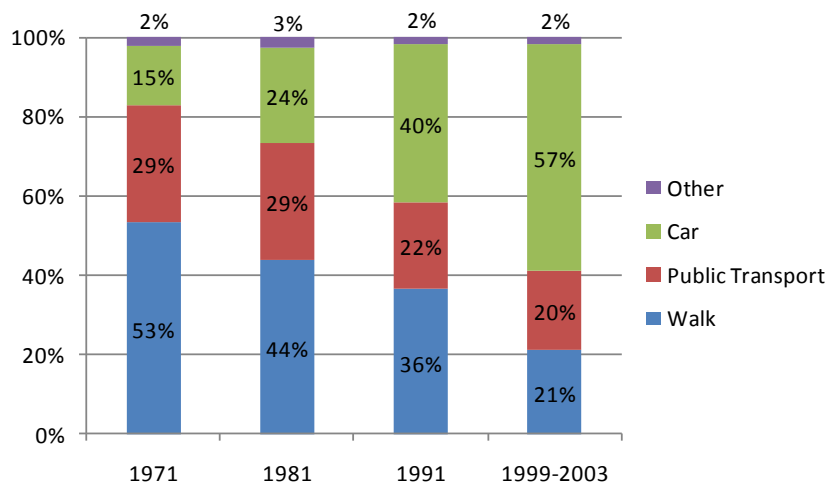


Figure 3.2 - Method of travel to/from school in Sydney
(Source: van der Ploeg et al. 2008)

Given the timing of school trips, this shift increases congestion costs and adds GHG emissions at a high rate per kilometre travelled. This trend is not unique to Australia, being the same (for example) as is happening in the UK and Italy.

The trip to school is a prime example of short trips that are eminently suited to walking or cycling, being undertaken by car. Overall, about 36% of trips in Melbourne are less than 2 kilometres in length, suited to walking or cycling, while another 24% are between 2 and 5 kilometres, well suited for cycling, provided suitable infrastructure is in place.

Strategies to reduce road transport GHG emissions should focus on increasing the safety with which walking and cycling can be undertaken. This applies particularly to urban areas, especially the larger cities. Melbourne's recent investments in on-road cycling facilities have contributed to a 7.5% average annual growth rate for journeys to work in Melbourne between 2001 and 2006 (DOI 2008).

A target for one quarter of all trips in the major cities to be undertaken by walking and cycling, compared to the current average share of around 16%, would contribute about 4.4 Mt of the targeted 36 Mt emission reductions at 2020.

Such a change in travel patterns towards a more substantial role for more active modes would have an associated benefit of reduced obesity and improved health

3.1.2 Reduce forecast total urban vehicle kilometres

Personal travel is the result of people undertaking activities at places that are separate to where they are located. The closer the desired activities are to the present location, the shorter the trip and the lower in general the emissions. Also, if various activities can be undertaken in a chained fashion, rather than with a return to base between each separate trip, travel distances can again be reduced.

Given that most travel is undertaken by car, reductions in vehicle kilometres is probably the single best proxy target for lowering emissions by shortening trip lengths and/or increasing trip chaining. Achieving reductions in vehicle kilometres by such means requires the structure of our cities to change considerably, so that more people live closer to where they work and play. Most Australian capital cities are aiming to achieve more compact settlement patterns, but low density growth on the fringe is still the dominant pattern. Progress in implementing more compact urban settlement patterns needs to be accelerated, to help reverse emission trends.

A 10% reduction of car vehicle kilometres, from shorter trip lengths and greater trip chaining, deriving ultimately from more clustered urban activity patterns, would contribute 3.5 Mt towards the 36 Mt reduction target.

3.1.3 Increase public transport's mode share of urban travel

Public transport typically carries between about 6 and 11% of motorised trips in Australian cities (depending on the city). The Victorian Government has adopted a target to raise this share to 20% by 2020 in Melbourne. While some commentators have dismissed this target as aspirational, Melbourne's public transport patronage is presently growing at around 8% per year, which is about the rate required to achieve the 20% share. Strong public transport patronage growth is also being experienced in other Australian cities.

The prospects for a 20% mode share of motorised trips by 2020 would be enhanced if a comprehensive road pricing regime was to be introduced, including congestion charging, to make road users accountable for the full costs of their travel (including GHG emissions, air pollution costs, road damage, noise costs, accident costs that are external to insurance cover and congestion costs). For example, road traffic levels have dropped about 20% in London in that city's congestion charging area. Comprehensive road pricing schemes would produce much smaller impacts across the city as a whole than in the most congested locations. However, BIC believes that comprehensive road pricing would still be a significant driver of public transport use across a wide area. Complemented by substantial improvements in public transport service levels, including on-road priority, a 20% mode share target by 2020 is not impossible, particularly if fuel prices remain high.

Political will is central to reform of road pricing arrangements. While this will is not apparent in Australia at present, the rapidly growing interest in road pricing internationally and in Australia suggests that it will figure prominently on the reform agenda within the next 5-10 years.

Doubling public transport's mode share at a time when total trip numbers are increasing means that the numbers of trips catered for by public transport needs to more than double by 2020. This will require a considerable increase in infrastructure and services.

Metlink Victoria has undertaken an economic evaluation of a five year service improvement program for Melbourne, that program being very similar to the *Meeting our Transport Challenges* program subsequently implemented by the Victorian Government. It found that the Metlink Five Year

Program would deliver a benefit-cost ratio of about 3, with reductions in congestion costs being the largest single benefit item.

Congestion costs are projected by the BTRE to grow from \$9.4 billion in 2005 to \$20.4 billion in 2020 (BTRE 2007c). This suggests that the social returns from improved public transport services will continue to remain high.

An increase in public transport mode share is not emissions free. Peak period utilisation of public transport is high. To minimise the impact of public transport patronage increase on emissions, peak-spreading strategies would be needed in the short term, until infrastructure expansion strategies can be implemented.

Achieving a 20% public transport modal share of urban motorised trips by 2020 (or around 15% of all trips) would reduce GHG emissions in that year by about 2.6 Mt.

Note: For the purposes of comparing active transport and public transport mode shares, public transport mode share figures quoted later in this document refer to the mode share of all trips (motorised and non-motorised).

3.1.4 Increase urban car occupancy rates

Car occupancy rates are typically low in Australia. For example, the average occupancy rate in Victoria is about 1.4. However, morning peak occupancy rates on the Melbourne's freeways are a mere 1.14 (VicRoads 2007). With the high mode share performed by the car, increasing occupancy rates must be a real opportunity to cut emissions. This should be a major focus of policy attention. Because the car mode share is so high, a small increase in occupancy rates achieved through trip sharing delivers important emission reductions.

Transit lanes that give priority to high occupancy vehicles must become commonplace in our cities, to encourage ride sharing and greater use of public transport. Allowing cars with three or more people to travel in these lanes, or occasionally two or more, and ensuring that transit lanes achieve much faster travel times than remaining lanes, would provide an incentive to increase occupancy. Also, motoring associations should promote a campaign among their members to car share as a more usual practice, raising awareness of the greenhouse benefits of this practice.

If the average car occupancy rate was increased from an estimated current 1.4 to 1.6 persons per car, this would cut GHG emissions in 2020 by around 3 Mt. Higher increases in occupancy rates would, of course, deliver even larger savings.

3.1.5 Reduce forecast fuel use for road freight

Freight movements are projected by BTRE (2007) to continue strong growth, doubling between 2000 and 2020. While freight tonnes moved have been growing roughly in line with economic growth, freight tonne-kilometres have grown twice as fast, as shown in Figure 3.3. While some of this growth in tonne-kms will be accounted for by long travelling distances in larger cities, it suggests there are real and significant opportunities to meet the same freight task more efficiently.

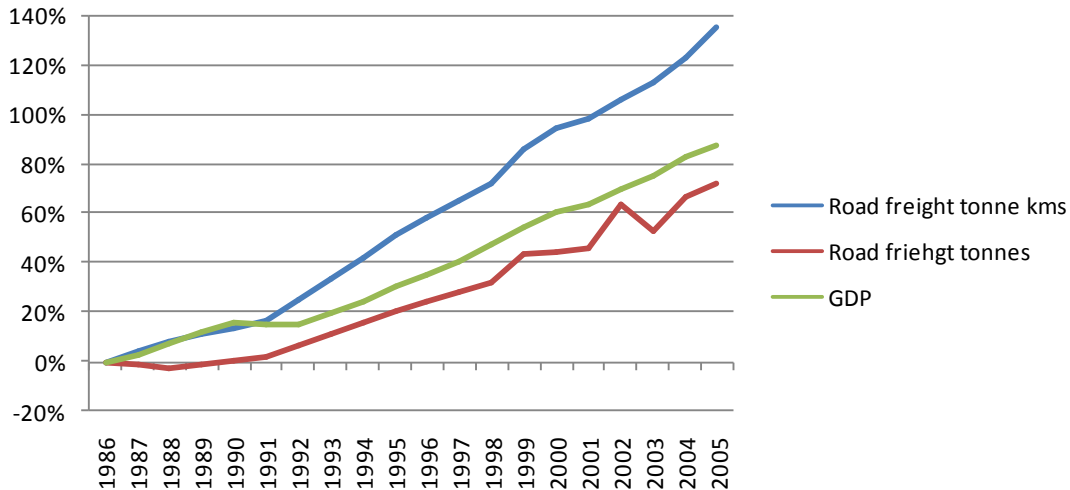


Figure 3.3 - Growth in road freight tonnes, road freight tonne kms and GDP since 1986

Two major opportunities here are improving the efficiency of truck movements and shifting greater volumes of freight onto rail.

Road freight efficiency can be improved in many ways. One important way is through use of higher capacity vehicles, utilising performance-based standards if needed to extend beyond general access requirements. Australia has led the way in terms of development of such vehicles. Facilitating greater innovation in vehicle design, while developing infrastructure (e.g. bridges) that is more suited to higher payloads, is an important way to allow fewer, more efficient trucks on the roads, and reduce emissions on a per tonne-kilometre basis.

Also, higher utilisation of trucks through better scheduling would reduce the number of unproductive trips. Surveys taken of trucks operating around the Port of Melbourne show that, on average, half the container slots were empty, and 37% of container trucks carried no containers at all (PMC 2006). Increased back-loading, through more integrated scheduling, could increase truck utilisation, reducing emissions from unproductive trips. In addition, shifting freight traffic from congested peak periods to other times of the day would also result in lower emissions.

Improving distribution networks can also reduce the kilometres of travel required to meet the freight task. Consolidation of distribution centres can mean that freight might travel from a supplier located on the eastern side of a city to a distribution centre on the western side, only to be shifted back again to a customer on the eastern side – many more kilometres than is actually necessary. Reversing the trend towards consolidation and/or improved logistics scheduling could reduce the number and length of movements required to meet the same freight task, resulting in fewer emissions per tonne moved. This would be encouraged by road pricing reform.

As noted above, fundamental to efficient resource use in transport is a pricing system that requires users to meet the marginal costs attributable to their travel decisions. Road use lacks such a system. While the national road pricing system implemented by the National Transport Commission is structured to charge heavy vehicles for their road damage costs, subject to some charge averaging provisions, other external costs of road use are completely ignored by pricing systems. These external costs are particularly substantial in congested urban areas, which account for 50% of total truck kilometres, and 62% of light commercial vehicle kilometres.

BIC (2001) estimated average external costs of articulated truck use in urban areas at 49-73c/L, **excluding congestion costs**. These costs would be considerably higher today. Congestion costs are

the largest single external cost of urban road use and would more than double the external costs of articulated truck use in peak periods. None of these external costs are charged to truck use, except for road damage costs. It is no surprise, therefore, that urban truck use is growing strongly.

Reform of road pricing arrangements is fundamental to reducing GHG emissions. If external costs were charged for road use by trucks, more intermodal freight hubs would suddenly become financially viable and the rate of growth of road freight would reduce, as logistics processes were reviewed, with corresponding reductions in GHG emissions.

To substantially cut transport emissions, rail must also play a much larger role. Critical to achieving a larger role for rail is fast-tracking the establishment of inter-modal freight terminals in our major cities, especially in relation to port and interstate freight movements, which would be assisted by reform of road pricing.

Improved inter-capital rail infrastructure for containerised freight is also important in achieving this change in mode split. The inter-modal freight hubs can thus play a distribution role for access/egress legs of such longer journeys, as well as in facilitating a larger rail share of the port traffic.

A recent study for QR Network Access highlighted the greenhouse gas emissions resulting from rail and road based inter-capital transport. Figure 3.4 shows the average greenhouse gas emission intensity across all routes studied.

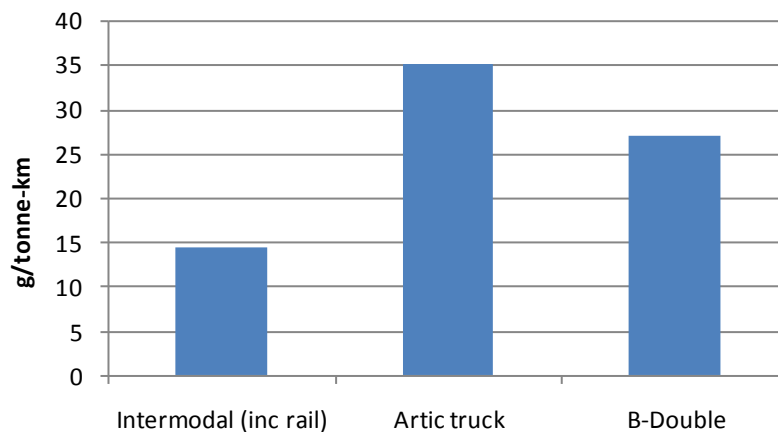


Figure 3.4 - Average greenhouse gas emission intensity on major inter-capital freight routes in Australia (source: BusVic analysis of QR Network Access 2002)

We assume sufficient improvements in truck productivity, scheduling and a mode shift to rail to deliver a 20% reduction in fuel use required to meet the forecast freight task, which translates to an emissions saving of 11.7 Mt in 2020. This emissions saving is made prior to efficiency improvements detailed below.

3.1.6 Improve vehicle efficiency

Bureau of Transport and Resource Economics research suggests that the overall fuel intensity of Australian road transport has shown little change over the 1990 to 2006 period (refer Figure 3.5). For example, average fuel economy for cars has fallen a bare 5% since 1990. For light commercial vehicles, the reduction was even less.

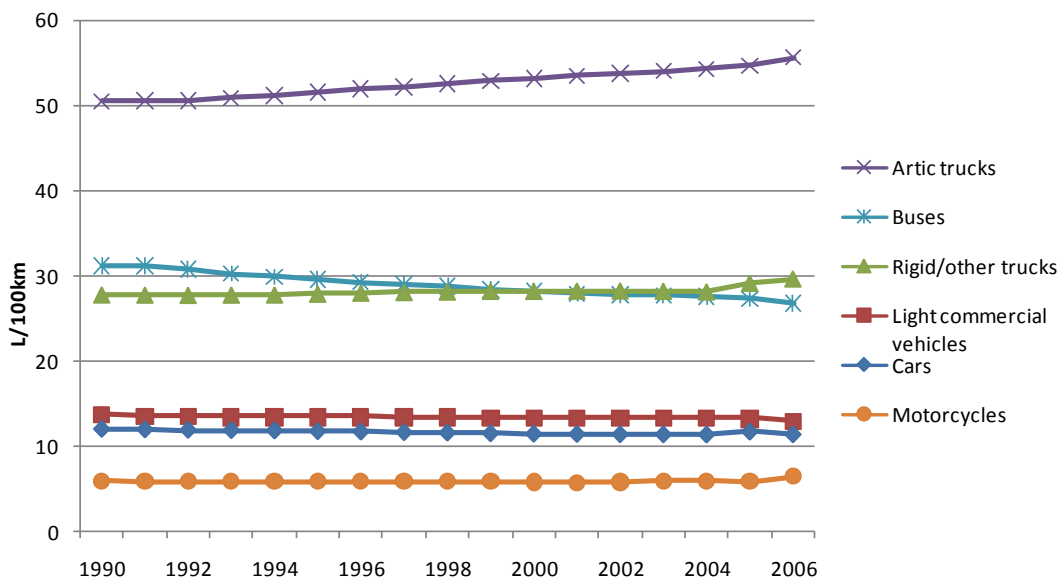


Figure 3.5 Australian Fuel Consumption rates (sources: BTRE 2007b & ABS 2007)

Changes in the vehicle mix within individual categories influences this outcome but aggregate fuel economy performance has made little contribution to lowering the GHG emissions from road transport. While engines are becoming technically more efficient, Australians are buying larger vehicles, offsetting the potential fuel savings. And many governments continue to add six cylinder vehicles to their fleets.

Figure 3.6 shows Australia’s emissions targets are still above those adopted by Japan, China and Europe. BIC is of the view that mandatory targets will be required to ensure more aggressive targets will be met.

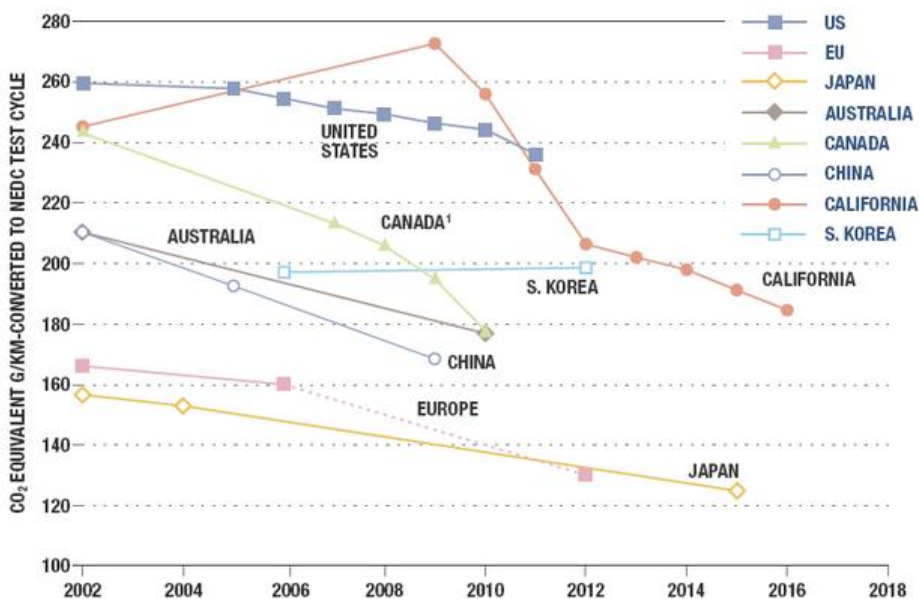


Figure 3.6 – Motor car emissions targets for various countries (source: An et al 2007)

In framing this initial set of options, the BIC approach has been to use vehicle fuel efficiency as the “gap filler”, between the overall reduction target that is being sought and the cumulative contribution from the preceding five initiatives.

A 30% reduction in average car fuel economy, and an 18% reduction in average freight vehicle fuel economy, would lower GHG emissions in 2020 by about 10 Mt CO₂e, once allowance is made for the changes already included above. This seems quite modest but, in view of the aggregate performance cited above for the 1990 to 2006 period, mandatory fuel efficiency standards are likely to be needed to deliver this outcome

For cars, the fleet average emissions intensity would need to drop from the current average of 220 g/km (11.4 L/100km) to around 151 g/km by 2020 (or 8.1 L/100km) to provide a 30% reduction.

The City of London’s Climate Change Action Plan highlights that emissions from new vehicles would fall by as much as 30% if people simply bought the most fuel efficient vehicle in each class (Greater London Authority 2007). If you took this further and influenced buying habits towards smaller cars, then emission reduction would be even greater - and that’s before considering new technology such as hybrid electric engines.

Another source of vehicle emissions intensity reductions is through driving efficiency training programs, particularly for professional drivers, where fuel savings of around 20% are not uncommon from driving vehicles in a smoother, and more fuel efficient manner.

3.2 Overall impact

Figure 3.7 and Table 3.1 show how the six components considered above combine to deliver the 36 Mt CO₂-e total reduction that is being sought.

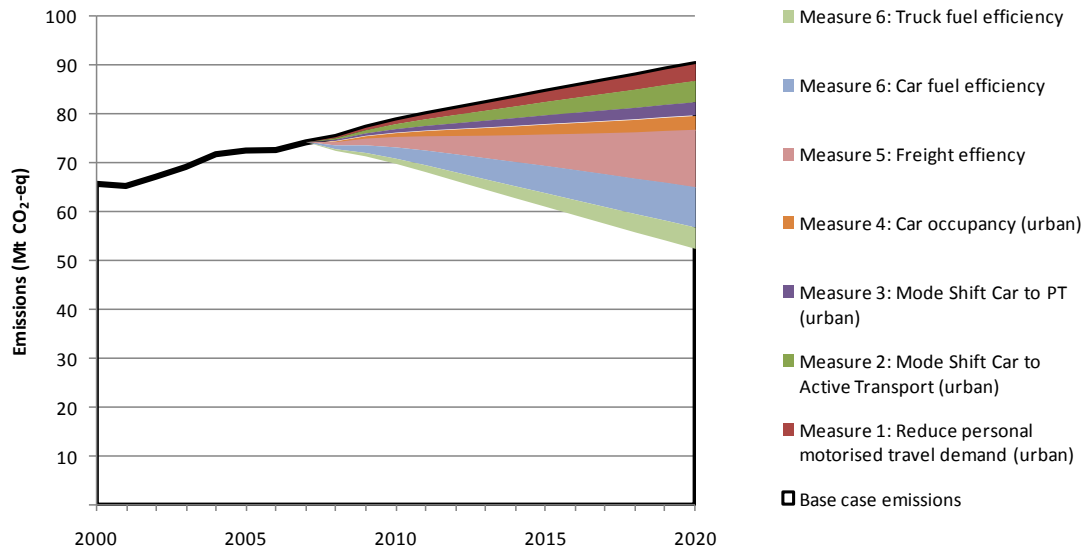


Figure 3.7 – Australian road transport emissions after six measures applied

Table 3.1 - Emissions savings (from forecast) from further reduction measures to achieve a 20% reduction on 2000 levels by 2020 (option A)

Measure	Target	2007	2020	Emissions saved (Mt)	Share of savings
1. Fewer/short car trips	Less car kms	-	10%	3.5	9.2%
2. Shift car to walking/cycling	Active transport mode share (urban)	16%	26%	4.4	11.6%
3. Increase public transport mode share	PT mode share (all urban trips)	7.5%	15%	2.6	7.0%
4. Increase car occupancy	Passengers/car	1.4	1.6	3.0	8.0%
5. Freight efficiency	Less fuel	-	30%	11.7	30.9%
6. Car Emissions intensity	Less than 2007	-	30%	8.2	21.8%
Truck emissions intensity	Less than 2007	-	18%	4.4	11.5%

These measures rely heavily on car and truck fuel efficiency improvements, which provide a third of the total emissions savings. The sheer size of our vehicle fleet means improvements in fuel efficiency have the greatest impact on emissions. Achievement of the indicated reductions would be assisted by changes in purchasing behaviour, such as reversing current trends toward large four wheel drive Sports Utility Vehicles.

Table 3.1 only describes one possible combination of measures that would achieve the nominated target, although it is a combination that BIC considers is feasible within the time frame, with concerted effort. To explore trade-offs between the measures, Table 3.2 shows alternative scenarios that achieve the same reductions target.

Table 3.2 – Alternative option sets to deliver a 20% reduction on 2020 levels for Australian Road Transport.

Measure	Target	2007	2020 (A)	2020 (B)	2020 (C)
1. Fewer/short car trips	Less car kms	-	10%	20%	25%
2. Shift car to walking/cycling	Active transport mode share (urban)	16%	26%	34%	39%
3. Increase public transport mode share	PT share of trips (all urban trips)	8%	15%	20%	21%
4. Increase car occupancy	Passengers/car	1.4	1.6	1.8	1.9
5. Freight efficiency	Less fuel than forecast	-	30%	30%	30%
6. Car emissions intensity	Less than 2007	-	30%	18%	13%
Truck emissions intensity	Less than 2007		18%	13%	8%

Table 3.2 shows that, if significant improvements in fuel efficiency are not achieved, very significant changes in travel behaviour – particularly mode choice – are required. Options B and C rely on much greater travel demand reduction and mode shift to active transport (car mode share is reduced from 77% to 48% in option B, and 40% in option C). This highlights the critical importance of achieving fuel efficient targets.

On the other hand, if fuel efficiency was to be the only method of emissions reduction, emissions intensity cuts of 54% for cars and 37% for trucks would be required over the entire fleet by 2020. Such large cuts would be extremely challenging given that a significant proportion of the current fleet will still be on the roads in 2020. This highlights the equally critical importance of travel behaviour changes for reducing emissions.

3.3 Emissions trading/carbon pricing

Australia is planning an emissions trading scheme as the centre-piece of its approach to cutting GHG emissions. How far might this go, on its own, to deliver the scale of emission reductions considered in this report?

Australian travel, both passenger and freight, is highly road-dependent. Fuel costs are a small proportion of the costs of such travel, with time costs typically being far more significant. As a consequence, the elasticity of demand for road travel with respect to changes in fuel prices tends to be low. Various studies of fuel price elasticities put short run values as low as -0.1 but long term values of the order of -0.6 to -0.7 are cited for petrol use by several sources (e.g. Goodwin et al 2003; Hagler Bailly 1999), including an Australian study by the then Bureau of Transport Economics (BTE 1991). Diesel use elasticities are typically lower, with Hagler Bailly (1999) citing values of around -0.4.

BIC has assumed long run elasticities for fuel use of -0.7, to suggest how carbon pricing might impact on fuel use and consequential GHG emissions. A carbon price of \$60/tonne is used in this assessment, since this figure is sometimes quoted as the level at which carbon sequestration might become economically viable. Also, McKinsey (2008) has recently estimated \$65/t as the marginal cost of reducing emissions in 2020 to 30% below 1990 levels. \$60/tonne would add about \$0.17/L to the price of petrol, a 12% increase on current prices of about \$1.40/L.

Applying an elasticity of -0.7 suggests a reduction in fuel use of only 8%, which is nowhere near enough against the GHG emission reduction targets considered in this paper. For example, the achievement of 2020 emission levels 20% below 2000 levels requires an emission reduction of about

40%, as illustrated in Section 2.2 above. Much stronger interventions will be required to complement emissions trading, including investment in improved public transport services and infrastructure, urban design initiatives to facilitate greater walking and cycling, road pricing reform and regulatory change to facilitate emission reductions (e.g. mandatory fuel economy standards), as considered above.

3.4 Urban structure and transport greenhouse gas emissions

Many of the initiatives considered in this section of the report will benefit from urban development policies and plans that facilitate more compact urban settlement patterns. Such urban design will help to reduce travel distances (e.g. because of closer proximity of trip origins and destinations), make walking and cycling easier and improve the economics of public transport service provision.

An illuminating example of how urban development patterns and associated public transport service provision influence travel patterns is presented by Bento et al (2005). They examined the effects of urban form and public transport supply on travel mode choices and annual vehicle travel in 114 US cities. Population centrality, the jobs-housing balance, city shape and density were found to have a significant effect on the amount of vehicle travel. They illustrate this connection by pointing out that the effect of moving a sample of households from a city with measures of urban form and transit supply the same as those of Atlanta (733 persons per km²; 7000 rail miles of service/km²; 10,000 bus miles of service/km²) to a city with the characteristics of Boston (1202 persons/km²; 18,000 rail miles of service/km²; 13000 bus miles of service/km²) reduces annual vehicle travel by 25% (from 16,899 miles per household per annum to 12,704). It reduces the probability of driving to work from 0.87 to 0.73, a very substantial drop. They point out that this reduction is driven by differences in public transport supply, city shape and especially in population centrality (essentially compactness).

While individual factors have only small impacts in the analysis by Bento et al, the joint impact of the various factors is significant, emphasising the importance of taking an integrated and systemic approach, to reducing transport GHG emissions, including both land use and transport elements. While urban structure only changes slowly, long term approaches must be taken to deliver substantial emission cuts and this will require land use to play a central role.

3.5 Equity implications

Research by the National Institute of Economic and Industry Research (2007) for the Brotherhood of St Laurence has demonstrated that carbon pricing regimes will have regressive distributional impacts. This concern has been noted by Garnaut in his Interim Report (Garnaut 2008). A relatively high reliance on car travel, and the impact of carbon pricing (or emissions trading) on fuel costs, is one way in which this regressive impact emerges.

BIC has argued that an increased public transport mode share is one very important way in which road transport GHG emissions can be reduced. This increased mode share should be pursued through two major policy and program emphases:

1. a mass transit agenda that primarily seeks to shift car users on to public transport, to reduce congestion costs and the environmental impact of car travel;
2. a social transit agenda, which aims to ensure that all people have access to a decent base level of mobility, irrespective of their personal circumstances.

By carefully framing the service improvement packages under these respective heads, the travel needs of disadvantaged people can be given high priority, to help to mitigate the regressive impacts of carbon pricing on fuel costs. In particular, bus service improvements in outer suburbs of our cities (and regional areas) will be central to this approach, as argued recently by Professor Graham Davison of Monash University (The Age, 30th March, 2008, p. 19):²

Too much recent debate has centred on big-ticket solutions to ease congestion in the inner city, through road tunnels or underground railways; too little on developing lower cost public transport solutions for the car-dependent outer suburbs. It's no longer good enough to release new residential land without a transport plan. And it's time someone looked again at our ossified suburban bus system. After all, it's in the outer suburbs that the poorest people now live and, as Ross Garnaut observed last week, that's where the high cost of our addiction to automobility is likely to be felt most acutely.

² Professor Davison is author of the book, Car Wars: How the Car Won Our Hearts and Conquered Our Cities, published by Allen and Unwin.

4 Meeting 2050 reduction targets

As noted previously, there is no necessary reason why each sector should cut GHG emissions by the nationally adopted target rate for any point in time. Achieving the most economically efficient outcome across the economy as a whole will almost certainly deliver a different result for each sector. However, it is illuminating to apply a possible national target to the key sectors, to assess whether there is a prospect of such target being achieved and, if so, under what circumstances. This may help to provide a source of comfort, or conversely of discomfort, with the national target. Equally, it can be argued that the big emitters, like road transport, need to be active pursuers of emission reduction, because their contribution to the overall problem is substantial. For both of these reasons, BIC has tried to identify the broad implications for the road transport sector of an 80% reduction target for 2050, against 2000 emission levels.

To shed light on what might be needed, BIC has developed a few broad scenarios which all deliver an 80% target cut in projected GHG emissions by 2050. Compared to the 2020 options that were presented, the 2050 variants impose much tougher restrictions. Because of the critical role of vehicle emissions in driving total road transport GHG emissions, three scenarios have been developed which vary in the degree of fuel efficiency improvement delivered by 2050. These scenarios are labelled in Table 4.1 as “extreme efficiency”, “very high efficiency” and “high efficiency”.

Table 4.1 - Road transport emission reduction scenarios that achieve an 80% cut below 2000 levels by 2050.

Measure	Target	2007	2020 (option A)	2050 Extreme efficiency	2050 Very high efficiency	2050 High efficiency
1. Fewer/short car trips	Less car kms	-	10%	10%	25%	30%
2. Shift car to walking/cycling	Active transport mode share (urban)	16%	26%	29%	45%	53%
3. Increase public transport mode share	PT mode share (all urban trips)	7.5%	15%	16%	33%	38%
	Car mode share	77%	59%	57%	23%	11%
4. Increase car occupancy	Passengers/car	1.4	1.6	1.7	2.6	2.8
5. Freight efficiency	Less fuel	-	30%	30%	60%	80%
6. Car emissions intensity	Less than 2007	-	30%	92%	84%	75%
	g/km	220	155	18	36	54
Truck emissions intensity	Less than 2007		18%	89%	83%	75%

Source: BIC projections.

The 80% target, not surprisingly, poses some very tough questions in terms of the future role to be played by cars and trucks. To illustrate the reason why the requirements are tough, with

- traffic projections suggesting that road traffic volumes might double, or more, by 2050 and
- a target of an 80% reduction in transport GHG emissions on 2000 levels by 2050,

projected emissions would need to fall by 90% or more per unit of travel distance for the road traffic projections to be consistent with the GHG targets.

Anything less than this and there is a clear incompatibility between the traffic projections and emissions targets. That incompatibility can only be resolved by

- lowering the traffic projection
- significantly changing travel behaviour to increase the role of low carbon modes,
- achieving greater emissions reductions in other sectors, or by
- lowering the target.

The Intergovernmental Panel on Climate Change has estimated what emissions intensity cuts may be achieved in coming years, using different fuel and engine combinations (Table 4.2).

Table 4.2 – Reduction of well-to-wheels greenhouse emissions for various drive train/fuel combinations

		Drive train/Fuel	GHG reduction (%)	Barriers
ICE	Fossil fuel	Gasoline (2010)	12-16	
		Diesel	16-24	Emissions (NO _x , PM)
		CNG	15-25	Infrastructure, storage
		G-HEV	20-52	Cost, battery
		D-HEV	29-57	Cost
	Biofuel	Ethanol-Cereal	30-65	Cost, availability (biomass, land), competition with food
		Ethanol-Sugar	79-87	
		Biodiesel	47-78	
		Advanced biofuel (cellulosic ethanol)	70-95	
	H ₂	H ₂ -ICE	6-16	H2 storage, cost
			Cost, infrastructure, deregulation	
FCV		FCEV	43-59	Technology (stack, storage), cost, durability
		FCEV+H ₂ ccs	78-86	
		FCEV+RE-H ₂	89-99	

Source: Kahn Ribeiro et al (2007), table 5.3.

Note: ICE = Internal combustion engine, FCEV = fuel cell electric vehicle, CNG = compressed natural gas, G-HEV = gas hybrid electric vehicle, D-HEV = Diesel hybrid electric vehicle, H₂ccs = hydrogen produced with carbon capture and storage. RE-H₂ = hydrogen produced from renewable energy.

The IPCC work shows that lifecycle GHG emissions of internal combustion engine (ICE) vehicles using biofuels and fuel cell vehicles (FCV) are dependent on the fuel pathways (Kahn Ribeiro et al 2007). While ICE-Biofuel CO₂ emission reduction potential is very large (30-90%), world potential is limited by high production costs for several biomass pathways and land availability (with demand for competing uses such as food). GHG reduction potential of natural gas sourced hydrogen fuel cell vehicles is moderate but lifecycle emissions can be very substantially reduced by using carbon capture and storage technology (FCEV-H₂ccs in Table 4.2). Using renewable energy such as clean energy can also help to deliver very substantial cuts.

Substantial research, development and implementation of new technologies is required to deliver the high end GHG emission reductions implied in Table 4.2, with some tough questions still needing answers (e.g. when CCS technology might be commercially available in Australia). For Victoria in particular, reliance on electric generation poses greater challenges given the State's current reliance on brown coal.

Table 4.1 shows three varying rates of improvement in car and truck emission intensity. Slightly greater improvements are included for cars than for trucks, because the Australian car fleet is relatively higher in emission intensity, compared to overseas cars, than our truck fleet, because of

the high reliance on imported chassis for trucks (and buses). This creates greater relative opportunities for improving car emissions (e.g. by importing more fuel efficient overseas models if they are not available locally).

Our “extreme efficiency” scenario, which embodies assumptions of 92% improvement in car emissions performance and 89% in truck performance over 2007, does not require huge gains in public transport mode share or in walking/cycling or reduced travel to achieve the 80% sectoral target. However, the other two scenarios show that any percentage point shortfall on emissions intensity achievement requires very large gains in the other initiative areas if 80% is to be anything more than a dream. For example, with a still substantial 75% improvement in car and truck emissions performance by 2050 (the “high efficiency” scenario), achieving the overall 80% target requires huge increases in public transport mode share, car occupancy rates, freight efficiency, the mode share of walking and cycling and large reductions in travel distances. All the scenarios are consistent with cities that are more compact than today, with the “high efficiency” scenario requiring the greatest increases in density to be achievable.

The 2050 target sets a clear challenge for Australia’s road transport sector. Massive technological change and equally massive change in travel behaviour, and the drivers thereof, are in prospect, or else the road transport sector will depend significantly on others to pick up what might be regarded as its responsibilities to clean up its greenhouse act!

5 Conclusions

5.1 Pathways to emission reduction

Australia's road transport sector is a major contributor to the nation's GHG emissions and road transport emissions are growing rapidly. Achieving major reductions in GHG emissions from the road transport sector must therefore be a central part of any national effort to cut such emissions.

A national Emissions Trading Scheme is a central part of Australia's response to combating climate change. BIC strongly supports this approach. However, our analysis suggests that an ETS by itself will only slow the rate of growth of road transport GHG emissions. Achieving reductions in road transport GHG emissions will require a much broader policy response.

Reducing road transport GHG emissions will require step changes in the conditions underlying personal and freight mode choices and in fuel efficiencies. However, BIC believes that the magnitude of changes that would be required to achieve the interim targets discussed in this paper, of a 20% reduction on 2000 emissions by 2020, is realistic and achievable, but only if an early start is made.

The 2050 indicative targets of an 80% cut on 2000 emissions are another matter. The changes implied by such a target appear to be beyond the realm of what it is possible to imagine at present from our road transport sector. They will require technological and behavioural shifts of momentous proportions.

BIC research has identified nine key areas from which emission reduction can be achieved, to complement gains from an ETS. These are:

1. Comprehensive road pricing
2. Increased investment in public transport
3. Major investment in walking and cycling
4. More compact, walkable urban settlements
5. Significantly improve fuel efficiency (mandatory targets)
6. Invest in rail freight and intermodal hubs
7. Freight efficiency (e.g. more productive vehicles; changed delivery times)
8. Reallocate road space to prioritise low emission modes
9. Behaviour change programs

5.2 Three key drivers

Three areas are of critical importance: vehicle emissions intensity, urban structure and road pricing. These drive so much of what is possible (including among the elements within the nine points listed).

5.2.1 Vehicle emissions technology

Technology has not contributed much to transport emission reduction over the period since 1990. Improved fuel efficiencies at the individual vehicle level have been offset by changes in purchasing patterns, which have favoured more fuel intensive vehicles. Much greater contributions from the technology front will be needed to drive pursuit of longer term emission targets, to complement the early contribution from behaviour change. Our analysis suggests that the more stringent the reduction targets, the greater the technological breakthroughs that must be achieved.

Current institutional arrangements on fuel economy standards, together with consumer vehicle choices, are not delivering sufficient downwards impetus to road transport GHG emissions. BIC believes that tough mandatory emission standards will be needed to achieve the major reductions required by the emissions targets considered in this paper. Europe is showing a more progressive approach, from which Australia should learn. Australia should harmonise with Europe on GHG emission limits for new vehicles.

5.2.2 Urban structure and infrastructure planning

Changes to settlement patterns are also crucial to what is possible in terms of emission reductions. Continued urban development at low density is a recipe for failure in meeting emission reduction targets and will accentuate the likely regressive impacts of emissions trading (carbon pricing).

Infrastructure development programs to encourage more compact settlement patterns, suited to use of low impact travel options like walking, cycling and public transport, must become the norm. Planning and investment processes must push development in this direction with more vigour than has been shown in past Australian urban development. Recently announced plans for major rail developments are encouraging in this regard. They must be supported by linked feeder bus service expansions. In areas where rail is uneconomic, which is most of Australia, bus services must play a substantially larger role in helping to cut emission levels.

The new Federal body, Infrastructure Australia, should ensure that, in proposing future infrastructure priorities, achieving national GHG reductions targets is of paramount importance in project generation. Assessing the implications of new infrastructure works on GHG emissions will rarely show much benefit. However, designing transport networks from first principles to maximise the possibility of reducing road transport GHG emissions is likely to show real potential. It will focus attention on the importance of reducing the need to travel, on providing options for travel in a more environmentally friendly manner.

5.2.3 Road pricing

Reforming transport pricing arrangements in Australia is also central to achieving substantial cuts in GHG emissions. While putting a price on carbon will directly increase transport costs and reduce the demand for travel, reforming transport pricing involves much more than carbon pricing. There is a wide range of external costs of transport, particularly road transport, which are not met by road users, resulting in excessive levels of traffic. Congestion pricing, in particular, should complement measures to price carbon. Other external costs that should be rolled up in reformed transport pricing include that part of accident costs which is met by the wider community, air pollution costs and noise costs. Incorporating these costs into user charges for road use will mean that the price of public transport can also better reflect the costs of service provision, except where governments

decide that service levels should be provided as a community service obligation. The result will be a more rational set of travel choices, reduced demand for new infrastructure, and achievement of significant economic benefits through lower congestion costs, as well as lower GHG emissions.

5.3 Wider benefits

Implementing the wide range of policy initiatives that will be required to cut road transport GHG emissions will not be cheap. However, the benefits of these initiatives will range far wider than just GHG benefits. They will include very substantial benefits from

- cutting road congestion costs
- lowering air pollution levels and reducing traffic noise
- cutting accident costs
- increasing social inclusion and, very importantly,
- improving the liveability of our communities.

BIC strongly recommends that these wider requirements for cutting road transport GHG emissions are included in the final Garnaut report. This will increase the prospects for delivering emissions reductions of some consequence.

References

An, F; Gordon, D; He, H; Kodjak, D; Rutherford, D (2007), Passenger Vehicle Greenhouse Gas and Fuel Economy Standards: A Global Update, July

Australian Bureau of Statistics (2007), Survey of Motor Vehicle Use, Australia, 12 months ended 31 October 2006, Australian Government, October

Australian Greenhouse Office (2006), *Transport Sector Greenhouse Gas Emissions Projections 2006*, Australian Government, December.

Bento, AM, Cropper, ML, Mobarak, AM and Vinha K (2005), The Effects of Urban Spatial Structure on Travel demand in the United States, *The Review of Economics and Statistics*, 87(3), 466-478.

Bureau of Transport Economics (1991), Demand Forecasts and Demand Elasticities for Australian Transport Fuel, Occasional Paper 103, Canberra.

Bureau of Transport and Regional Economics (BTRE) (2005), Is the World Running Out of Oil? A Review of the Debate, *Working Paper 61*, February

Bureau of Transport and Regional Economics (BTRE) (2007a), Freight Measurement and Modelling in Australia, *Report No. 112*, BTRE

Bureau of Transport and Regional Economics (BTRE) (2007b), Projections of Australian Transport Emissions to 2020, Draft Report for Australian Greenhouse Office
Department of the Environment and Water Resources, August (unpublished)

Bureau of Transport and Regional Economics (BTRE) (2007c), Estimating urban traffic and congestion cost trends for Australian cities, Working Paper 71, June

Bus Industry Confederation (2001), *Getting the prices Right*, Submission by the Bus Industry Confederation to the Commonwealth Fuel Tax Inquiry, October.

Department of Climate Change (2008), *Transport Sector Greenhouse Gas Emissions Projections*, Canberra.

Department of Infrastructure (DOI) (2008), Transport Demand Information Atlas for Victoria 2008, Volume 1: Melbourne, A compendium of statistics and information, February.

Garnaut Climate Change Review (2008), *Interim Report to the Commonwealth, State and Territory Governments of Australia*, February.

Goodwin, P, Dargay, J, and Hanly, M (2003), Elasticities of Road Traffic and Fuel Consumption With Respect to Price and Income: A review, ESRC Transport Studies Unit, University College London (www.transport.ucl.ac.uk), commissioned by the UK department of the Environment, Transport and the Regions.

Greater London Authority (2007), Action Today to Protect Tomorrow, The Mayor's Climate Change Action Plan, February.

Hagler Bailly (1999), Potential for Fuel taxes to reduce Greenhouse Gas Emissions from Transport, Transportation Table of the Canadian National Climate Change Process (www.tc.gc.ca/Envaffairs/subgroups1/fuel_tax/study1/final_Report/Final_Report.htm)

Kahn Ribeiro, S., S. Kobayashi, M. Beuthe, J. Gasca, D. Greene, D. S. Lee, Y. Muromachi, P. J. Newton, S. Plotkin, D. Sperling, R. Wit, P. J. Zhou, 2007: Transport and its infrastructure. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

McKinsey & Company (2008), An Australian Cost Curve for Greenhouse Gas Reduction. www.mckinsey.com/locations/australia_newzealand/knowledge/pdf/1802_carbon.pdf. Accessed 31st March 2008.

National Institute of Economic and Industry Research (2007), The Impact of Carbon Prices on Victorian and Australian Households, Report for the Brotherhood of St Laurence, May.

Port of Melbourne Corporation (2006), Port Development Plan, Consultation Draft, August

QR Network Access (2002), Comparison of Greenhouse Gas Emissions by Australia Intermodal Rail and Road Transport, report by Affleck Consulting Pty Ltd, Brisbane, available at: http://www.networkaccess.qr.com.au/Images/Emissions_tcm10-2847.pdf

Stern Review (2006), The Economics of Climate Change. www.hm-treasury.gov.uk/media/8AC/F7/Executive_Summary.pdf, accessed 11/01/2007.

van der Ploeg HP, Merom D, Corpuz G, Bauman AE (2008). Trends in Australian children travelling to school 1971-2003: burning petrol or carbohydrates?, Preventive Medicine; 46: pages 60–62, available at: <http://www.transport.nsw.gov.au/tdc/documents/trends-in-school-travel.pdf>

VicRoads (2007), Traffic System Performance Monitoring 2005/2006, Information Bulletin.