Climate Policy at the Junction

The role of transport in preventing dangerous climate change

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1 EMISSION TRENDS

1.1 Emission cuts need to be deeper, sooner

Intergovernmental Panel on Climate Change (IPCC) Assessment Reports are justifiably regarded as authoritative, however it is also increasingly recognised that they do not represent the leading edge of climate science due to the long delays built into the drawn-out peer review process and the political interference of some member governments (Adam & Traynor 2007; Zarembo & Maugh 2007).

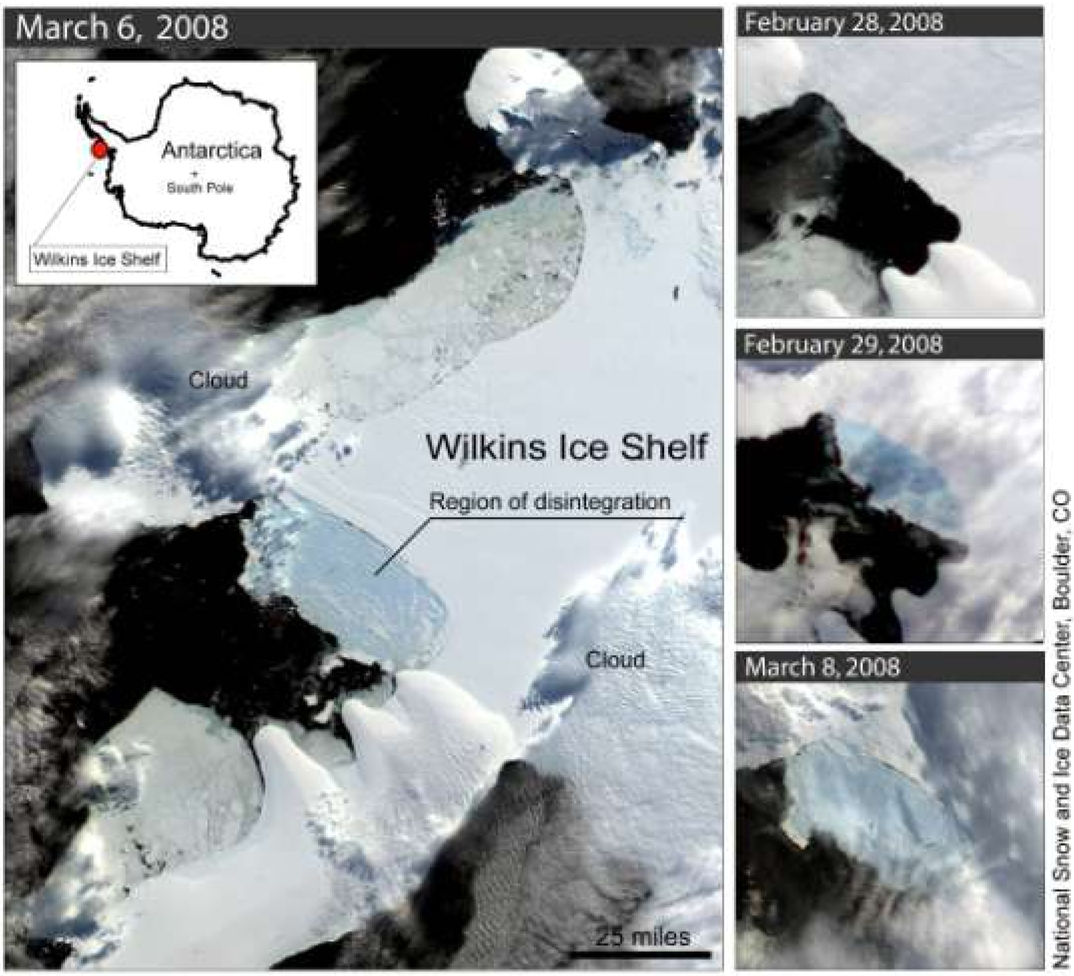
Research that emerged too late for inclusion in the latest IPCC Assessment Report is now painting a picture of natural systems undergoing significant and rapid change (Spratt & Sutton 2008; Darby 2008). Many of these changes herald the initiation of serious positive feedback loops such as the melting of ice caps (and associated 'albedo flip'), the thawing of high latitude permafrost and added stress on natural carbon sinks that face increasing drought and bushfires.

In some ways the rapid pace of polar ice loss and other signs of warming should not be surprising. Global emissions and average temperatures are surpassing even the most pessimistic predictions of the IPCC and serve as a warning that the situation is much more serious and urgent than many people recognise (Rahmstorf *et al* 2007).

Extreme weather events such as cyclones and other storms, floods, droughts and heatwaves are more frequently showing Australians the consequences of rampant emissions growth. A rapid reduction in emissions down to levels at which natural sinks can absorb excess carbon is now seen as a necessity to prevent significant risk of catastrophic climate change (Spratt & Sutton 2008; Matthews & Caldeira 2008). The scale and the speed of the required cuts in emissions go well beyond current policy in Australia.

The non-linear nature of many climate processes, such as the feedbacks mentioned above, also mean that it is extremely foolhardy to talk of 'balancing' emission cuts with economic growth or continuing high levels of motor vehicle use (Barker *et al* 2007; Hansen *et al* 2007). It is not enough to be 'a little bit sustainable' as this effectively condemns us to dangerous climate change. The stability of the global climate and of the social and economic systems that rely upon it are dependent upon rapid decarbonisation of society and the economy.

Figure 1.1: The rapid disintegration of the Wilkins Ice Shelf, Antarctica



Source: National Snow and Ice Data Center/NASA

The Interim Report of the Garnaut Climate Change Review has proposed four possible emission paths: business as usual; partial *ad hoc* mitigation; effective firm global mitigation (550ppm) and effective ambitious mitigation (450ppm). In light of the latest scientific evidence on accelerating climate change, we propose a fifth path: prudent science-based mitigation (~350ppm). Clearly there is some degree of overshoot associated with this path, however there is credible evidence pointing to this as a requirement to avoid dangerous climate change (Weaver *et al* 2007; Hansen *et al* 2008), and it is important that we know how to get there sooner rather than later.

1.2 The impact of transport is often underestimated

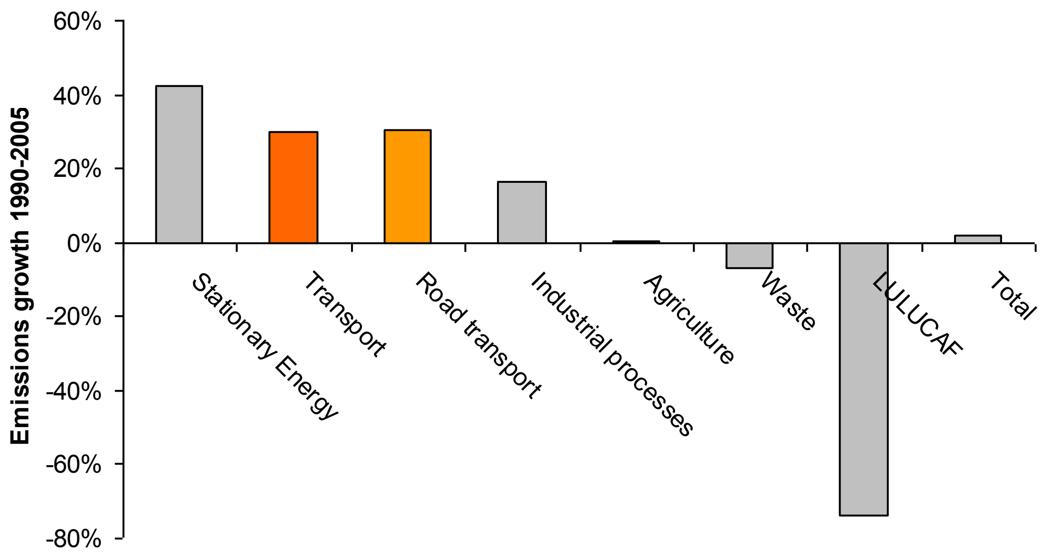
1.2.1 Transport is already a major source of emissions

1.2.1.1 Current emissions trajectory

> "Transport emissions are one of the strongest sources of emissions growth in Australia"
> (National Inventory Report 2005)

The transport sector is one of the largest and fastest growing sources of emissions in Australia. If the Australian transport sector were a country, it would be one of the world's top 50 greenhouse polluters. Based on the sector's average growth rate over the last 15 years, transport emissions in 2050 will go close to the *total* level of emissions allowed across *all* sectors under a weak 60% emissions reduction target[1]. This rapid growth in transport emissions could place additional pressure on other sectors to seek increasingly costly abatement options in order to keep the economy within the overall carbon budget, and would make stronger targets impossible to achieve.

Figure 1.2: GHG emissions growth 1990-2005



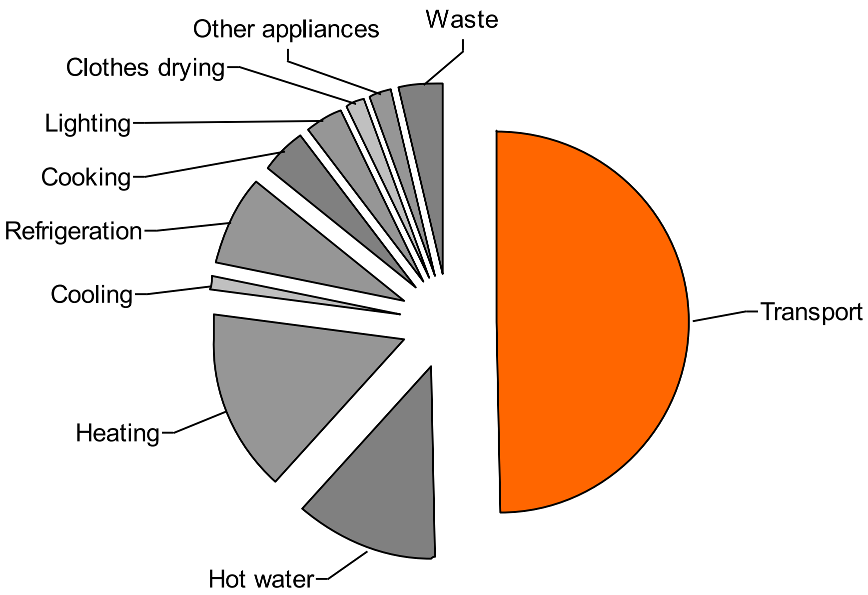
Source: Australian Greenhouse Office

Transport is also the dominant source of emissions for most households. Transport emissions from a typical household can be nearly 20 times higher than emissions resulting from lighting which is the target of the incoming ban on incandescent light bulbs. This makes transport one of the most significant

[1] Based on Kyoto accounting. As discussed under Section 1.2.2, emissions across the full transport system cycle would probably exceed the entire national carbon 'budget'.

items that can be addressed by individuals and households - provided that government policy and programs support more sustainable transport choices.

Figure 1.3: Household emissions



Source: AGO/CSIRO: National Kilowatt Count of Household Energy Use, 2002

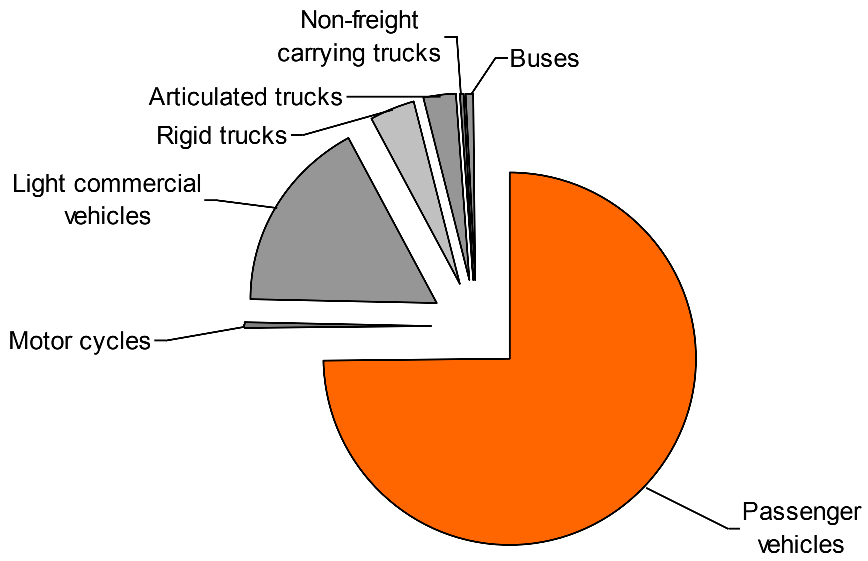
According to the Australian Greenhouse Office (AGO 2006) current measures, such as existing state government programs to improve public transport use, will only reduce transport emissions by 5% compared to 'business as usual'. There is a clear need for more ambitious measures to reduce transport emissions.

1.2.1.2 Cars are the dominant source of transport emissions

Passenger cars account for the vast majority of vehicle use in Australia (Figure 1.4), so it is hardly surprising that they are also responsible for the majority of GHG emissions from the transport sector (Figure 1.5). The large volume of cars on the roads is also the main cause of traffic congestion which increases the emissions intensity of *all* vehicles on the network (BTE 2000), including trucks and buses.

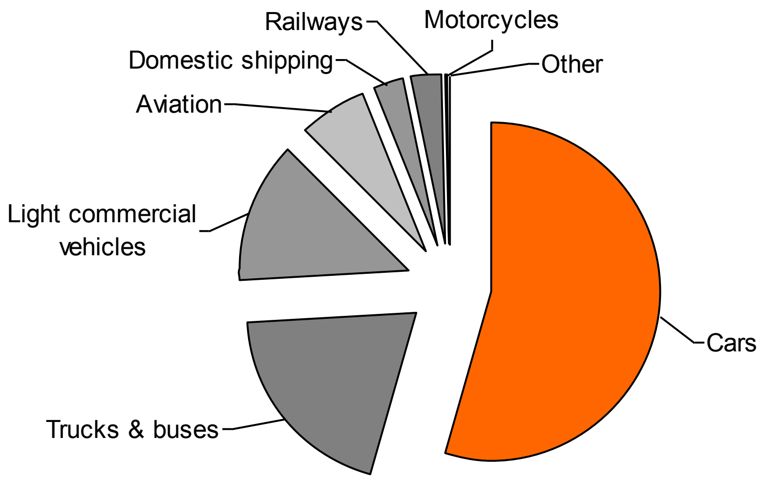
The bulk of road infrastructure expansion is also driven by the perceived need to cater for expanding traffic volumes. Whether such road expenditure is framed as improving the productivity of freight transport or improving road safety, the inescapable reality is that low-occupancy passenger vehicles dominate use of that infrastructure. As discussed in Section 2.5.2, road capacity expansion has been proven to encourage additional passenger and freight vehicle traffic and consequently increase transport emissions. By encouraging greater use of private vehicles, road infrastructure expansion also undermines the viability and quality of public transport and rail freight, leading to further modeshift away from low carbon modes towards private car use and road freight (Mogridge 1990; Lewis & Williams 1999; PTUA 2008, pp.15-17).

Figure 1.4: Share of vehicle kilometres of travel in Australia



Passenger cars make up three quarters of the traffic on Australian roads. The proportion is higher in urban areas where congestion is mostly concentrated.
Source: ABS 2007

Figure 1.5: Transport sector emissions in Australia (2005)



Source: Australian Greenhouse Office

1.2.2 "Other" emissions

1.2.2.1 Other sectors

A range of transport-related emissions are not allocated to 'transport' in many analyses of GHG emissions. These transport-related non-transport emissions would fall along with transport emissions if more sustainable transport patterns were adopted. These 'other' emissions include fugitive emissions from fossil fuel production and emissions resulting from the production of biofuels, vehicles and transport infrastructure. For example, use of natural gas may offer lower vehicle CO_2 emissions compared to diesel, however this would be offset by increased methane emissions from the natural gas supply chain (Weiss *et al* 2000). A proportion of emissions attributed to stationary energy, mining, agriculture and fugitive emissions could therefore be allocated to transport.

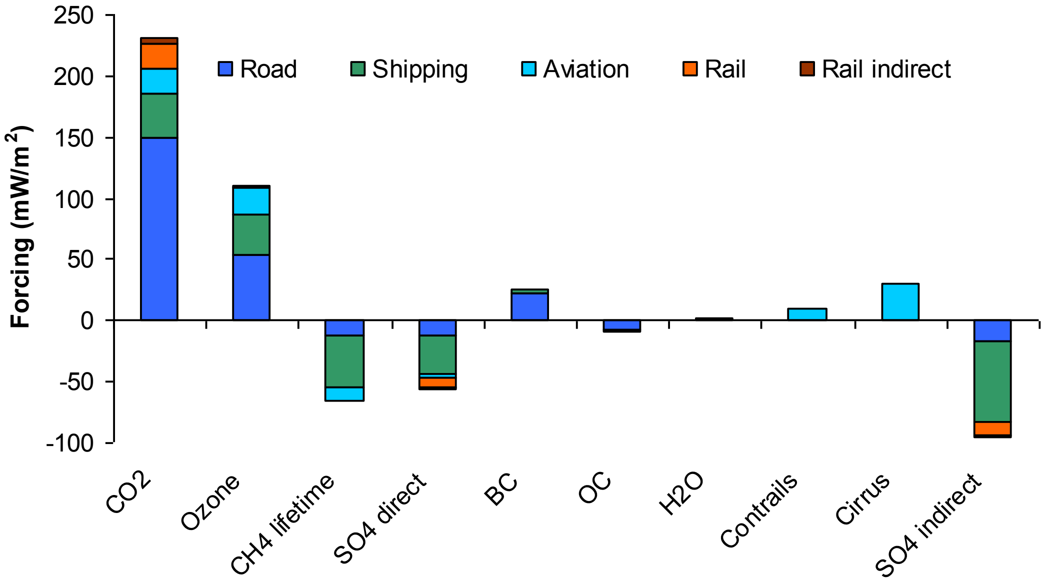
The BTCE (1995) estimated that emissions across the full transport system cycle are about one third greater than direct emissions resulting from end use. This adjustment would take transport-related emissions from about 80 million tonnes per annum to over 107 million tonnes per annum, which would be equivalent to doubling direct emissions from light commercial vehicles, heavy trucks and buses. On current growth trends it would also take full transport system cycle emissions in 2050 to over 230 million tonnes per annum, which is higher than Australia's entire national carbon 'budget' under a 60% emissions reduction target and over twice the total budget with an 80% reduction target.

1.2.2.2 Other gases

Although ozone in the stratosphere protects us from harmful solar radiation, ozone in the troposphere (lower atmosphere) is both a GHG and an air pollutant that is damaging to health and agricultural productivity (Shindell *et al* 2006). Although ozone *per se* is not covered by the Kyoto Protocol and ozone-causing emissions are not generally reported as GHG emissions, ozone is responsible for a significant proportion of the earth's warming (Marenco *et al* 1994; Hansen & Sato 2001; Shindell *et al* 2006).

Ozone is formed by photochemical reactions involving oxides of nitrogen (NOx), carbon monoxide (CO), volatile organic compounds (VOC) and methane. Motor vehicles are major sources of these 'precursor' emissions, and Figure 1.6 shows that the contribution of transport emissions to global warming through ozone production equates to about half the level of warming attributed to CO_2 (Fuglestvedt *et al* 2007). While this does nothing to lessen the need for deep cuts in CO_2 emissions, it does highlight that focussing on CO_2 or Kyoto GHGs to the exclusion of other significant forcings may squander opportunities to achieve cost-effective abatement (Hansen *et al* 2007).

Figure 1.6: Radiative forcing by substance and transport sub-sector



Source: Fuglestvedt et al 2008

Reductions in vehicle emissions could also have a double dividend of reducing climate forcing and reducing negative health impacts from the air pollution that is taking a major toll on public health (Kjellstrom *et al* 2002; Beer 2004). In other words, the health benefits of reducing vehicle emissions will help to pay for the costs of abatement.

Recent research has also indicated that climate change could further increase ozone levels and nullify efforts to clean up motor vehicle tailpipe emissions, with serious consequences for public health (Jacobson 2008; Engelhaupt 2008). There is therefore little scope for complacency on air pollution from motor vehicles, and ozone precursor emissions should be part of the broader GHG emissions reduction strategy. Although inclusion of indirect GHGs may raise the baseline from which emissions must be reduced, it also opens up a range of additional abatement opportunities that may provide more cost-effective and rapid emissions reductions.

1.2.3 Transport carbon intensity may get worse

The transport sector consumes the largest share of energy in Australia, with road transport accounting for about three quarters of the sector's energy consumption and air transport forecast to rise rapidly over the next two decades (ABARE 2007).

Figure 1.7: Energy use by sector

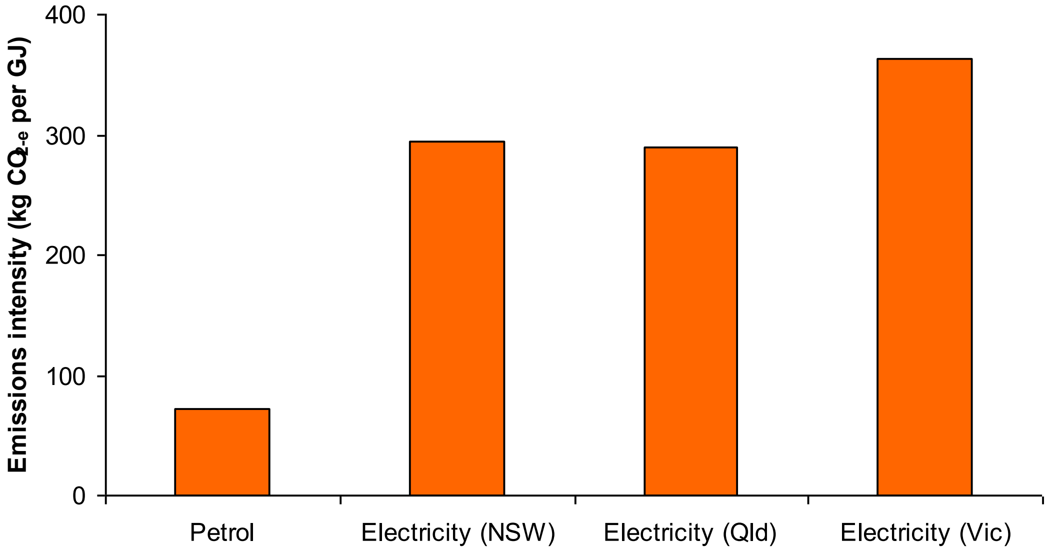
Source: ABARE 2007

The large discrepancy between transport's share of final energy consumption and its share of GHG emissions is largely explained by the relatively low carbon intensity of transport fuel compared to stationary energy at present (Figure 1.8). To put the high level of transport energy consumption in perspective, increasing the carbon intensity of the sector's energy use to the same level as electricity consumption in NSW would increase transport GHG emissions by over 4 times. This increased level of emissions would equate to nearly 60% of total current GHG emissions in Australia, or about 10% higher than emissions from stationary energy.

Continuing high oil prices have led to increased interest in substitutes for conventional petroleum (SCP). Many of these substitutes, such as heavy oil and coal liquefaction, have substantially higher carbon intensity than conventional petroleum which currently dominates transport fuel supply (Sims *et al* 2007; Lovell 2008). Given the current high level of transport energy consumption, an increase in the life-cycle carbon intensity of transport fuel would result in a large increase in GHG emissions.

Brandt and Farrell (2008) have estimated that increased use of SCPs could lead to as much as 21 gigatonnes of additional carbon in the atmosphere by mid-century, or nearly 40 times Australia's total emissions in 1990.

Figure 1.8: Full fuel cycle emissions per unit of final energy



Source: Department of Climate Change 2008

There is now mounting evidence that global conventional oil production will peak within the next decade, if it has not done so already (Hirsch *et al* 2005; Hirsch 2007; State of Queensland 2007). Australian production of crude oil and condensate peaked in 2000-01 and has since declined by over a quarter. Without major reductions in transport fuel consumption, depletion of conventional oil will lead to increased reliance on deep sea reserves and on heavy or synthetic oils that provide a much reduced Energy Return on Investment (EROI). In other words, much higher energy consumption (and exploration and development expenditure) will be required to maintain a given level of oil production, and massively higher life-cycle emissions for transport fuels will result (Moriarty & Honnery 2007a).

To the extent that internal combustion engines are substituted with electric motors, this will also substitute a relatively low carbon-intensity fuel (i.e. conventional petroleum) with a high carbon-intensity fuel (i.e. coal) and could significantly increase the scale and complexity of the task of decarbonising the stationary energy sector (Moriarty & Honnery 2007a).

Despite these doubts about the ability to maintain or increase production of conventional oil, it is widely accepted that oil and gas reserves are sufficient to take atmospheric carbon concentrations close to or beyond the threshold for dangerous climate change and that current trends point to all readily-available reserves being exploited (Leggett 2005, pp.127-8; Hansen *et al* 2007). The inescapable conclusion that follows is that there is almost no scope for further emissions from other fossil fuels such as coal, shale oil or tar sands, and that conventional oil and gas supplies should be stretched while energy production is decarbonised (Hansen *et al* 2007). Squandering such energy-dense and low carbon intensity fuels on inefficient transport systems effectively increases the urgency of decarbonising other sectors while simultaneously making such decarbonisation more difficult (e.g. by using gas supplies that could instead be used to displace coal for stationary energy).

"After 2015, easily accessible supplies of oil and gas probably will no longer keep up with demand."

Jeroen van der Veer, CEO, Royal Dutch Shell, January 2008

2 ABATEMENT OPTIONS

2.1 *Transport is central to effective mitigation*

The trends outlined in Section 1 clearly show that transport emissions are a large and growing contributor to climate change, and that the transport sector (including the upstream transport energy industry) must be a core part of any emissions reduction strategy such as an emissions trading scheme.

Exclusion of transport from a pricing scheme would limit the range of abatement options available in the scheme and leave included emitters with potentially higher cost abatement options. A range of low cost abatement options are believed to exist in the transport sector (e.g. McKinsey & Company 2008), especially if co-benefits are considered (Section 2.6.5). The higher abatement costs resulting from a scheme with restricted coverage would need to be passed on to consumers in the form of higher prices for electricity and everyday goods and services.

The transport sector also offers some quick wins that are both important and achievable. Tropospheric ozone is relatively short-lived compared to CO_2, so rapid and deep cuts in ozone precursors could significantly reduce positive forcings in the medium term and take advantage of the earth's thermal inertia to keep warming below crucial tipping points (Hansen *et al* 2007). Pollution from motor vehicles also harms the effectiveness of natural carbon sinks, so reducing transport emissions would allow plants to more effectively extract carbon from the atmosphere (Loya *et al* 2003; Hopkin 2007).

This section looks at how the transport sector can 'pull its weight' and thereby ensure greater success in reducing overall emissions without imposing an unfair burden on other sectors such as electricity generation or agriculture.

2.2 *The target for transport*

Australian governments have already committed to reducing GHG emissions by 60% by 2050. At the very least there is now implicit acknowledgement that Australia must go substantially further than this target, with proposed targets ranging from 80% up to effectively 100% from a growing number of scientists (e.g. Weaver *et al* 2007; Hansen *et al* 2008).

Without endorsing it as adequate, an 80% target provides a mid-point between 60% and 100% and can provide a broad indication of the scale of emission cuts required. This gives the transport sector a target of cutting emissions from their current level of over 80 million tonnes per annum to below 15 million tonnes per annum by mid-century. Given the current emissions trajectory, this is formidable challenge and one that becomes less and less achievable the longer serious action is delayed.

Although current policy only targets reductions of 60%, 80% is already the commonly accepted minimum benchmark for global GHG emission reductions, and consensus may quickly move beyond this to yet more ambitious targets. It is therefore important to ensure government policy and programs are not inconsistent with targets that are more ambitious than 60%. At the very least this means "first, do no harm" while international targets are developed under the Bali Roadmap. As discussed below, this implies a moratorium on motorway construction (Section 2.5).

2.3 *Vehicle efficiency isn't enough*

2.3.1 The potential of technical efficiency

Discussions on abatement measures in the transport sector are often heavily focussed on improving the efficiency of motor vehicles. Although improvements in vehicle efficiency are clearly needed, there are limits to the scale and speed of emission reductions available from such measures. As long ago as 1865, British economist William Jevons recognised that improvements in the efficiency of energy consumption can actually *increase* demand by making the process more productive and profitable to undertake.

More recent evidence on the effects of reducing motor vehicle operating costs (e.g. reducing fuel consumption) has shown that each 10% increase in vehicle efficiency results in an additional 2% of vehicle use (Litman 2008b). In other words, the net benefits in terms of reduced energy consumption and emissions are only about 80% of the improvement in technical efficiency, or a 10% improvement in vehicle efficiency will only reduce emissions by up to 8%. Due to this 'rebound effect' a 90% increase in vehicle efficiency would therefore still fall short of an 80% emissions reduction target.

Average passenger car emissions of 110-130 g/km have been suggested as plausible by the automotive industry (Brook Lyndhurst 2006, p.19). Even assuming no growth in motor vehicle use due to population growth or other causes, and no rebound effect from increased efficiency, average emissions in this range would result in passenger car emissions of 17-20 million tonnes per annum[2] which is somewhat higher than the target of 15 million tonnes for the transport sector as a whole including aviation, railways, trucks and buses. A technical efficiency or efficient vehicle approach is therefore totally inadequate, even for weak targets such as 60%. An efficient transport *system* or social efficiency approach is therefore needed that addresses *access* rather than getting caught up in *mobility* by individual motorised transport (Litman 2005; Moriarty & Honnery 2007a; Moriarty & Honnery 2008b).

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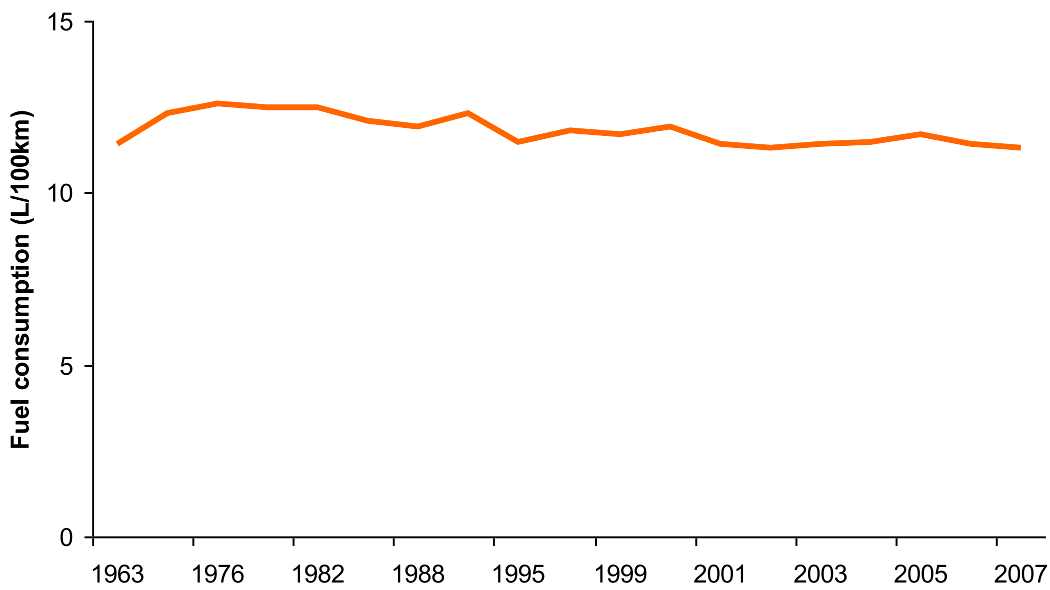
[2] Based on 156,184 million kilometres in the 2006 ABS Survey of Motor Vehicle Use. This also implies full system cycle emissions of 22-27 million tonnes per annum (see Section 1.2.2.1).

Assuming an average of 120g/km and cars maintaining their current share of total transport emissions[3], the amount of travel undertaken by cars in 2050 will have to be reduced by at least 57%[4] from current levels if the emissions target for transport is to be achieved. If any other transport sub-sectors (such as aviation or trucks) increase their share of total transport emissions, there will need to be a corresponding reduction in passenger car use beyond this 57% figure. Since at least some of the reduced car travel will need to be absorbed by public transport – not all of which will be zero emissions – it would be reasonable to assume that car use should fall by over 60%.

Furthermore, achieving an average of 120g/km in practice is by no means assured even if certain models perform better than this figure. Average vehicle fuel consumption has proven remarkably stubborn despite technological advances and, more recently, steep increases in petrol prices. Not only is the average fuel consumption of passenger vehicles in Australia no better now than when EH Holdens were fresh off the production line nearly half a century ago, the high price of petrol shows little sign of reversing the strong growth in sales of large, heavy Sports Utility Vehicles (ABS 2008; AAP 2008).

Figure 2.1: Average passenger car fuel consumption 1963-2007



Source: Australian Bureau of Statistics Survey of Motor Vehicle Use

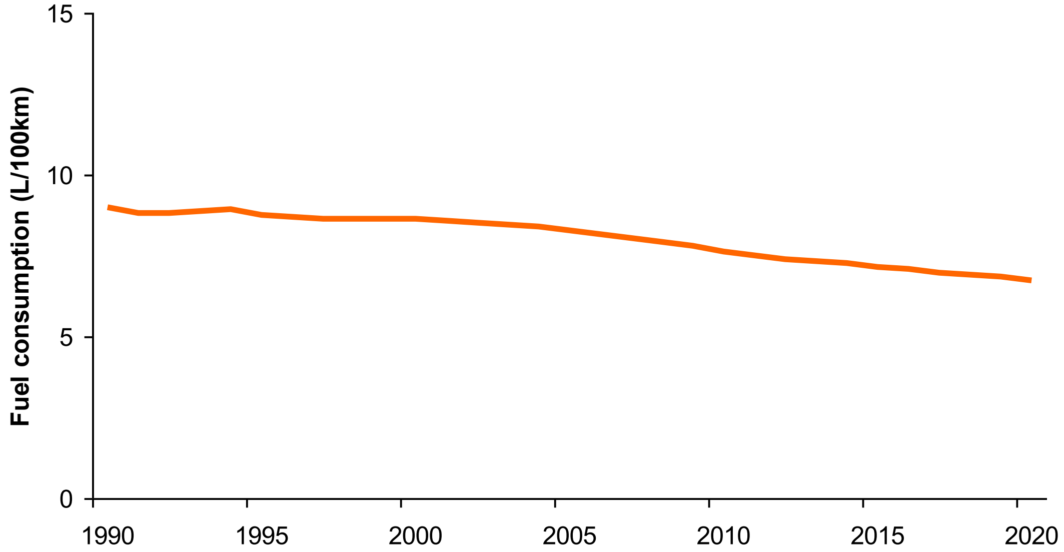
The likelihood of average fuel consumption falling to these levels through voluntary measures appears slim. Environmental impact hardly rates as a

[3] Cars currently produce 54.34% of transport emissions.

[4] Allowance for cars in 2050 would be 54% of 14.9 million tonnes = 8.1 million tonnes. This would allow 67,529 million kilometres pa assuming 120g/km, or 43% of passenger car kilometres in 2006. 100% - 43% = 57%.

consideration for new car buyers in Australia (ABS 2006a) and international research shows that few car buyers would pay more for a less environmentally harmful vehicle (Porter 2008). Significant advances in vehicle efficiency therefore seem unlikely in the absence of strong disincentives against the purchase and use of inefficient vehicles.

Figure 2.2: Base case projected average new passenger car fuel consumption



Vehicles built around 2020 will still form a significant proportion of the vehicle fleet towards the middle of the century. This will influence average fleet emissions as demonstrated by the difference between new vehicle consumption in this chart and average fleet consumption in Figure 2.1. Source: BTRE

The take up of efficient vehicles, if available, is likely to be a slow process due to the low turnover of the national car fleet. With the large reduction in vehicle use that is required to meet the emissions reduction target, new car sales and fleet turnover would also be likely to fall and the take up of more efficient vehicles would slow even further (Moriarty & Honnery 2008a). In this context an efficient *system* becomes more important than ever.

2.3.2 Hybrid and electric vehicles

Hybrid petrol-electric vehicles can offer reduced fuel consumption compared to conventional petrol-only vehicles. This improved technical efficiency is interpreted by some as demonstration that current transport patterns are sustainable. In practice, hybrid technology has been used to improve vehicle performance as much as to reduce fuel consumption and emissions (Wald 2005). Emissions from some hybrid passenger vehicles are nearly double the target of 110-130g/km.

The adoption of hybrid technology does not offer anywhere near the scale of emission reductions required to prevent dangerous climate change. A study for APEC concluded that fuel consumption would still grow by 16% from 2006 to 2015 even if hybrids comprised 20% of new car sales (APEC 2005). Similarly, California predicts that hybrid vehicles will merely slow down the rate of growth in fuel consumption rather than reverse it (California Energy Commission 2005).

The advent of plug-in hybrids and fully electric vehicles could lead to the convergence of transport carbon intensity with that of the stationary energy sector (see Section 1.2.3). The amount of primary energy produced by the stationary energy sector would also have to be significantly higher than the energy consumed when operating the vehicle since a large amount of energy is lost during battery charging. Similar problems exist with the production of hydrogen for transport (Ramesohl & Merten 2006). The resulting demand for electricity could also lead to an increase in water use by the stationary energy sector (King & Webber 2008), which is already a major user of water[5]. With significant water supply problems facing most parts of Australia, attempting to meet demand for water through desalination would act as a positive feedback and further complicate the already huge task of reducing emissions (Dickie 2007).

2.3.3 Embedded energy

Although relatively minor compared to energy consumption and emissions resulting from vehicle use, the manufacture and servicing of motor vehicles also result in significant energy use and emissions (Hendrickson *et al* 2006). Around one third of the GHG emissions generated across a vehicle's life-cycle can be from activities other than operation of the vehicle itself (Hendrickson *et al* 2006, p.74). These emissions are often counted under sectors other than 'transport' (e.g. manufacturing or extractive industries) and are a frequently overlooked when estimating the emission reduction potential of encouraging the purchase of new, more efficient cars. For example, the manufacture of the 835,000 new passenger cars and SUVs sold in Australia in 2007 is likely to have resulted in GHG emissions of over 8 million tonnes[6], which is equivalent to a 10% increase in emissions from Australia's transport sector.

The embedded energy of hybrid and electric vehicles can also be higher than that of conventional vehicles, although total life-cycle energy use will tend to be lower (Tahara *et al*, 2001).

Replacing old, dirty cars with newer cars will often not be the optimal all-round solution since older cars are frequently a second or third car and/or

[5] Loy Yang A, Loy Yang B and Yallourn power stations in the Latrobe Valley, which together supply nearly three quarters of Victoria's electricity, use close to 100 billion litres of water a year – about two thirds of the capacity of the proposed south Gippsland desalination plant, and a fifth of Melbourne's total water consumption.

[6] Based on ~10 tonnes $CO_{2\text{-}e}$ per car in Hendrickson *et al* 2006.

owned by a low-income household. In such cases, it will often be more socially and environmentally beneficial to provide better non-car alternatives instead of perpetuating high levels of car dependence, especially in an era of high fuel prices.

2.3.4 Cleaning up the current vehicle fleet

2.3.4.1 Vehicle maintenance

Adequate maintenance and servicing can prevent major deterioration in vehicle emission levels. The difference between well-maintained cars and identical poorly-maintained cars can be much greater than the difference between different models in similar condition (AATSE 1997; EPA 2006). Some jurisdictions have mandatory periodic emissions and safety testing, however this is not yet universal.

2.3.4.2 Vehicle operation

Reduced driving speed can significantly reduce air pollution (Newman & Kenworthy 1992; EFT&E 2005), especially if drivers adopt more economical driving styles as many have advocated (Table 2.1). Some of the more significant future improvements in vehicle efficiency are also expected to be obtained by designing only for low speed operation such as 30-50km/h (Moriarty & Honnery 2007a).

Reduced speed limits would also make urban environments less dangerous and intimidating for pedestrians and cyclists (Samuels 1997; Archer *et al* 2007; Woodcock *et al* 2007) and encourage a shift away from driving to walking and cycling (see Section 2.7).

Table 2.1: Change in emissions with speed change from 50km/h to 30km/h

	Driving Style	
Emission	**2nd gear aggressive**	**3rd gear calm**
Carbon monoxide	-17%	-13%
Volatile Organic Compounds	-10%	-22%
Oxides of nitrogen	-32%	-48%

Source: Newman & Kenworthy 1992

2.3.5 Car pooling

Vehicle occupancy rates have been in long-term decline in Australia as in most other high-income countries (Moriarty & Honnery 2007a; Mees, Sorupia & Stone 2007, p.7). There appears to be little prospect for any significant improvement in car occupancy since car pooling sacrifices the advantages of single occupant car use (e.g. privacy, convenience, autonomy) without benefiting from the advantages of an effective public transport system such as network coverage and service frequency (compared to single destination, single service shared cars).

Only modest success in boosting car occupancies seems to have been achieved from intense efforts to encourage car pooling. Rather than reducing vehicle movements, car pooling schemes can undermine public transport and result in an increase in motor vehicle traffic (Greene & Schafer 2003).

2.3.6 Conclusion

Improvements to vehicle efficiency are clearly an important part of reducing GHG emissions, however they are far from sufficient and do not offer a wider range of co-benefits such as congestion reduction and healthier communities (see Section 2.6.5). The current tendency to focus on vehicle efficiency could be regarded as an attempt to reduce cognitive dissonance related to awareness of the negative impacts of motor vehicle use and its incompatibility with actual travel behaviour (Steg & Vlek 1997 in Gärling & Steg 2007, p.261)

Reduced fuel consumption can also be achieved by better maintaining existing vehicles and calming traffic movements. This would also make zero emissions walking and cycling more appealing to a wider range of people, and should be pursued ahead of efforts to promote car pooling.

Box 2.1: Efficient vehicles and efficient transport systems

To keep up with the latest technology, John buys a new car every 3 years. He is very proud of his new 'environmentally-friendly' hybrid which travels 100 kilometres on just 4.4 litres of fuel. He uses his car extensively to ferry his kids to school and their part-time jobs. He also drives it to and from work each day as well as for shopping and social trips. He travels about 25,000 kilometres and produces nearly 2.7 tonnes of CO_2 each year. The production of each new car John buys results in an additional 11 tonnes of CO_2.

Alannah owns a 1995 Ford Falcon which uses 12.5 litres of fuel to travel 100 kilometres. Most days her cars sits in the garage since she catches the train to work and her children go to school using the walking school bus. She occasionally uses the car for shopping, but the shopping centre next to the railway station allows her to buy most daily items on her way to or from work. Each year Alannah drives about 6,000 km and produces about 1.8 tonnes of CO_2.

Which is more efficient?

2.4 Alternative fuels aren't clean or scalable

2.4.1 Synfuel

Rising oil prices and the abundance of coal reserves have led to renewed interest in coal-to-liquids (CTL). This process is being portrayed by some as 'clean' due to the possibility that emissions from the production phase may be captured and sequestered (CCS).

However, CTL with CCS produces transport fuel that has tank-to-wheels emissions that are comparable to conventional fuel and well-to-wheels emissions that may be around 8% higher (Hawkins 2006). Furthermore, conventional oil and gas supplies are sufficient to take the world's climate up to crucial tipping points (Leggett 2005; Hansen *et al* 2007), so an additional method of putting just a fraction of carbon from coal deposits into the atmosphere would take us well into the realm of dangerous climate change. In order to prevent the addition of more carbon to the atmosphere, any opportunities to use CCS should focus on the stationary energy sector where closer to 100% of the emissions can be captured, and mitigation efforts in the transport sector focus on reducing energy demand.

Emissions from CTL without CCS are about double conventional fuel which would take the carbon intensity of transport energy up to similar levels as stationary energy. Given the large amount of energy consumed by the transport sector (Section 1.2.3), this would make the absolute quantity of transport emissions comparable to, if not greater than, that of the electricity generation sector.

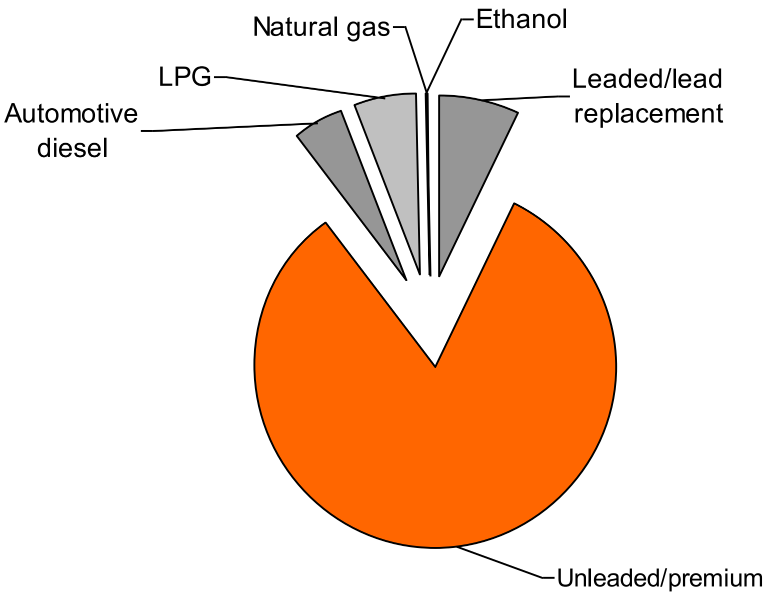
2.4.2 Biofuel

2.4.2.1 Scalability

Despite 800 million people around the world facing chronic hunger, humanity is already appropriating 24% of the earth's primary production for activities such as growing food, raising livestock and producing timber (Haberl *et al* 2007). Meeting the needs of the extra 2.5 billion people expected by 2050 will place even greater pressure on planet earth's resources. Increasing our consumption of nature's output to grow biofuels would further imperil endangered plant and animal species and undermine the ability of natural systems to perform ecosystem services such as pollination and maintenance of air, soil and water quality. Already the cultivation of energy crops (and of food crops displaced from elsewhere by biofuel production) is a major cause of deforestation in the Amazon basin and South East Asia, and is uprooting indigenous peoples in many regions of the world (Oxfam 2007; Naylor *et al* 2007; Doyle 2008).

From a low base, biofuel production has grown rapidly in recent years and appropriated a significant and growing proportion of agricultural output. As a result, commodity and food prices have increased steeply and raised serious food security concerns in countries right around the world (Quiggin 2007; Ennis 2008). About 40% of global maize production takes place in the USA, and use of maize for ethanol production has now overtaken maize exports. More than half of Brazil's sugarcane crop is used to produce ethanol, and while biofuel represents a significant proportion of domestic transport fuel consumption, transport energy use is very low by Australian standards and the USA has replaced Brazil as the world's largest biofuel producer. Plans to expand biofuel production in Brazil look set to cut swathes into Amazonian rainforest, releasing large quantities of carbon in the process (Naylor *et al* 2007). Despite this massive diversion of food and feed crops to produce transport energy, bio-ethanol only accounts for 2.5% of US petrol consumption (Naylor *et al* 2007). A larger role for biofuel in Australia is also constrained by the significant number of motor vehicles that are unable to run on ethanol-blended fuel (Hagan 2007).

Figure 2.3: Share of car energy consumption in Australia (2004)



Source: Bureau of Transport and Regional Economics

This miniscule contribution to global transport energy needs is coming at great cost to taxpayers. A report for the OECD found that each tonne of CO_2 saved by replacing petroleum with biofuel can require several hundred dollars of subsidies and tax credits – many times the cost of replacing coal with renewable energy (Doornbosch & Steenblik 2007).

Hopes for a larger role for biofuel are now largely pinned on second generation biofuels utilising agricultural residues and non-food crops such as switchgrass. Production of second generation, or cellulosic, biofuels has yet to be undertaken on a commercial scale and there are many barriers to this occurring. For example, cultivation of feedstock for second generation biofuels may be just as likely as first generation energy crops to displace food production or to result in deforestation. The removal of biomass such as crop residues from agricultural or natural systems is also likely to deplete soil nutrients and force the application of fertilisers that release additional GHGs. Other problems such as soil erosion may also be exacerbated (Pimentel & Lal 2007).

It is also not yet clear that cellulosic biofuels will offer anything more than a marginally positive net energy return (Moriarty & Honnery 2007b). Anything less than a large EROI will also limit the catchment area for biofuel feedstock since transporting low energy density biomass to the refinery will consume significant fuel. Scale may also be constrained by the perishability of feedstock and the resulting limits on transport and storage time.

Even if sufficient land can be found to grow energy crops without displacing communities, food crops or biodiversity, water supplies would be a major constraint on biofuel production (Moriarty & Honnery 2007b). Furthermore, many plants proposed as feedstock for biofuel production have the potential to become invasive weeds in Australia (Low & Booth 2007) which raises the prospect of biofuel crops becoming the next cane toad.

2.4.2.2 Climate impacts

A reduction in GHG emissions is one of the main objectives of biofuel use, however it is clear that emissions from the production of at least some biofuels are much higher than from the conventional fuel they replace.

Land use change, particularly deforestation, is already a major contributor to global GHG emissions. In some parts of the world destruction of rainforest is accelerating to make way for energy crops, such as palm oil or soy beans, or for food crops that have been displaced from elsewhere by energy crops such as sugarcane (Naylor *et al* 2007).

The large amount of energy involved in the cultivation, harvesting, transport, processing and distribution of biofuel means that it has a low EROI compared to conventional fuel. Many studies indicate that more energy is expended in the biofuel supply chain than is provided by the biofuel itself (e.g. Pimentel & Patzek 2005). This also means that GHG emissions resulting from the biofuel life-cycle can be of a similar magnitude or larger than the emissions that would result from using conventional fuel (Reijnders & Huijbregts 2006; Crutzen *et al* 2007; Scharlemann & Laurance 2008; Searchinger *et al* 2008).

The blending of ethanol in transport fuel can also raise emissions of VOCs and NOx with serious implications for public health and resulting in higher levels of tropospheric ozone which adds to global warming (Jacobson 2007; Cooney 2007).

As for synfuels (Section 2.4.1), it may be more effective to restrict the use of biomass for energy to the stationary energy sector so that closer to 100% of emissions can be captured and sequestered, instead of using it for transport fuel where tailpipe emissions are returned immediately to the atmosphere. Provided CCS can be deployed successfully, use of biomass in this way may turn part of the energy sector into a carbon sink - rather than a clear positive forcing as it is now – and contribute to more rapid climate stabilisation (Rhodes & Keith 2005; Azar *et al* 2006; Hansen *et al* 2007). Comments above about the limited scalability of biomass energy still stand, however, and emphasise the importance of not squandering energy (and sequestration opportunities) on inefficient transport systems (Huesemann 2006).

2.4.3 Conclusion

Alternative transport fuels that have good prospects of commercialisation within an acceptable time scale offer limited emission reduction benefits and may do little more than ameliorate the increasing carbon intensity of conventional fuels discussed in section 1.2.3. In the absence of rigorous life-cycle assessment and regulation, some alternative fuels may significantly increase the carbon intensity of transport fuels. A reduction in the carbon intensity of transport fuel cannot be counted upon to contribute to a reduction in transport emissions, and the focus should be on improving the efficiency of the transport *system*.

It is also clear that some supposedly 'green' biofuels may result in higher GHG emissions than conventional fuel. Deterioration in the life-cycle carbon intensity of transport fuel should be guarded against by adopting best-practice life-cycle assessment and social and environmental certification of transport fuels using California's Low Carbon Fuel Standard and proposed amendments to the EU's fuel quality directive as models.

2.5 Congestion is cheap and easy demand management

2.5.1 Environmental benefits of free-flowing traffic

Hybrid and electric vehicles are commonly regarded as the means to significantly increase vehicle efficiency and reduce transport emissions. Much of the increased efficiency of such vehicles comes from a reduction in engine idling and the use of regenerative braking which turns the kinetic energy of the vehicle's motion into stored energy ready to be re-used for acceleration. As a result, hybrid and electric vehicles have a significant advantage over conventional vehicles when driving in stop-start or congested conditions.

The gains from regenerative braking are significantly diminished in free-flow traffic, which eliminates much of the supposed environmental justification for attempting to reduce congestion. With hybrid and electric vehicles held up as the future of motoring, free-flowing traffic should no longer be seen as offering significant reductions in vehicle emissions, and transport appraisal should ignore emission reductions as a supposed benefit of congestion reduction.

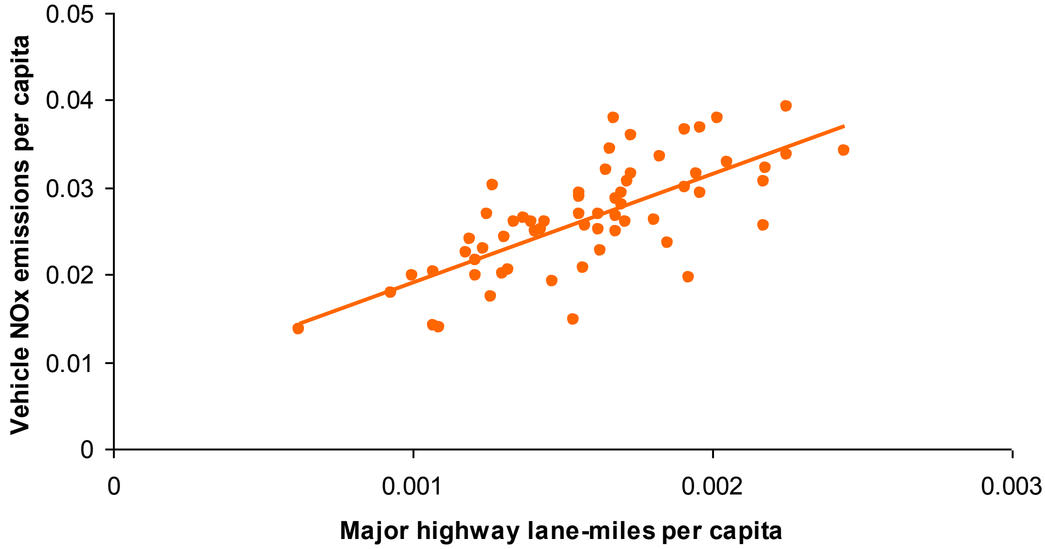
Furthermore, in light of the characteristics of regenerative braking, free-flowing traffic acts as a disincentive to choosing a hybrid or electric vehicle, or as a reward for choosing a conventionally powered vehicle. This further emphasises the vanishing benefits of congestion reduction as an emissions reduction tool.

2.5.2 Impacts on travel behaviour

Congestion management is another key area where the distinction between efficient vehicles and an efficient transport *system* becomes clear. While reduced congestion has in the past offered reduced emissions per vehicle kilometre (albeit temporarily), it has also encouraged additional vehicle kilometres, lower vehicle occupancy and higher aggregate emissions. Road congestion is one of the most dominant influences on travel behaviour, with lower (expected) congestion very strongly associated with increased probability of travel by low occupancy private car.

Numerous studies have demonstrated how increased road supply induces additional traffic, results in higher aggregate emissions and ultimately fails to reduce congestion (e.g. Newman, Kenworthy & Lyons 1988; Mogridge 1990; STPP 2001; Cassady *et al* 2004; Bento *et al* 2005; PTUA 2008, pp.15-19).

Figure 2.4: Road supply and transport emissions

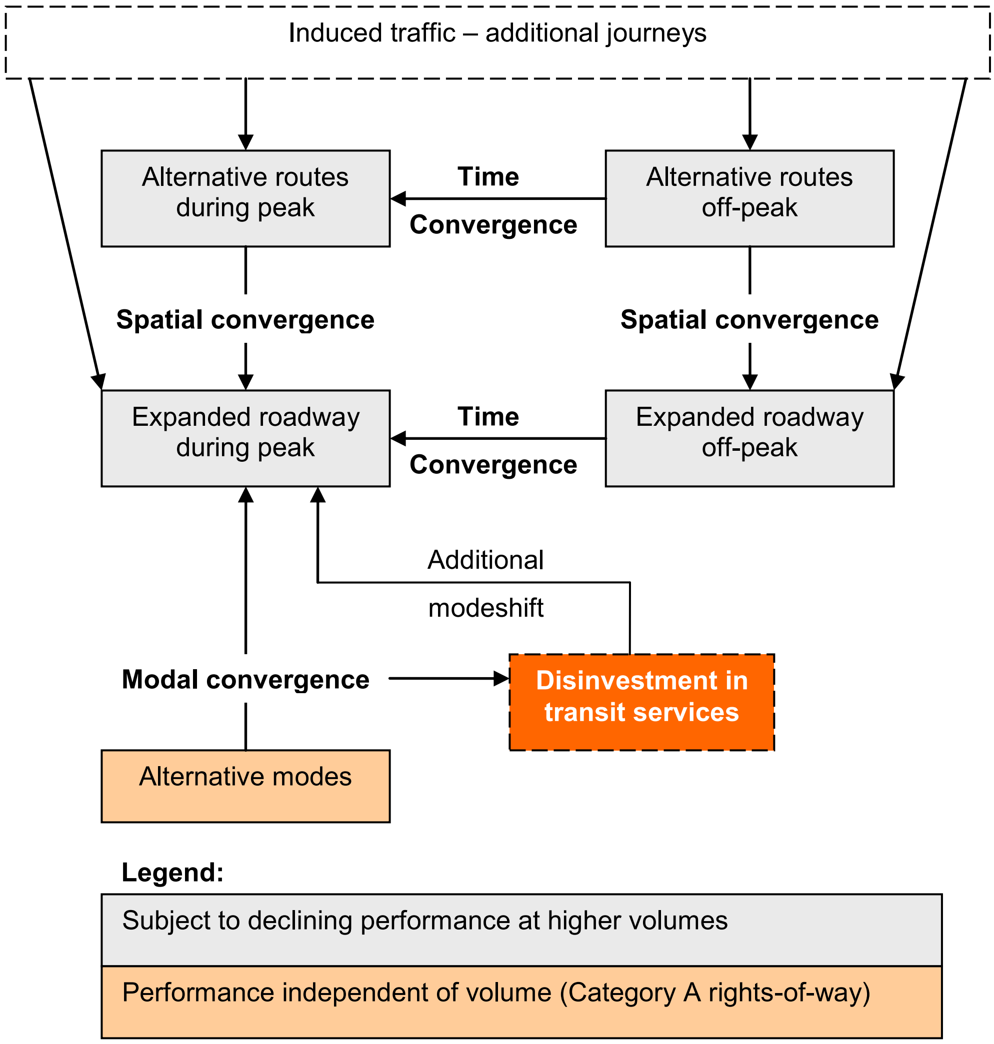


Source: Cassady et al 2004

The failure of road capacity expansion as a congestion management or emissions reduction strategy is explained by the concept of 'triple convergence'. The existence of congestion indicates high latent demand, so an increase in capacity quickly induces additional traffic. Some of the additional traffic relates to new journeys that had been deterred by the congestion, some relates to journeys that shift from alternative routes (spatial convergence) or from off-peak times (time convergence), and some relates to journeys shifted from alternative modes such as public transport (modal convergence). The use of the term 'convergence' is deliberate as the shift in journeys reaches equilibrium when travel times for each of the alternative routes, times and modes are approximately equal (or have converged).

A negative effect of the modal convergence is that public transport service levels may be reduced in response to the reduced patronage, which in turn makes travel by public transport slower and less attractive, leading to further modeshift to private cars at the expense of public transport. This second round effect further reduces the performance of the road network (below the first round equilibrium), so congestion ends up worse than prior to the road capacity expansion. This perverse outcome is also appropriate referred to as the 'Downs-Thomson Paradox' due to the counter-intuitive impact of expanding road capacity. Regardless of how it is described, it demonstrates that road capacity expansion is ineffective at reducing congestion or emissions.

Figure 2.5: Triple convergence following roadway expansion



Spatial convergence: *road users shift to the expanded roadway from alternative routes.*
Time convergence: *road users shift time to use the expanded capacity during the high-value peak period.*
Modal convergence: *transit passengers change mode to use expanded road capacity, adding to total number of vehicles and reducing the financial viability of transit which in turn leads to disinvestment in transit quality which leads to additional mode shift from transit to car.*
Induced traffic: *additional journeys are encouraged by the new capacity and by existing capacity released through spatial convergence (Litman 2007b). The effect is particularly strong where congestion levels have been high.*
Equilibrium: *convergence ceases when journey times are approximately equalised. The critical speed – the lowest acceptable road speed – is dependent upon the speed and efficiency of public transport (Suchorzewski 1973).*
Source: PTUA 2008, p.17; Based on Lewis & Williams 1999

In the context of the Garnaut Climate Change Review, it should also be noted that expanding road capacity tends to reduce the generalised cost of driving and thereby reduce the price elasticity of petrol demand. Road expansion therefore increases the level of the carbon price required to achieve a given reduction in emissions (see also Section 3.3).

Even if we ignore the impacts of regenerative braking, induced traffic and triple convergence, the large reduction in vehicle travel required to meet effective emission reduction targets (see Section 2.3.1) means that congestion will be reduced without having to increase road capacity. The possibility of travel plateauing in the relatively near future has already been raised in the context of rising oil prices (Mitchell & Ife 2008), so an ambitious travel demand management program could allow us to reallocate road space to more sustainable uses without significant harm to traffic flow.

2.5.3 Conclusion

The benefits of expanding road capacity have long been overstated (e.g. Wilmot 2006), however the much-vaunted potential of hybrid and electric vehicles will further reduce the supposed environmental benefits of congestion reduction.

The need to shift a large proportion of motor vehicle journeys to walking, cycling and public transport as well as the counter-productive effects of road capacity expansion both demonstrate the need for a moratorium on new roads as announced in France (Stone 2007, p.5; Akerman & Hojer 2006). The competitiveness of alternative modes would also be boosted by reallocating existing roadspace away from general traffic so that more sustainable modes are faster and more reliable, and are therefore able to attract people out of their cars and reduce pressure on remaining roadspace.

2.6 Public transport

As outlined above, focussing solely on vehicle efficiency is totally inadequate for achieving effective emissions reductions. We clearly need to adopt an efficient transport *system* approach that can also address other problems such as congestion, air quality, road trauma, affordable mobility and the need to encourage healthier lifestyles (Litman 2005 & 2008a). Part of establishing an efficient transport system is recognising that mobility is not equal to access, and that cars are not the only form of mobility. Access to employment, education and other services can be improved through better integration of transport and land use planning. Similarly, more equitable, inclusive and sustainable mobility can provided by enhancing the coverage and quality of transport alternatives.

Public transport has a major role to play in managing congestion (Section 2.5.2), and is a pre-requisite for effective and equitable road or congestion pricing. Public transport also complements walking and cycling by providing a car-free means of travelling beyond walking and cycling distance, and by helping to reduce the high traffic volumes that deter pedestrians and cyclists (Section 2.7).

Public transport is also proven technology with a foundation of infrastructure and services already in place, so extensive research and development is not required prior to expansion and upgrading. Nevertheless, large potential for increased efficiency exists by progressively acquiring more efficient rolling stock and better utilising existing resources. With Australia being one of the most urbanised nations on earth, public transport has the potential to serve a much larger share of motorised journeys and to stimulate landuse patterns that are better suited to walking and cycling.

2.6.1 Decarbonising public transport

2.6.1.1 Renewable energy

Electrified public transport, which in the Australian context means most suburban train and tram networks, can be powered by any primary energy source that is connected to the grid. Due to the efficiency of passenger rail systems, electrified public transport is a relatively small proportion of the overall electricity load. This means that a significant portion of public transport in Australia can be easily decarbonised by sourcing renewable energy for public transport operations. Accessing energy in this way also makes rail systems 'technology neutral' and not reliant on new production and distribution infrastructure in the way that hydrogen or other alternative fuels may be constrained.

Figure 2.6: Wind-powered tram

In a demonstration project involving Yarra Trams, Pacific Hydro and Sustainability Victoria, wind power is being procured to power one of Melbourne's trams.
Source: Yarra Trams

As outlined in Section 2.4 above, sourcing renewable fuels for non-electrified public transport is more problematic. This should be addressed by electrifying the remaining diesel urban and peri-urban rail services and progressively converting high volume non-rail services to rail. Fuel used by the remaining non-electrified services should be covered by the fuel quality standard proposed in Section 2.4.3.

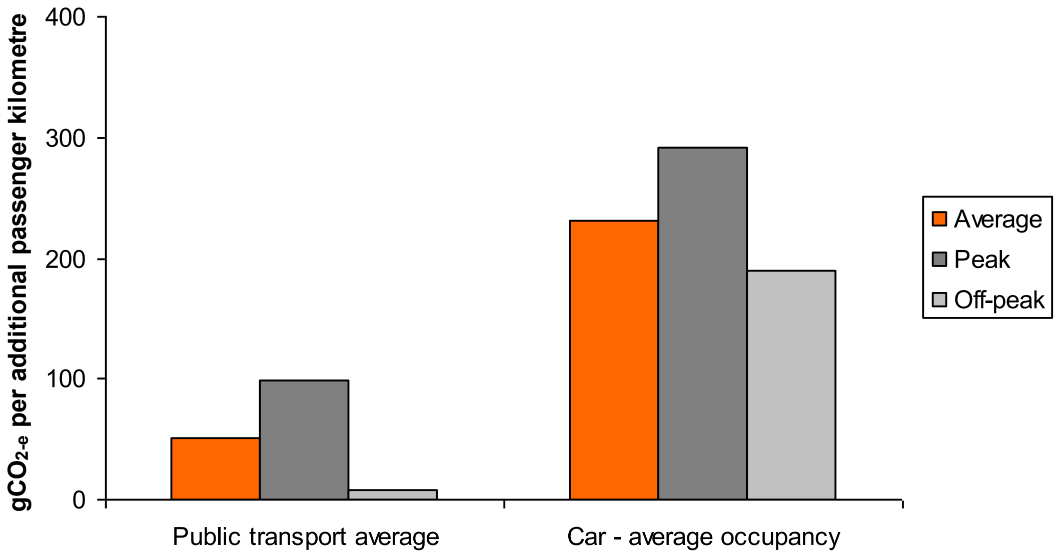
2.6.1.2 Improving energy efficiency

Low energy prices in Australia and the inherently superior energy efficiency of public transport compared to private motor vehicles have allowed public transport to 'rest on its laurels' to some extent in terms of energy efficiency. As a consequence, many public transport operations fall short of international best-practice on energy efficiency. This does however mean that significant opportunities remain for further cost-effective improvements to the energy efficiency of public transport in Australia.

Due to the frequent stopping of public transport services, there is large potential to improve efficiency through measures such as the introduction of regenerative braking and lighter rolling stock (Meyer *et al* 2004). Energy consumption can also be reduced by ensuring routes are as direct as possible and additional vehicle kilometres do not result from circuitous or meandering routes that can also add to travel times for passengers. Effective route reforms are however likely to require well integrated strategic and tactical planning by public transport agencies (van Oort & van Nes 2008).

The efficiency of public transport in terms of energy consumption per passenger kilometre can also be improved by boosting occupancy levels, especially attracting more off-peak journeys onto public transport. Even assuming no improvement in public transport vehicle efficiency or a switch to renewable energy, large GHG emission reductions can be achieved by shifting car journeys to public transport (Figure 2.7). Strategies to encourage modeshift to public transport are discussed in section 2.6.2.

Figure 2.7: Comparative incremental GHG emissions



Source: McCarthy 2007

2.6.2 Cost-effective mode shift to low emissions transport

The first step in achieving cost-effective mode shift is identifying the key factors driving mode choice decisions and targeting measures accordingly. Travel is largely a derived demand serving various objective or instrumental motives for destination and mode choice, such as employment, education and recreation (Jakobsson 2007).

A large body of research has identified a core set of factors that explain mode choice decisions (Taylor 1982; Gray 1992; Kenworthy 2000; Black, Collins & Snell 2001; Asensio 2002; Bento *et al* 2005; ABS 2006a; Mann & Abraham 2006; Lumsdon, Downward & Rhoden 2006; Chorus, Molin, Van Wee, Arentze & Timmermans 2006). Gray (1992) categorised the key factors influencing mode choice using the acronym SCARCE:

- Safety
- Comfort
- Accessibility
- Reliability
- Cost
- Efficiency

2.6.2.1 Safety

After physical needs such as food and water, safety is one of the most fundamental human needs identified by Maslow. To encourage modeshift, potential passengers must perceive the system as safe, in addition to it actually being safe. Fear of crime, especially in the case of women, can be a major deterrent to using public transport. These fears can be particularly acute off-peak where there is the greatest potential to boost public transport occupancies and hence boost system energy efficiency.

Perceptions of security can be enhanced by ensuring a consistent staff presence on public transport vehicles and around transport interchanges. Staff can also provide customer assistance to make the experience more pleasant for irregular users and reduce the uncertainties of using a service for the first time.

Passive security can also be enhanced by adopting crime prevention through environmental design (CPTED) or 'design out crime' principles around transport interchanges and along walking and cycling routes (Cozens *et al* 2004). These measures can also enhance security for local residents and for pedestrians and cyclists who are not using public transport.

Reliance on park and ride can also leave passengers vulnerable to property crime while their cars are left unattended for large parts of the day. Higher quality feeder services and better network integration can reduce this vulnerability as well as allow large, intimidating car parks around stations to be replaced with commercial and residential activity that offers passive surveillance for passengers.

Public transport is statistically much safer than private transport in terms of accidental death and injury, however crashes involving trains receive much greater media attention than the almost daily waste of human lives on the nation's roads. Despite the greater safety of public transport, a perception of greater control while at the wheel can lead some people to avoid putting their lives in the hands of professional train, tram and bus drivers. An untapped competitive advantage for public transport authorities may be the reduced probability of death or injury while using public transport compared to sharing the road with others who may be reckless, drunk or otherwise dangerous drivers.

2.6.2.2 Comfort

Greater comfort and personal space are among the key motives for driving rather than using public transport (Mann & Abraham 2006). There is also evidence that car drivers are more concerned about comfort than existing public transport users (Ceder 2004), hence efforts to encourage modeshift away from private cars will need to ensure passenger comfort is given sufficient attention.

Comfort includes factors such as crowding, availability of seating, smoothness of ride, cleanliness, noise and exhaust emissions, protection from the weather and the standard of customer service. Research in North America has shown that acceptable comfort levels, rather than theoretical capacity, place an upper limit on patronage levels that can be achieved in practice (Demery & Higgins 2005).

Rail systems tend to provide higher levels of comfort (Demery & Higgins 2005; IBI Group 2006; Litman 2006), however service levels should be adequate regardless of mode to prevent overcrowding and long periods of exposure to the elements. Given adequate levels of comfort, passengers can use their on-board time productively, which is a potential competitive advantage compared to driving where full attention must be paid to the road and which can be quite stressful (Mann & Abraham 2006).

2.6.2.3 Accessibility

Public transport will not be a realistic choice unless both the journey origin and the destination are covered by the network, services operate when they are needed and search and information costs are not too high. Physical accessibility is also important and can be a problem if passengers have a physical impairment or services are simply too crowded to accommodate more passengers.

Accessibility could be improved by better integration of transport and landuse planning so that significant trips generators are located close to high quality public transport and services are made available as soon as an area begins to develop (rather than waiting until after the area is fully developed and car dependence is entrenched).

Service operating hours and frequencies also need to be adequate to ensure that services are actually available at the time of travel and waiting times are not so excessive that driving becomes the only realistic option.

Service information and ticketing must recognise the needs of irregular users and a multi-modal, whole-of-network approach should be taken so that diverse origins and destinations can be served with minimal confusion to passengers.

2.6.2.4 Reliability

Current and potential passengers unequivocally dislike unexpected delays and poor reliability. A great deal of research shows that poor reliability relative to private cars is a major deterrent to increased mode share for public transport (e.g. Taylor 1982; Chorus *et al* 2006; Mann & Abraham 2006). Poor reliability undermines passengers' sense of control and leads them to seek greater control by using a private car.

Fixed guideway systems operating in Category A rights-of-way[7] offer the highest level of reliability and should be the preferred solution where justified by potential passenger volumes. Traffic light priority measures, headstart lanes and dedicated lanes or fairways can also improve the reliability of public transport provided they are enforced effectively.

Damage to perceptions of reliability can be minimised by comprehensive risk management and contingency planning to respond to service disruptions in a prompt and effective manner. Continuous improvement in reliability should also be pursued by regular, comprehensive and transparent benchmarking against international best practice.

2.6.2.5 Cost

Public transport must compete against private cars that are currently undercharged relative to their full social and environmental costs (see Section 2.10), and whose cost structure is heavily biased towards fixed or periodical costs like registration, insurance and finance costs. In the case of company cars that are subject to Fringe Benefits Tax, some costs are even reduced by increased travel. As a result, the marginal cost of car use, or the direct cost of each individual journey, can appear very low relative to the cost of a buying a public transport ticket.

To be competitive with car use, public transport fares should be multi-modal and based on time and broad zones (as opposed to route-based) so that transfers do not incur additional cost and the full network can be accessed to reach diverse destinations. Periodical tickets should be priced attractively to encourage their take-up so that the marginal cost of public transport use compares favourably to the marginal cost of motor vehicle use. Individual journeys should however be priced competitively as well so that irregular users are not deterred from replacing some car trips with public transport trips.

While financial cost is an important factor in mode choice, it should also be recognised that failure to significantly reduce the non-financial costs of public transport use (relative door-to-door journey times, convenience, comfort, reliability, etc) will ensure that private motor vehicle use remains high and that carbon or congestion pricing merely penalise motorists rather than reduce emissions or congestion.

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[7] **Categories of rights-of-way:**
Category A: fully separated with guided technology (usually rail), offering much higher capacity, reliability and safety than street-based systems.
Category B: partially separated, such as median strip, crossing intersections at grade.
Category C: share roads with mixed traffic, and generally not competitive with car travel (Vuchic 1999, pp.42-43)

2.6.2.6 Efficiency

From the passenger's perspective, efficiency largely relates to overall journey times, including average speeds that are competitive with other modes and minimal waiting times for connections.

Travel time

In-vehicle travel time can be reduced by utilising Category A rights-of-way where possible and implementing traffic light priority and head-start lanes for road-based public transport (Morton 2007). Meandering routes that add to journey times and operational costs should also be avoided and urban planning regulations should ensure that all developments can be served by efficient and direct public transport routes.

Table 2.2: Comparative speed of road traffic and public transport

	Melbourne	Sydney	Brisbane	Perth
Average road network speed (km/h)	43	36	50	46
Average road-based public transport speed in km/h (% of road network speed)	21 (49%)	21 (58%)	27 (54%)	25 (54%)
Average segregated rail transport speed in km/h (% of road network speed)	40 (93%)	47 (131%)	48 (96%)	50 (109%)

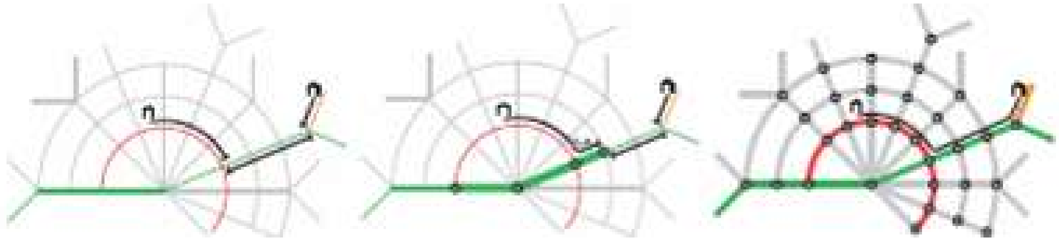
Source: Scheurer et al 2005

Transfers and connection times

There is widely diverging evidence on the effect of transfers and connection times on passenger perceptions, however perceptions will ultimately be a function of actual waiting time, trip purpose, ease of transfer and the environs of the interchange (Algers *et al* 1975; Vuchic 1981). For instance, 15 minutes seated comfortably under cover with helpful staff on-hand and reliable real-time service information available will be perceived much more favourably than 15 minutes spent at an isolated stop on a cold and wet night with nagging doubts over the likelihood of the next service appearing as scheduled or the ability to squeeze onboard when it does turn up.

Given the diversity of origins and destinations in most urban areas, transfers will be inevitable in any system seeking to serve more than a tiny minority of journeys. Rather than vainly attempting to eliminate transfers, attention should focus on minimising actual connection times by providing frequent, harmonised services (see Figure 2.8), and making interchanges as user-friendly as possible. Perceptions of transfers and waiting time should also be addressed by ensuring interchanges are clean and safe and offer protection from the elements. The provision of accurate real-time information can also aid perceptions, however unreliable information can exacerbate negative perceptions of system reliability (Chorus *et al* 2006; Dziekan & Kottenhoff 2007). Transfers on journeys to work are also viewed more favourably than transfers on social journeys, therefore the elimination of transfers on journeys to the CBD would be a lower priority than other service quality factors such as integration and reliability.

Figure 2.8: The network effect for public transport users



An unlinked collection of low-frequency routes (a non-network) The area you can reach by a simple journey is restricted to walking distance from your closest line. Users need to have detailed information about timetables. Transferring is difficult and crossing points have little value.	**Some high-frequency services** Good service along high-frequency lines makes some transfers more attractive, but only in the direction towards the high-frequency service. Increased frequencies on the best sections will do little to improve general conditions.	**The full network effect** Many lines operating at high frequencies, or with coordinated timetables, create a network. In the same way that motorists use intersecting roads, travellers can go anywhere, anytime. Transfers open up many travel options.

Source: HiTrans 2005; Stone 2007

2.6.3 Bringing it together

All of the factors underlying mode choice should be considered together to effectively encourage mode shift to public transport. For example, addressing coverage and service integration together is much more powerful than addressing either in isolation.

A safe, comfortable, accessible, reliable, cost-competitive and efficient public transport network does not happen by accident. An effective public transport authority (PTA) with the skills, resources and authority to drive holistic improvements across each of these areas is now widely recognised as a necessary pre-requisite for delivering a cost-effective and attractive public transport system (Vuchic 1999; WS Atkins 2001; Colin Buchanan and Partners 2003; HiTrans 2005; Kennedy *et al* 2005). The transport community or federation model originating in continental Europe is commonly identified as best-practice in this regard, and is increasingly being adopted outside continental Europe in cities such as London, Toronto, Vancouver, Perth and (in the near future) Brisbane. Governance arrangements such as this should be a requirement for Commonwealth funding to ensure the effective and efficient application of scarce resources.

2.6.4 Can public transport cope with more passengers?

The recent upsurge in public transport patronage - resulting to some extent from high petrol prices - has caught a number of public transport systems unprepared. Overcrowding is now commonplace on many peak services and has led some people to question the ability of public transport to accommodate a larger proportion of passenger journeys.

As discussed in Section 2.7, many car journeys can be shifted to walking and cycling. This would have a multitude of benefits on top of reducing emissions and easing pressure on other infrastructure (PTUA 2007; Woodcock *et al* 2007; Moriarty & Honnery 2008b). Public transport would therefore not have to absorb all journeys shifted away from private motor vehicles.

An efficient transport *system* can also reduce the total amount of travel by providing *access* rather than promoting *mobility* by private car. International experience demonstrates that each kilometre of public transport use can replace at least 4 kilometres of car travel due to the reduction in chauffeuring (see Box 2.2) and the encouragement of transport and landuse patterns that are less car dependent (Newman & Kenworthy 1999, pp.87-88; Litman 2006, pp.7-14).

Box 2.2: Replacing chauffeured trips with public transport

Lyn drives her son and daughter to their schools each morning and then returns home. Lyn's toddler accompanies her on the journey. Lyn's car produces 300 grams of CO_2 per kilometre during the peak school run. The journey consists of 3 main legs:

* 3 kilometres to her son's school
  - (3 vehicle kilometres, 12 passenger kilometres and 900g of CO_2);
* 2 kilometres to her daughter's school
  - (2 vehicle kilometres, 6 passenger kilometres and 600g of CO_2); and
* 5 kilometres back home
  - (5 vehicle kilometres, 10 passenger kilometres and 1.5 kg of CO_2).

In total, Lyn's school run results in 10 vehicle kilometres, 28 passenger kilometres and 3 kg of CO_2 at an average of 107 grams of CO_2 per passenger kilometre.

The following term, Lyn's son decides to ride to school. His journey results in zero vehicle kilometres, zero passenger kilometres and zero emissions. Lyn's daughter decides to catch the bus with her friends. Her trip to school results in zero additional vehicle kilometres (although 5 kilometres with Lyn's daughter on-board), 5 passenger kilometres and zero additional emissions (although on average the bus produced 110 grams of CO_2 per passenger kilometre). Lyn and her toddler don't have to make the journey at all, so no vehicle kilometres, passenger kilometres or emissions result.

By using sustainable transport modes, Lyn's family has reduced vehicle travel by 10 kilometres (100%), passenger travel by 23 kilometres (82%) and emissions by at least 2.4 kg (82%). This is despite emissions for each passenger kilometre of motorised travel increasing marginally. Furthermore, Lyn now has more time to spend on more productive activities, and there is less traffic on the road during the morning peak. The results would be broadly similar if Lyn's son also caught the bus.

In historical terms, public transport patronage is recovering from historical lows. For example, train patronage in Melbourne bottomed out in the 1980s and has only recently reached the levels of half a century ago. In many cases, public transport service levels also remain close to historical lows. A range of Melbourne's train and tram routes are running less frequently now than they were in the 1970s, despite the addition of new infrastructure such as the City Loop.

Despite these shortcomings, public transport does absorb a large proportion of journeys to work in the inner areas of Australia's largest cities. This substantial modeshare is noteworthy as it demonstrates the ability of public transport to move large numbers of people in the most crowded parts of our largest cities and at the busiest times of the day.

The greater 'scalability' of public transport was demonstrated when some relatively minor timetable adjustments on the Dandenong railway line in Melbourne added more passenger capacity to that corridor that the current $1 billion widening of the Monash Freeway that runs parallel. Even at current levels, the line still falls well short of the patronage levels achieved on similar infrastructure internationally (Mees 2007).

Nonetheless, chronic overcrowding on some public transport systems in Australia is undeniable. Declining reliability lies at the heart of much of the overcrowding, with cancellations and late running often forcing two or more train loads of passengers onto one service (Stone 2007, pp.16-17). Rectifying these reliability problems would improve passenger satisfaction and increase the actual effective capacity of the system.

Infrastructure investment is also clearly needed to improve capacity and reliability. Single track sections of suburban railway should be duplicated to allow higher service levels and urban rail networks expanded to ensure good coverage of fast, high capacity rail services that can both attract and accommodate substantial growth in patronage. Public transport infrastructure measures should also be a key focus for *Infrastructure Australia*, and the National Infrastructure Audit should include a thorough, independent expert assessment of current and potential impediments to higher public transport and rail freight service levels.

By way of contrast, overcrowding is not a problem on most public transport services outside of peak periods. Since most instances of off-peak overcrowding result from operational practices rather than capacity constraints, there is great scope for public transport to accommodate a much larger share of off-peak journeys. As a large proportion of off-peak travel is not pure radial journeys, attracting a larger share of such travel will require tightly integrated networks that better serve diverse origins and destinations (Stone 2007, pp.18-19).

2.6.5 Co-benefits

> "In general, a gallon of fuel conserved, or a ton of air pollution emissions avoided, due to reduced vehicle travel is worth an order of magnitude more than the same energy savings and emission reductions provided by increased vehicle fuel efficiency or shifts to alternative fuels. This occurs because mileage reductions also reduce traffic congestion, road and parking facility costs, consumer costs, accidents, water and noise pollution, and sprawl, and often improve mobility options for non-drivers and increase public fitness and health. Many mobility management programs are justified for their economic benefits, and so provide essentially *free* environmental benefits. In contrast, increase vehicle fuel efficiency tends to stimulate more total vehicle travel, which exacerbates transportation problems." (Litman 2008a, p.11)

The cost-effectiveness of shifting journeys out of private cars is significantly boosted by the social, economic and environmental benefits that result. Litman (2008a) identifies numerous positive impacts from modeshift including reduced congestion, reduced parking and road infrastructure costs, reduced motoring expenditure, reduced road trauma, and improved mobility for non-drivers. Truly optimal GHG emission reduction strategies are unlikely to be identified unless these co-benefits are given due recognition in decision making.

The PTUA (2007) has outlined a range of co-benefits associated with a shift from car use to walking, cycling and public transport in the Australian context. These co-benefits point to savings of many billions of dollars in terms of improved health and productivity and reduced congestion, pollution and transport costs (see also Woodcock *et al* 2007).

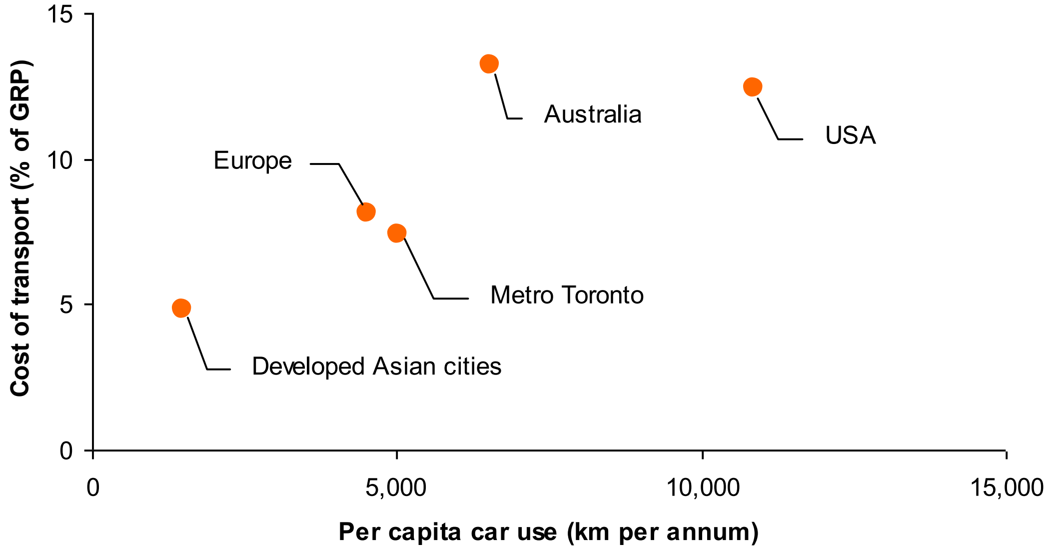
Table 2.3: Impact of $1 million expenditure

Expenditure category	Regional income*	Regional jobs*	Full-time jobs#
Petroleum	n/a	n/a	4.5
General automobile expenditure	$307,000	8.4	7.5
Non-auto consumer expenditure	$526,000	17.0	n/a
Public transport	$1,200,000	62.2	21.4

** Analysis performed in Texas, USA (Miller et al 1999)*

 # Analysis performed in British Columbia, Canada (BC Treasury Board 1996 in Litman & Laube 2002)

Figure 2.9: Car use and regional transport costs



As car use increases, a greater proportion of Gross Regional Product (GRP) must be spent on transport. Source: Newman 2000

The fact that modeshift is not being pursued more aggressively given these co-benefits points to fundamental problems with government decision making. A range of analyses – Benefits-Cost Analysis, Environment Impact Assessment, etc – tend to have narrow perspectives that ignore overarching directions. Proper consideration of all factors may require a framework of Strategic Environmental Assessment (SEA) that is becoming popular in other countries. SEA can help to avoid actions that may be individually innocuous, but that add to momentum down an unsustainable path.

2.6.6 Conclusion

Public transport offers major transport emission reductions as part of an overall strategy to establish an efficient transport *system*. While already more energy efficient than private transport, substantial opportunities to further reduce the carbon intensity of public transport remain.

An expanded role for public transport would also have major payoffs in terms of congestion, air quality and quality of life. The failure to more aggressively pursue modeshift points to serious deficiencies in transport governance that will need to be resolved if public transport is to provide more sustainable, equitable and inclusive transport options in a carbon constrained world.

2.7 Walking and cycling

Walking and cycling are the most sustainable forms of transport and also offer major health and financial benefits to those who are able to adopt them. In most cities around Australia, at least half of car journeys are less than 5 kilometres in length, and between a quarter to a third are within 3 kilometres. Many of these journeys are ideally suited to walking or cycling which would enable major reductions in GHG emissions and other air pollution. Eliminating short car journeys such as these also offers particularly strong benefits due to the high emissions intensity of driving with a cold engine.

Most of the key factors preventing greater walking and cycling are a direct consequence of attempts to increase the convenience of driving and parking – which reduce the relative competitiveness of walking and cycling journey times – and the resulting high traffic volumes that make walking and cycling less pleasant and less safe (ABS 2006a; Black *et al* 2001; PTUA 2008, pp.37-38). Traffic and parking restraint measures are both vital parts of any strategy to increase the attractiveness of walking and cycling and should be integral parts of transport and urban planning strategies at all levels of government. The reduction in car use discussed in section 2.3.1 would clearly improve amenity and safety for pedestrians and cyclists.

Walking and cycling are also the dominant methods of accessing public transport in cities with successful public transport systems. On the other hand, reliance on park and ride does little to reduce forced car ownership or improve mobility for people without access to a car. The large area of valuable land required for park and ride could be used more productively in line with Transit Oriented Design principles if improved access to interchanges was provided by high quality feeder buses and safe walking and cycling routes.

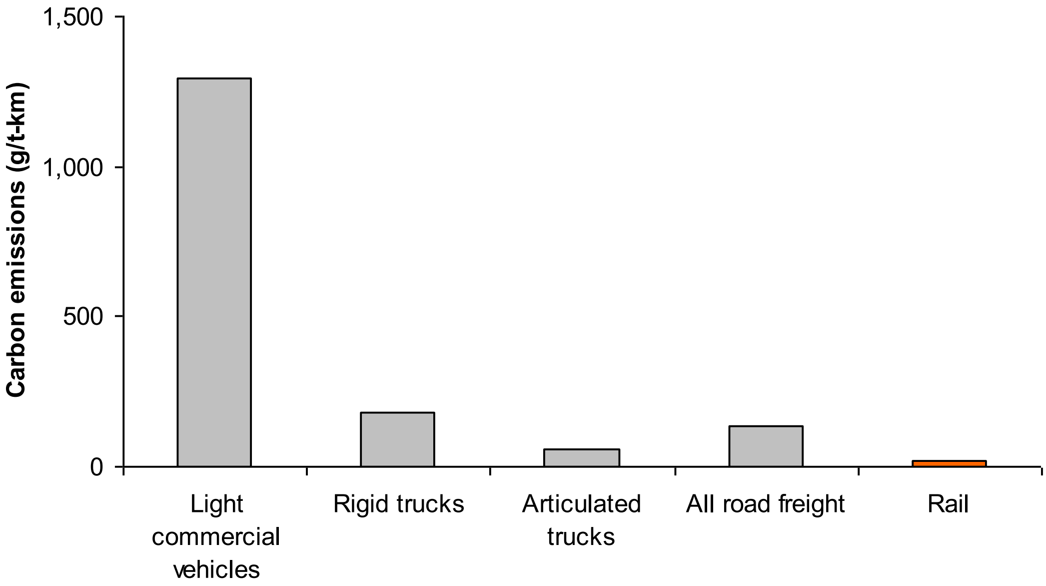
2.8 Freight

Road freight accounts for about one third of Australia's transport emissions, and significant growth has been forecast in the use of light commercial vehicles which have the highest carbon intensity per tonne-kilometre. The carbon intensity of rail freight is vastly lower than road freight, however rail freight networks have been left to decay in recent decades while billions of federal and state dollars have been poured into freeway networks. As a result rail has lost market share to road freight.

Major investment in rail networks by federal and state governments is now needed to remedy break of gauge problems that have persisted for over a century, to realign rail routes to reduce travel times, to restore decaying infrastructure, and to eliminate bottlenecks such as single track sections with inadequate passing loops.

Intermodal terminals offer the potential to shift freight from road to rail, however there is some work to be done to ensure adequate connectivity with interstate standard gauge lines and with ports. Opportunities also exist to consolidate urban freight to reduce both congestion and emissions resulting from short-haul freight movement[8].

Figure 2.10: Carbon intensity of freight modes



Source: Australian Greenhouse Office

2.9 Offsetting

Offsets are likely to be part of the adjustment to a low carbon society. In a way, an emissions trading scheme could be thought of as a large scale market for offsets. However, for an ETS or offset scheme to be effective, there must be a net reduction in emissions somewhere, otherwise offsetting is nothing more than a modern version of buying indulgences.

For offsets to be effective, they must be based upon scientifically sound, independently verified measures that offer *permanent* and *additional* carbon reductions. Appropriate regulation and monitoring should also be in place to guard against measures that harm vulnerable communities or exacerbate other environmental problems[9], and to discourage marketing practices that play down the importance of emission reductions relative to offsetting.

[8] http://www.start-project.org/
[9] e.g. see concerns raised by Carbon Trade Watch: www.carbontradewatch.org

2.10 Fiscal measures

We estimate that road users are currently undercharged by at least $18 billion per annum excluding congestion[10]. This 'road deficit' equates to an average subsidy of about 8.7 cents/kilometre or 63 cents/litre of fuel[11], and is a key driver of Australia's high and rapidly growing transport-related emissions.

Table 2.4: The Road Deficit - road-related revenues and costs in Australia

Annual costs imposed by motorists		Annual revenue collected from motorists	
Item	*Expense ($ million)*	*Item*	*Revenue ($ million)*
Road construction & maintenance	8,800	Excise (net of rebates)	9,800
Land use cost	6,000	GST on fuel	1,700
Road trauma	17,300	Vehicle registration fees	3,250
Noise	700	Insurance premiums	9,700
Urban air pollution	4,300	Tolls	750
Climate change	2,900	Other revenue	2,300
Tax concessions	5,200	**Total (2)**	**$27,500**
State fuel subsidies	600		
Total (1)	**$45,800**	**Road deficit (1-2)**	**$18,300**

Source: http://www.ptua.org.au/myths/petroltax.shtml

While a price on carbon may decrease the road deficit, it is unlikely to eliminate it given the likely range of a carbon price. It is therefore important to look at the structure of these subsidies as well as the magnitude. For example, the statutory formula for valuing motor vehicle fringe benefits encourages additional driving at a cost approaching $2 billion per annum (Treasury 2007, p.150), with the largest concessions for a given amount of driving going to the highest value cars (i.e. it is regressive in nature). This perversity should be eliminated immediately and the savings redirected to improving public transport.

Table 2.5: Tax concessions and GHG emissions resulting from the statutory formula

Annual travel (km)	Statutory fraction	Average annual GHG emissions	Maximum tax concession $35,000 car	Maximum tax concession $70,000 car
Under 15,000	26%	Up to 3.8 tonnes	$12,044	$24,087
15,000-24,999	20%	3.8 to 6.4 tonnes	$13,020	$26,040
25,000-40,000	11%	6.4 to 10.2 tonnes	$14,485	$28,970
Over 40,000	7%	Over 10.2 tonnes	$15,136	$30,272

The likelihood that the road deficit will not be fully eliminated further emphasises the importance of also favouring public transport through complementary measures such as federal funding of public transport infrastructure and winding down spending on arterial roads and motorways.

[10] http://www.ptua.org.au/myths/petroltax.shtml

[11] Based on 209.4 billion km of travel and 28,898 megalitres of fuel pa (ABS 2007).

3 EQUITY IMPACTS AND CAR DEPENDENCE

3.1 Transport disadvantage

Decades of large-scale expenditure on road networks by all three tiers of government, along with under-pricing of motor vehicle use relative to its full social and environmental costs, have encouraged unsustainable transport and land use patterns and excessive dependence upon private cars. Strong demand for desirable property has driven up house prices in inner and middle suburbs and pushed many lower and middle income households to fringe areas that are poorly serviced by public transport. These factors combine to literally force outer suburban families to own and extensively operate multiple cars – frequently at least one car per adult in the household.

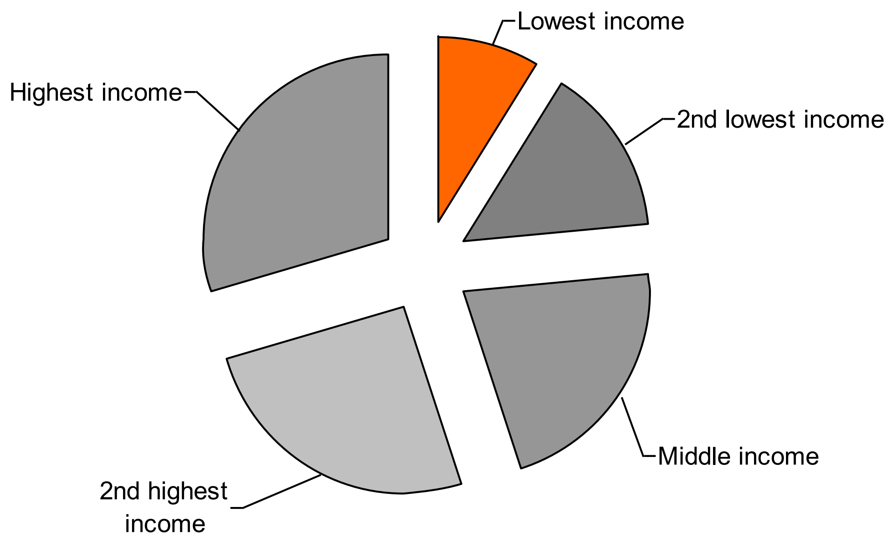
The extent of this 'forced car ownership' has been illustrated by Senbergs and Currie (2007), and the distribution of vulnerability to high petrol prices graphically shown by Dodson and Sipe (2006). It is now clear that inadequate public transport is already a major financial burden for many low income households, and financial stress on such families is only likely to worsen in a carbon-constrained world unless transport alternatives are significantly improved.

3.2 The incidence of fuel taxation and carbon pricing

Without diminishing the financial impact of forced car ownership on lower income households, it must be pointed out that the majority of fuel is purchased by high and middle income households in urban areas. In economic terms, the incidence of fuel taxation (and any future carbon price) therefore falls mainly on households with reasonable ability to pay and some access to alternative transport (however inadequate it may be at present). A small minority of fuel taxation is paid by low income households or by people without any form of alternative transport.

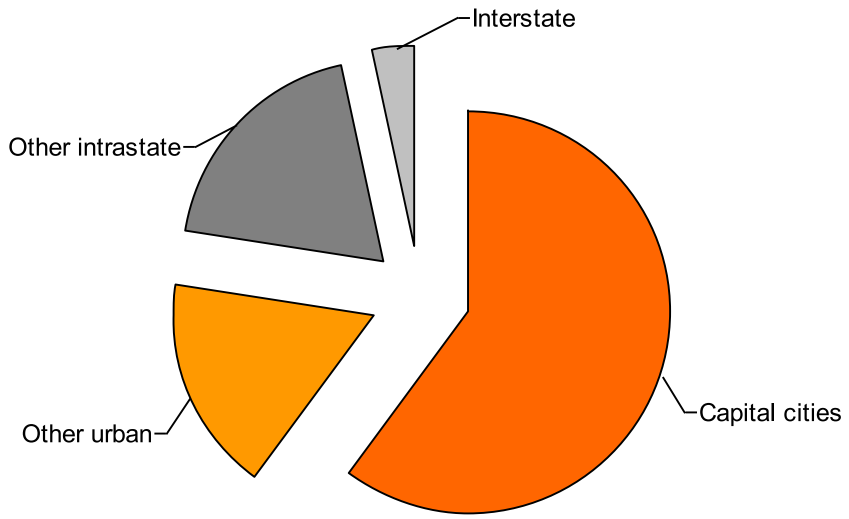
This obviously does not mean that the equity impacts of carbon pricing can be ignored, but it does clearly mean that attempting to keep the price of petrol down would mainly benefit those who need the least assistance and would also undermine efforts to reduce transport emissions. Not only would middle and upper income urban households be the main beneficiaries of measures aimed at lowering petrol prices, lower income households would still face various other costs of car ownership and operation that come with car dependence such as tolls, insurance, repairs and maintenance.

Figure 3.1: Weekly expenditure on fuel by household income



Source: ABS 2006b

Figure 3.2: Location of passenger vehicle use



Source: ABS 2007

Efforts to minimise the negative equity impacts of carbon pricing would be more effective and better targeted if they reduce car dependence among low income households, expand the coverage of good quality public transport and provide general financial assistance to vulnerable households. Such an approach would also reinforce the emissions reduction objectives of carbon pricing, whereas attempting to keep petrol prices low would contradict the environmental objectives of carbon pricing.

3.3 Enhancing the effectiveness of carbon pricing

Like most normal goods with limited substitutes, demand for petrol is often said to be unresponsive to higher prices, or that petrol demand is relatively price inelastic. Managing demand for price inelastic goods can be a challenge for policy makers since large price increases may be required to achieve relatively minor changes in the quantity demanded, and the impacts can be severe for lower income households.

The inelasticity of petrol demand results from the need for mobility in modern societies and the current poor quality of substitutes to private motor vehicle use. Both of these factors can be addressed by focussing greater attention on ensuring *access* to employment, education and other services (rather than *mobility*) and by providing high quality transport alternatives.

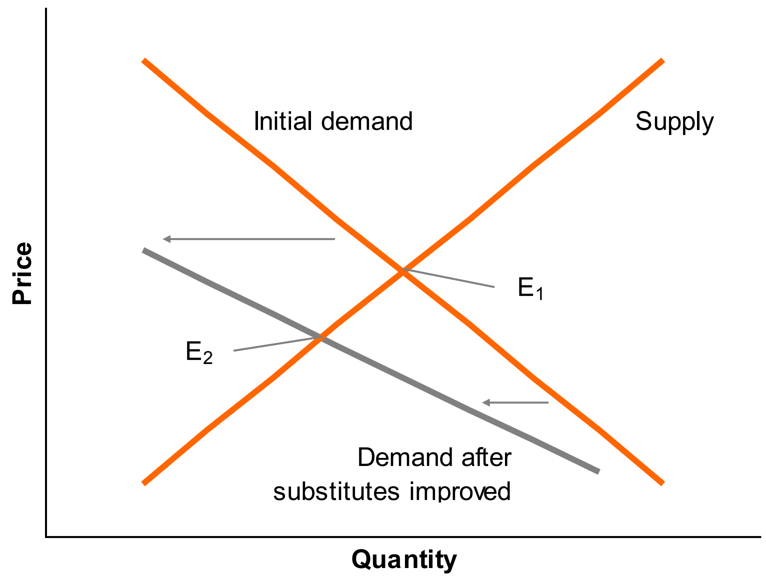
Increasing the ability of households to reduce motor vehicle use in response to higher petrol prices would ensure that a lower carbon price would be needed to achieve a given reduction in emissions and consequently that the financial impacts would be minimised for those who continue to drive out of necessity.

The decision to drive is strongly influenced by the 'generalised cost' of travel which includes financial expenses such as fuel and tolls as well as the time cost of various travel options. For many people, especially in outer suburbs, the time cost is of such great significance that large increases in the financial cost are required to change travel behaviour. Improving the quality of transport alternatives (as outlined in Section 2.6.2) reduces the generalised cost of substitutes to motor vehicle use and shifts the petrol demand curve to the left, thus reducing both petrol consumption *and* prices.

In contrast, expanding the capacity of roads or parking or enabling faster traffic speeds lowers the generalised cost of private motor vehicle use and shifts the petrol demand curve to the right. Even if the increased road capacity is tolled, the dominance of time cost in the generalised cost of travel overwhelms the deterrent effect of tolls and leads to increased motor vehicle use and fuel demand.

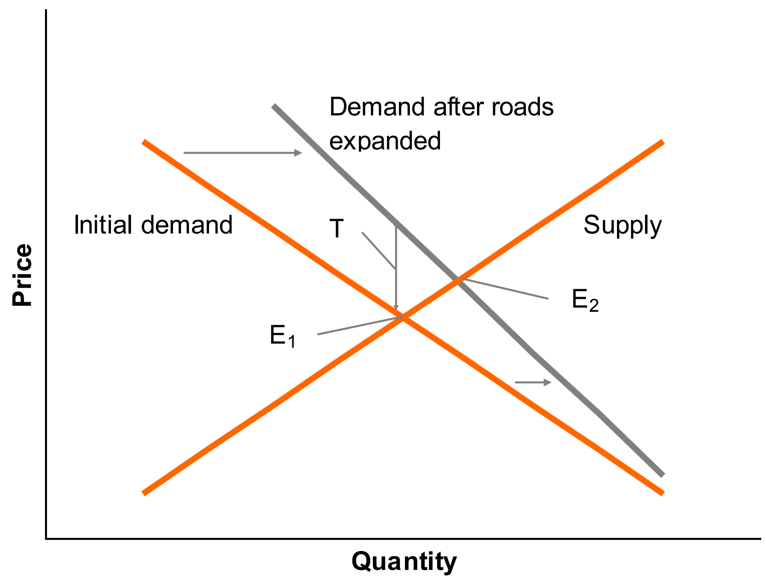
If vehicle use is encouraged in this way, a substantially higher carbon price is required to achieve a given reduction in emissions and low income households are more severely impacted by the higher petrol prices that result.

Figure 3.3: Impact on fuel demand of improving substitutes to car use



Prior to improvements being made to public transport, fuel demand and supply are in equilibrium at E_1. After public transport is improved, the demand curve for fuel becomes more elastic and shifts to the left. A new equilibrium is established at E_2 with lower fuel consumption (and emissions) and lower fuel prices (inclusive of carbon price).

Figure 3.4: Impact on fuel demand of improving roads



Prior to improvements being made to roads, fuel demand and supply are in equilibrium at E_1. After roads (a complement to fuel) are improved, the demand curve for fuel becomes more inelastic and shifts to the right. A new equilibrium is established at E_2 with higher fuel consumption (and emissions) and higher fuel prices. An additional carbon price of T would be required to lower emissions to their initial level at E_1.

In light of these impacts on transport energy consumption, all tiers of government should be diverting transport expenditure away from roads and into walking, cycling, public transport and rail freight in order to enhance the effectiveness of carbon pricing on energy demand and to reduce the negative impacts on low income households.

3.4 Dumping gas guzzlers onto low income households

While much attention is focussed on encouraging the uptake of more efficient new cars by consumers, low income households tend to buy used cars that can be well over a decade old. The ability of low income households to buy efficient vehicles is therefore subject to the purchasing practices of past new car buyers.

Fleet buyers, particularly government fleets, are among the largest suppliers of vehicles onto the used car market. Such fleets tend to base their procurement decisions upon time horizons of only two or three years and to favour large Australian-made vehicles with fuel consumption figures that are unremarkable at best (Millar 2008). Such procurement practices effectively dump large volumes of inefficient vehicles onto lower income households where they remain for a decade or two and exacerbate vulnerability to higher fuel prices.

The equity impacts of higher fuel prices could be mitigated by fleet buyers, particularly government fleets, ensuring their procurement policies prioritise fuel efficiency and emissions. Over time, albeit quite slowly given the turnover of motor vehicles, such policies would reduce the proportion of gas guzzlers in low income households and help to minimise the negative equity impacts of carbon pricing.

4 CONCLUSION

4.1 In a nutshell

The Garnaut Climate Change Review is an important step forward in Australian climate policy, recognising as it does the need for much greater urgency in making deep cuts to GHG emissions if dangerous climate change is to be avoided. However despite this belated shift in official discourse on climate change, there is still evidence that the proposed measures do not go far enough.

While stationary energy is often the focus of discussion on GHG emissions, major changes to the way we think about transport are also needed. If transport is not part of the solution, it will surely be a key factor in our failure to prevent runaway climate change. While important, improvements in vehicle efficiency will be nowhere near enough to achieve the sort of emissions reductions required to prevent dangerous climate change. Walking, cycling and public transport will have to assume much larger roles in society if emissions are to be successfully brought under control.

Fortunately the required changes to the way we move ourselves and our freight will also make our cities much more liveable and have multiple paybacks including reduced air pollution, fewer road casualties, less traffic noise, greater social inclusion and healthier lifestyles (Gärling & Steg 2007; Woodcock *et al* 2007; PTUA 2007; PTUA 2008). There is also ample evidence that large increases in walking, cycling and public transport use can lead, rather than rely on, higher urban densities and revitalisation of local communities (Litman & Laube 2002; Mees 2000; Moriarty & Honnery 2008b).

It is also clear that time and resources should not be squandered on expanding arterial roads and motorways when these encourage the exact opposite of the changes needed to prevent dangerous climate change. All tiers of government now need to divert resources to greatly improving the coverage and quality of public transport so it provides a more viable option for a larger proportion of people and journeys. Motor vehicles also need to be tamed to ensure our streets and public places are safe and inviting for families to walk and cycle without feeling the need to encase themselves in metal cocoons.

Climate change therefore presents the most significant threat of at least a generation, but also a tremendous opportunity. Government must play a leading role in grasping this opportunity by shifting the focus of transport policy to enabling more sustainable and equitable participation in society instead of concentrating on moving ever larger volumes of motor vehicles.

5 REFERENCES

AAP, 2008, 'Higher rates, fuel don't break SUV sales', *The Age*, 4 April, http://news.theage.com.au/higher-rates-fuel-dont-break-suv-sales/20080404-23q4.html

AATSE, 1997, *Urban Air Pollution in Australia*, Australian Academy of Technological Sciences and Engineering, http://www.environment.gov.au/atmosphere/airquality/publications/urban-air/pubs/urban.pdf

ABARE, 2007, *'Australian Energy Statistics - Australian Energy Update' 2007*, Australian Bureau of Agricultural and Resource Economics, Canberra

ABS, 2006a, *Environmental Issues: People's Views and Practices, Mar 2006*, Australian Bureau of Statistics, Canberra,

ABS 2006b, *Household Expenditure Survey, 2003-04*, Australian Bureau of Statistics, Canberra,

ABS 2007, *Survey of Motor Vehicle Use*, Australian Bureau of Statistics, Canberra,

ABS, 2008, *Sales of New Motor Vehicles, Australia, Feb 2008*, Australian Bureau of Statistics, Canberra,

Adam, D. & Traynor, I., 2007, 'Scientists' stark warning on reality of warmer world', *The Guardian*, 7 April, http://environment.guardian.co.uk/climatechange/story/0,,2051915,00.html

Akerman, J. & Hojer, M., 2006, 'How much transport can the climate stand? - Sweden on a sustainable path in 2050', *Energy Policy*, Vol. 34 Issue 14, pp.1944-1957, doi: 10.1016/j.enpol.2005.02.009

Algers, S., Hanson, S., & Tegner, G., 1975, 'Role of waiting time, comfort, and convenience in modal choice for work trip', *Transportation Research Record, 534*, 38-51

AGO, 2006, *Transport Sector Greenhouse Gas Emissions Projections*, Department of Environment and Heritage, Canberra

APEC, 2005, *Impact of Oil Prices on Trade in the APEC Region*, http://abareonlineshop.com/product.asp?prodid=13276

Archer, J., Fotheringham, N., Symmons, M. & Corben, B., 2007, 'The Impact of Lowered Speed Limits in Urban/Metropolitan Areas: A Literature Study', *Australasian Road Safety 2007 Research Policing and Education Conference*, 17–19 October, Melbourne

Asensio, J., 2002,'Transport Mode Choice by Commuters to Barcelona's CBD', *Urban Studies*, Vol. 39, No. 10, pp. 1881-1895

Azar, C., Lindgren, K., *et al* ,2006, 'Carbon capture and storage from fossil fuels and biomass – Costs and potential role in stabilizing the atmosphere', Climatic Change 74(1-3): 47-79

Barker, T., Bashmakov, I., Bernstein, L., et al., 2007, Technical summary. In: Metz, B., Davidson, O.R., Bosch, P.R., et al. (Eds.), *Climate Change 2007: Mitigation*. CUP, Cambridge, UK, pp. 25–93.

Beer, T. 2004, *Air pollution death toll needs solutions*, media release, 2 March, CSIRO, http://www.csiro.au/files/mediaRelease/mr2004/PrAirPollution2.htm

Bento, A.M., Cropper, M.L., Mobarak, A.M. & Vinha, K., 2005, 'The Effects of Urban Spatial Structure on Travel Demand in the United States', *Review of Economics and Statistics*, Vol. 87, No. 3, pp.466-478, doi: 10.1162/0034653054638292

Black, C., Collins, A. & Snell, M., 2001, 'Encouraging Walking: The Case of Journey-to-school trips in Compact Urban Areas', *Urban Studies*, Vol. 38, No. 7, pp.1121-1141

Brandt, A. & Farrell, A., 2008, *Dynamics of the Oil Transition: Modelling Capacity, Costs, and Emissions*, University of California Energy Institute, Berkeley

Brook Lyndhurst, 2006, *The City Climate Challenge for 2050: Your city – your responsibility*, Brook Lyndhurst, London

BTCE, 1995, *Greenhouse Gas Emissions from Australian Transport: Long-term projections*, Report 88, AGPS, Canberra

BTE, 2000, *Urban Congestion – the Implications for Greenhouse Gas Emissions*, Bureau of Transport Economics, Canberra

California Energy Commission, 2005, *Forecasts of California Transportation Energy Demand 2005-2025*, http://www.energy.ca.gov/2005publications/CEC-600-2005-008/CEC-600-2005-008.PDF

Cassady, A., Dutzik, T. & Figdor, E., 2004, *More Highways, More Pollution*, Environment California, http://www.environmentcalifornia.org/uploads/DT/xt/DTxtE1628jWJvtqR5OkNng/More_Highways_More_Pollution.pdf

Ceder, A., 2004, 'New Urban Public Transportation Systems: Initiatives, Effectiveness and Challenges', *Journal of Urban Planning and Development*, Vol. 130, No. 1, pp. 56-65

Chertok, M, Voukelatos A, Sheppeard V, Rissel C. Comparison of air pollution exposure for five commuting modes in Sydney – car, train, bus, bicycle and walking. *Health Promot J Aust* 2004; 15: 63-67

Chorus, C., Molin, E., van Wee, B., Arentze, T. & Timmermans, H., 2006, 'Responses to Transit Information among Car-drivers: Regret-based Models and Simulations', *Transportation Planning and Technology*, Vol. 29, No. 4, pp. 249-271

Colin Buchanan and Partners, 2003, *Transferability of Best Practice in Transport Policy Delivery*, Scottish Executive, Edinburgh, http://www.scotland.gov.uk/Resource/Doc/47133/0031335.pdf

Cooney, C., 2007, 'Higher ozone levels from renewable fuels', *ES&T News*, Vol.41, Iss.12, pp.4182-4183, http://pubs.acs.org/subscribe/journals/esthag/41/i12/html/061507news1.html

Cozens, P., Neale, R., Jillier, D. & Whitaker, J., 2004, 'Tackling Crime and Fear of Crime While Waiting at Britain's Railway Station', *Journal of Public Transportation*, Vol. 7, No. 3, pp.23-41

Crutzen, P. J., Mosier, A. R., Smith, K. A. &Winiwarter, W., 2007, 'N2O release from agro-biofuel production negates global warming reduction by replacing fossil fuels', *Atmospheric Chemistry and Physics Discussions*, Vol 7, No 4, pp. 11191-11205, http://www.atmos-chem-phys-discuss.net/7/11191/2007/

Darby, A., 2008, 'Cold reality: ice shelf loses vast chunk', *The Age*, 27 March, http://www.theage.com.au/news/environment/ice-shelf-loses-vast-chunk/2008/03/26/1206207208864.html

Demery, L.W. & Higgins, J.W., 2005, *Rapid Bus and Rapid Rail: Peak Period Service Supply vs Observed Passenger Utilization*, publictransit.us

Department of Climate Change, 2008, *National Greenhouse Accounts (NGA) Factors*, Department of Climate Change, Canberra

Dickie, P., 2007, *Making Water. Desalination: option or distraction for a thirsty world?*, WWF, http://assets.panda.org/downloads/desalinationreportjune2007.pdf

Dodson, J. & Sipe, N., 2006, *Shocking the Suburbs: Urban Location, Housing Debt and Oil Vulnerability in the Australian City*, Griffith University

Doornbosch, R. & Steenblik, R., 2007, *Biofuels: Is the cure worse than the disease?*, Organisation for Economic Cooperation and Development, Paris

Doyle, A., 2008, *Climate Solutions Often Harm Indigenous Peoples – UN*, Reuters, 3 April, http://www.planetark.com/dailynewsstory.cfm/newsid/47753/story.htm

Dziekan, K. & Kottenhoff, K., 2007, 'Dynamic at-stop real-time information displays for public transport: effects on customers', *Transportation Research Part A: Policy & Practice*, Vol. 41, Iss. 6, pp. 489-501

EFT&E, 2005, *Road transport speed and climate change*, European Federation for Transport & Environment, Brussels, http://www.transportenvironment.org/docs/Positionpapers/2005/2005-09_cars21_speed_co2.pdf

Engelhaupt, E., 2008, 'Global warming increases deadly air pollution', *Environmental Science & Technology News*, Vol. 42, No. 5, p.1392, http://pubs.acs.org/subscribe/journals/esthag/42/i05/html/030108news3.html

Ennis, D., 2008, *UN Sees More Hunger, Unrest Over Food Inflation*, Reuters, http://www.planetark.com/dailynewsstory.cfm/newsid/47381/story.htm

EPA 2006, *What can you do to improve motor vehicle emissions?*, http://www.epa.vic.gov.au/air/vehicles/individuals_improve.asp

Friedemann, A., 2007, *Peak Soil: Why Cellulosic ethanol and other Biofuels are Not Sustainable and are a Threat to America's National Security*, http://www.culturechange.org/cms/index.php?option=com_content&task=view&id=107&Itemid=1

Fuglestvedt, J., Berntsen, T., Myhre, G., Rypdal, K. & Bieltvedt Skeie, R., 2008, 'Climate forcing from the transport sectors', *Proceedings of the National Academy of Sciences*, Vol.105, No.2, pp.454-458, http://www.pnas.org/cgi/content/abstract/0702958104v1

Gärling, T. & Steg, L. (eds) 2007, *Threats from Car Traffic to the Quality of Urban Life*, Elsevier, Amsterdam

Gray, G. 1992, 'Perceptions of Public Transportation', in Gray, G.E. and Hoel, L.A., *Public Transportation: Planning, Operations and Management*, 2nd edition, Prentice-Hall, 1992, http://ntl.bts.gov/lib/11000/11800/11877/Chapter22.pdf

Greene, D.L. & Schafer, A., 2003, *Reducing greenhouse gas emissions from US transportation*, Pew Centre on Global Climate Change, http://www.pewclimate.org/docUploads/ustransp.pdf

Haberl, H., Erb, K.H., Krausmann, F., Gaube, V., Bondeau, A., Plutzar, C., Gingrich, S., Lucht, W. & Fischer-Kowalski, M., 2007, 'Quantifying and mapping the human appropriation of net primary production in earth's terrestrial ecosystems', Proceedings of the National Academy of Sciences, Vol. 104, No. 31, pp.12942-12947, http://www.pnas.org/cgi/content/abstract/104/31/12942

Hagan, K. 2007, 'Study puts brakes on ethanol fuel plan', *The Age*, 10 March, http://www.theage.com.au/news/national/study-puts-brakes-on-ethanol-fuel-plan/2007/03/09/1173166986002.html

Hansen, J. & Sato, M., 2001, 'Trends of measured climate forcing agents', *Proceedings of the National Academy of Sciences*, Vol. 98, No. 26, pp.14778-14783

Hansen, J., Sato, M., Kharecha, P., Russell, G., Lea, D.W. & Siddall, M., 2007, 'Climate change and trace gases', *Phil. Trans. Royal. Soc. A*, 365, 1925-1954, doi:10.1098/rsta.2007.2052

Hansen, J., Sato, M., Kharecha, P., Beerling, D., Masson-Delmotte, V., Pagani, M., Raymo, M., Royer, D. & Zachos, J.C., 2008, *Target Atmospheric CO2: Where Should Humanity Aim?*, http://www.columbia.edu/~jeh1/2008/TargetCO2_20080317.pdf

Hawkins, D G. 2006, *Testimony to the Full Committee Hearing on Coal Liquefaction and Gasification*, Committee of Energy and Natural Resources, United States Senate, http://docs.nrdc.org/globalWarming/glo_06042401a.pdf

Hendrickson, C.T., Lave, L.B. & Matthews, H.S., 2006, *Environmental Life Cycle Assessments of Goods and Services: An Input-Output Approach*, Resources for the Future, Washington DC

Hirsch, R., 2007, *Peaking of World Oil Production: Recent Forecasts*, National Energy Technology Laboratory, US Department of Energy

Hirsch, R., Bezdek, R. & Wendling, R., 2005, *Peaking Of World Oil Production: Impacts, Mitigation, & Risk Management*,

HiTrans, 2005, *Public transport - Planning the networks*, HiTrans, Stavenger, Norway

Hopkin, M. 2007, 'Carbon sinks threatened by increasing ozone', *Nature*, 26 July, http://www.nature.com/nature/journal/v448/n7152/full/448396b.html

Huesemann, M., 2006, 'Can advances in science and technology prevent global warming?', *Mitigation and Adaptation Strategies for Global Change*, 11, pp. 539-577, doi:10.1007/s11027-006-2166-0

IBI Group, 2006, *Streetcar and Local Bus Comparative Review*, City of Vancouver, http://www.city.vancouver.bc.ca/engsvcs/transport/streetcar/pdfs/comparativeReview.pdf

Jacobson, M., 2007, 'Effects of Ethanol (E85) versus Gasoline Vehicles on Cancer and Mortality in the United States', *Environ. Sci. Technol.*, 41 (11), 4150 -4157, 2007. doi:10.1021/es062085v S0013-936X(06)02085-2, http://pubs.acs.org/cgi-bin/abstract.cgi/esthag/2007/41/i11/abs/es062085v.html

Jacobson, M. Z., 2008, 'On the causal link between carbon dioxide and air pollution mortality', *Geophys. Res. Lett.*, 35, L03809, doi:10.1029/2007GL031101

Jakobsson, C., 2007, 'Instrumental motives for private car use', in Gärling, T. & Steg, L. (Eds.), *Threats to the Quality of Urban Life from Car Traffic: Problems, Causes, and Solutions*, Elsevier, Amsterdam

Kennedy, C., Miller, E., Shalaby, A., McLean, H. & Coleman, J., 2005, 'The Four Pillars of Sustainable Urban Transportation, *Transport Reviews*, Vol.25, pp. 393-414

Kenworthy, J., 2000, *Techniques of Urban Sustainability: Quality Transit*, Institute for Sustainability and Technology Policy, Murdoch University, http://www.istp.murdoch.edu.au/ISTP/casestudies/Case_Studies_Asia/qtrans/qtrans.html

King, C. & Webber, M., 2008, 'The Water Intensity of the Plugged-In Automotive Economy', *Environ. Sci. Technol.*, 10.1021/es0716195, http://pubs.acs.org/cgi-bin/abstract.cgi/esthag/asap/abs/es0716195.html

Kjellstrom, T., Neller, A. & Simpson, R.W. 2002, 'Air pollution and its health impacts: the changing panorama', *Medical Journal of Australia*, 177 (11/12): 604-608, http://www.mja.com.au/public/issues/177_11_021202/kje10481_fm.pdf

Kottenhoff, K. & Lindh, C., 1995, ‘The value and effects of introducing high standard train and bus concepts in Blekinge, Sweden’, *Transport Policy*, Vol. 2, No.4, pp. 235-241

Leggett, J., 2005, *Half Gone*, Portobello Books, London

Lewis, D. & Williams, F.L., 1999, *Policy and Planning As Public Choice: Mass Transit in the United States*, Ashgate

Litman, T., 2005, ‘Efficient Vehicles Versus Efficient Transportation: Comparing Transportation Energy Conservation Strategies,’ *Transport Policy*, Vol. 12, No. 2, pp.121-129, http://www.vtpi.org/cafe.pdf

Litman, T., 2006, *Rail Transit In America: A Comprehensive Evaluation of Benefits*, Victoria Transport Policy Institute, Victoria BC, http://www.vtpi.org/railben.pdf

Litman, T., 2007, *Win-Win Emission Reduction Strategies*, Victoria Transport Policy Institute, http://www.vtpi.org/wwclimate.pdf

Litman, T., 2007b, *Generated Traffic and Induced Travel: Implications for Transport Planning*, Victoria Transport Policy Institute, http://www.vtpi.org/gentraf.pdf

Litman, T., 2008a, *Smart Transportation Emission Reductions: Identifying Truly Optimal Energy Conservation And Emission Reduction Strategies*, Victoria Transport Policy Institute, http://www.vtpi.org/ster.pdf

Litman, T., 2008b, *Appropriate Response to Rising Fuel Prices*, Victoria Transport Policy Institute, http://www.vtpi.org/fuelprice.pdf

Litman, T. & Laube, F., 2002, *Automobile Dependency and Economic Development*, Victoria Transport Policy Institute, http://www.vtpi.org/ecodev.pdf

Lovell, J., 2008, *Rising Energy Prices Create Global Climate Conundrum*, Reuters, 27 February, http://www.planetark.com/dailynewsstory.cfm/newsid/47199/story.htm

Low, T. & Booth, C., 2007, *The Weedy Truth About Biofuels*, Invasive Species Council, http://www.invasives.org.au/downloads/isc_weedybiofuels_oct07.pdf

Lumsdon, L., Downward, P. & Rhoden, S., 2006, ‘Transport for Tourism: Can Public Transport Encourage a Modal Shift in the Day Visitor Market?’, *Journal of Sustainable Tourism*, Vol. 14, No. 2, pp. 139-156

Loya, W.M., Pregitzer, K.S., Karberg, N.J., King, J.S. & Giardina, C.P., 2003, ‘Reduction of soil carbon formation by tropospheric ozone under increased carbon dioxide levels’, *Nature* 425, 705-707 (16 October 2003) | doi:10.1038/nature02047

Mann, E. & Abraham, C., 2006, ‘The role of affect in UK commuters’ travel mode choices: An interpretive phenomenological analysis’, *British Journal of Psychology*, Vol. 97, No. 2, pp.155-176, DOI: 10.1348/000712605X61723

Marenco, A., Gouget, H., Nédélec, P., Pagés, J.-P. & Karcher, F., 1994, ‘Evidence of a long-term increase in tropospheric ozone from Pic du Midi data series: Consequences: Positive radiative forcing’, *J. Geophys. Res.*, 99(D8), 16,617–16,632.

Matthews, H. D. & Caldeira, K., 2008, ‘Stabilizing climate requires near-zero emissions’, *Geophys. Res. Lett., 35*, L04705, doi:10.1029/2007GL032388

McCarthy, A., 2007, ‘Public Transport and Climate Change’, *Climate Change – The Transport Response – AITPM Victorian Branch ½ day seminar*, 16 October, Melbourne

McKinsey & Company, 2008, *An Australian Cost Curve for Greenhouse Gas Reduction*, McKinsey and Company, Sydney

Mees, P., 2000, *A Very Public Solution: Transport in the Dispersed City*, Melbourne University Press, Melbourne

Mees, P., 2007, *How to double the capacity of the Dandenong line without new infrastructure*, Australasian Centre for the Governance and Management of Urban Transport, Melbourne, http://www.gamutcentre.org/media/recent%20publications/Dandenong_line-Final1.pdf

Mees, P., Sorupia, E. & Stone, J., 2007, *Travel to work in Australian capital cities, 1976-2006: an analysis of census data*, Australasian Centre for the Governance and Management of Urban Transport, Melbourne

Meyer, M., Menth, S. & Keller, T., 2004, 'Specification and verification of energy efficient rolling stock', *2nd UIC Railway Energy Efficiency Conference*, 4-5 February, Paris

Millar, R., 2008, 'Government fleet's greenhouse emissions on rise', *The Age*, 12 March, http://www.theage.com.au/news/global-warming/black-balloons-from-brumby-saloons/2008/03/12/1205125968879.html

Mitchell, G. & Ife, H., 2008, 'Oil price rise signals more petrol pain', Herald Sun, 6 March, http://www.news.com.au/heraldsun/story/0,21985,23326569-662,00.html

Mogridge, M., 1990, *Travel in towns: jam yesterday, jam today and jam tomorrow?*, Macmillan Press, London

Moriarty, P. & Honnery, D., 'The prospects for global green car mobility', *J Clean Prod* (2007), doi:10.1016/j.jclepro.2007.10.025

Moriarty, P. & Honnery, D., 2007b, 'Global bioenergy: problems and prospects', *International Journal of Global Energy Issues*, Vol. 27, No.2 pp. 231-249

Moriarty, P. & Honnery, D., 2008a, 'Mitigating greenhouse: Limited time, limited options', *Energy Policy*, Vol. 36, No. 4, pp.1251-1256, doi:10.1016/j.enpol.2008.01.021

Moriarty, P. & Honnery, D., 2008b, Low-mobility: the future of transport,

Morton, A.B., 2007, 'Observational Analysis of Tram Delays in Inner Melbourne', *Australasian Transport Research Forum (ATRF'07)*, Melbourne, September 2007

Naylor, R., Liska, A., Burke, M., Falcon, W., Gaskell, J., Rozelle, S. & Cassman, K., 2007, 'The Ripple Effect: Biofuels, food security, and the environment', *Environment*, Vol. 49, No. 9, pp.31-43

Newman, P., 2000, *Sustainable Transportation and Global Cities*, Murdoch University, Perth,http://www.istp.murdoch.edu.au/ISTP/casestudies/Case_Studies_Asia/sustrans/sustrans.html

Newman, P. & Kenworthy, J., 1992, *Winning back the cities*, Pluto Press, Sydney

Newman, P. & Kenworthy, J., 1999, *Sustainability and Cities: Overcoming Automobile Dependence*, Island Press

Newman, P., Kenworthy, J. & Lyons, T., 1988, 'Does Free-Flowing Traffic Save Energy and Lower Emissions in Cities?', *Search*, 19(5-6), 267-272.

Oxfam, 2007, *Bio-fuelling Poverty: Why the EU renewable-fuel target may be disastrous for poor people*, Oxfam International, Oxford, http://www.oxfam.org/en/files/bn_biofuelling_poverty_0711.pdf

Pimentel, D. & Lal, R., 2007, 'Biofuels and the Environment', *Science*, Aug 17; 317 (5840):897-8

Pimental, D. & Patzek, T.W., 2005, 'Ethanol Production Using Corn, Switchgrass & Wood; Biodiesel Production Using Soybean & Sunflower', *Natural Resources Research*, Vol. 14, No. 1, pp. 65-76, DOI: 10.1007/s11053-005-4679-8

Porter, I., 2008, 'Money rules the road to a green car', *The Age*, 6 March, http://www.theage.com.au/news/environment/money-rules-the-road-to-a-green-car/2008/03/05/1204402555605.html

PTUA, 2007, *Moving Australians Sustainably*, Public Transport Users Association, Melbourne, http://www.ptua.org.au/federal/moving_australians-web.pdf

PTUA, 2008, *Enhancing Victoria's Liveability*, Public Transport Users Association, Melbourne

Quiggin, J., 2007, *Drought, Climate Change and Food Prices in Australia*, School of Economics and School of Political Science and International Studies, University of Queensland,http://www.acfonline.org.au/uploads/res/Climate_change_and_food_prices_in_Australia.pdf

Rahmstorf, S., Cazenave, A., Church, J., Hansen, J., Keeling, R., Parker, D. & Somerville, R., 2007, 'Recent Climate Observations Compared to Projections', *Science*, Vol. 316, p.709, 10.1126/science.1136843

Ramesohl, S. & Merten, F., 2006, 'Energy system aspects of hydrogen as an alternative fuel in transport', *Energy Policy*, Vol. 34 Issue 11, p1251-1259, doi:10.1016/j.enpol.2005.12.018

Reijnders, L. & Huijbregts, M., 2006, 'Life cycle greenhouse gas emissions, fossil fuel demand and solar energy conversion efficiency in European bioethanol production for automotive purposes', *Journal of Cleaner Production*, Vol. 15 Issue 18, p1806-1812, doi: 10.1016/j.jclepro.2006.05.007

Rhodes, J.S. & Keith, D.W., 2005, 'Engineering economic analysis of biomass IGCC with carbon capture and storage', *Biomass and Energy* 29: 440-450, http://www.ucalgary.ca/~keith/papers/67.Rhodes.2005.BiomassCCS.e.pdf

Samuels, T. 1997, *Implications of Reduced Traffic Speeds on the Urban Environment*, http://www.walkablestreets.com/speed.htm

Scharlemann, J.P.W. & Laurance, W.F., 2008, 'How Green Are Biofuels?', *Science*, 4 January, Vol 319, Issue 5859, pp.43-44, http://www.sciencemag.org/cgi/content/full/319/5859/43

Scheurer, J., Kenworthy, J. & Newman, P., 2005, *Most Liveable and Best Connected?*, Metropolitan Transport Forum, Melbourne, p.7

Searchinger, T., Heimlich, R., Houghton, R.A., Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes, D. & Yu, T., 2008, 'Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land Use Change', *Science*, http://www.sciencemag.org/cgi/content/abstract/1151861

Senbergs, Z. & Currie, G., "'Forced' Car Ownership – Links to Transit and Accessibility", *Peak Oil, Petrol Prices and Climate Change: Preparing Victoria for the Future*, Melbourne, 27 July 2007

Shindell, D., G. Faluvegi, A. Lacis, J. Hansen, R. Ruedy, and E. Aguilar (2006), 'Role of tropospheric ozone increases in 20th-century climate change', *J. Geophys. Res.*, 111, D08302, doi:10.1029/2005JD006348

STPP, 2001, *Easing the Burden: A Companion Analysis of The Texas Transportation Institute's 2001 Urban Mobility Study*, Surface Transportation Policy Project, Washington DC, http://www.transact.org/PDFs/etb_report.pdf

R.E.H. Sims, R.N. Schock, A. Adegbululgbe, et al., Energy supply, in: B. Metz, O.R. Davidson, P.R. Bosch, et al. (Eds.), *Climate Change 2007: Mitigation*. CUP, Cambridge, UK, 2007, pp. 251-322

Smerk, G., 1988, *Mass Transit Management: A Handbook for Small Cities*, Spratt, D. & Sutton, P., 2008, *Climate Code Red*, Friends of the Earth, Melbourne, http://www.carbonequity.info/download.php?id=6

State of Queensland, 2007, *Queensland's Vulnerability to Rising Oil Prices*, Taskforce Report, http://www.epa.qld.gov.au/publications/p02190aa.pdf/Queenslands_vulnerability_to_rising_oil_prices__taskforce_report.pdf

Stone, J., 2007, *A review of current literature on transport greenhouse emissions and abatement strategies: the potential for greater public transport use in Melbourne*, Australasian Centre for the Governance and Management of Urban Transport, Melbourne,http://www.gamutcentre.org/media/recent%20publications/Greenhouse_and_public_transport-options_for_Melbourne.pdf

Tahara, K., Sinha, S., Sakamoto, R., Kojima, T., Taneda, T., Funasaki, A., Ohtaki, T., Inaba, A., 2001, 'Comparison of CO2 Emissions from Alternative and Conventional Vehicles', *World Resources Review*, vol.13 no.1, pp. 52-60

Taylor, M., 1982, 'Travel Time Variability – The Case of Two Public Modes', *Transportation Science*, Vol. 16, No. 4, pp. 507-521

Treasury, 2007, *Tax Expenditures Statement 2007*, Commonwealth of Australia, Canberra, http://www.treasury.gov.au/documents/1333/PDF/TES_2007_Combined.pdf

VACC, 2005, *VACC Five Point Safety Inspections Report*, Victorian Automobile Chamber of Commerce, http://www.tacc.net.au/LinkClick.aspx?fileticket=2VOfLkJJM5s%3D&tabid=2102

van Oort, N. & van Nes, R., 2008, 'Improving Reliability in Urban Public Transport in Strategic and Tactical Design', TRB 87th Annual Meeting Compendium of Papers, Transportation Research Board, Washington DC

Vuchic, V., 1981, *Urban Public Transportation, System and Technology*, Prentice-Hall, Inc., pp. 200-201.

Vuchic, V., 1999, *Transportation for Livable Cities*, Center for Urban Policy Research, New Brunswick

Wald, M., 2005, 'Hybrid Cars Burning Gas in the Drive for Power', *The New York Times*, 17 July, http://www.nytimes.com/2005/07/17/automobiles/17hybrid.html

Weaver, A. J., K. Zickfeld, A. Montenegro, & M. Eby (2007), 'Long term climate implications of 2050 emission reduction targets', *Geophys. Res. Lett.*, 34, L19703, doi:10.1029/2007GL031018

Weiss, M.A., Heywood, J.B., Drake, E.M. et al, 2000, *On the Road in 2020: A Lifecycle Analysis of New Automobile Technologies*, Energy Laboratory Report # MIT EL 00-003

Wilmot, K., 2006, 'Fool's gold at end of EastLink rainbow', *The Age*, 20 October, http://www.theage.com.au/news/business/fools-gold-at-end-of-eastlink-rainbow/2006/10/19/1160851066435.html?page=fullpage

Woodcock, J., Banister, D., Edwards, P., Prentice, A. & Roberts, I., 2007, 'Energy and transport', *The Lancet*, Vol 370, Issue 9592, pp.1078-1088, doi: 10.1016/S0140-6736(07)61254-9

WS Atkins Transport Planning 2001, *Study of European Best Practice in the Delivery of Integrated Transport: Summary Report*, WS Atkins Transport Planning, Epsom, http://www.cfit.gov.uk/docs/2001/ebp/ebp/exec/pdf/exec.pdf

Zarembo, A. & Maugh, T., 2007, 'Bleak U.N. report on global warming derided as too soft', *Los Angeles Times*, 7 April, available at: http://www.mercurynews.com/healthandscience/ci_5616208