Greenhouse Gas Emissions and Australian Transport

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Abstract:

This paper presents estimates of total greenhouse gas emissions from Australian domestic transport, and details emissions, by mode, from the urban and non-urban passenger and freight transport sectors. It discusses the magnitude of the task involved in making substantial reductions in transport emissions, and examines the potential for reducing them by alternative means. These include fuel economy improvements, use of alternative fuels, transport system improvements including modal shift, and reductions in discretionary travel. Some attention is given to the difficulties involved in assessing the costs and benefits of emission reduction strategies to the economy.

The dominant role of the private car in generating emissions is highlighted, and the paper concludes that if a substantial and rapid reduction in transport sector emissions is required, it may be impossible to avoid reduction in motor car usage.

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Introduction

The Federal Government's decision of 11 October 1990, adopting an interim planning target for greenhouse gas emissions, should now be common knowledge among transport operators, users and administrators The target required that emissions of greenhouse gases not controlled by the Montreal Protocol on Ozone Depleting Substances be stabilised at 1988 levels by 2000, and reduced by 20 per cent by 2005, with the proviso that the adoption of response measures should not result in adverse effects on the economy in the absence of similar action by major greenhouse producing countries

What is perhaps less well recognised is the magnitude of the challenge this decision could imply for the transport sector Transport fuel consumption has been projected to grow at about 2.2 per cent per year, to 2004-05, by the Australian Bureau of Agricultural and Resource Economics (ABARE 1991), and 1.9 per cent per year by the National Institute of Economic and Industry Research (NIEIR 1990a) If growth is 2 per cent per year, a reduction of some 43 per cent from the likely emission levels in 2005 would be required to achieve the target in the transport sector. This would appear to be a demanding task, especially when it is recognised that the forecasts already incorporate some allowance for improved fuel economy from autonomous technical change.

A 20 per cent cut in transport sector emissions may not, of course, be warranted. To achieve the required reduction in Australian emissions in the most efficient way, the cost of various levels of emission reduction in the transport sector need to be compared with the cost of effecting similar reductions in other sectors. However there are analytical difficulties in quantitative modelling the national welfare costs or benefits of emissions reduction strategies (see BTCE 1991), and there are many gaps in our knowledge - of the outlook for vehicle engineering and production economics, the behavioural response of consumers and firms, and the implications of other externalities and distortions within the transport economy - which also make it difficult to determine these costs Perhaps because of this, early studies came to substantially different conclusions concerning the ease with which emission reduction could be achieved [see Australian Minerals and Energy Council (1990), Burmot Australia Pty Ltd and the Centre for Applied Economic Research and Energetics (1991), Deni Greene Consulting Services and NIEIR (1990), NIEIR (1990b), Greene (1990), and Marks et al (1989)].

Some convergence in thinking will hopefully emerge from the current investigations by the Industry Commission and the Ecologically Sustainable Development Committee, particularly its Transport Working Group A consultancy funded by the Commonwealth and Victorian Governments, exploring the scope for, and costs of, effecting improvements in vehicle fuel economy should also assist in establishing the costs of emission reduction

The transport task, energy consumption and greenhouse gas emissions

In this paper the emphasis is on domestic transport It is worth noting however that fuel used in international transport to and from Australia might be roughly half as large as domestic transport fuel consumption[1]

Table 1 Estimated energy consumption in Australian domestic transport (full fuel cycle), 1987-88

Mode	Full fuel cycle[a] (Petajoules)	Per cent of total Australian energy consumption
Road[b]	834	23.6
Rail	45	1.3
Air	63	1.8
Sea[c]	23	0.7
Total[d]	963	27.3

a. Full fuel cycle energy consumption refers to the amount of (predominantly fossil) fuel combusted to deliver energy for end-use. It includes the generation and transmission losses for electricity, and energy used in fuel extraction, refining and distribution. In the case of liquid fuels used in transport adjustment to a full fuel cycle basis is estimated to add around 10 per cent to end-use energy consumption.
b. Excludes fuel for off-road purposes in farming and mining.
c. Excludes fishery and pleasure craft
d. Total has been adjusted to avoid double-counting energy used in the domestic transport of fuel

Sources BTCE estimates, ABARE 1989 ABS (1990)

In 1987-88, the domestic transport task amounted to around 242 billion passenger kilometres, and around 260 billion tonne kilometres of freight, and this transport task consumed an estimated 963 petajoules[2] (PJ) of energy on a 'full fuel cycle'[3] basis (table 1) Domestic transport accounted for an estimated 27.3% of total Australian energy consumption

Greenhouse gas emissions from transport

The main greenhouse gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and chlorofluorocarbons (CFCs). Carbon monoxide (CO) should also be regarded as a greenhouse gas since it largely oxidises to carbon dioxide and it reacts to reduce methane and ozone absorption The method used in this paper for calculating carbon dioxide emissions is based on the total carbon content of the fuel, where it is assumed that there is complete combustion of the fuel's carbon to carbon

1 Domestic transport is defined to exclude off-road mobile equipment used in agriculture and mining and off-shore uses such as fishing and pleasure boating.
2 A petajoule equals 10^{15} joules.
3 Full fuel cycle includes energy used in extraction transport of feedstock refining and power generation and distribution/transmission as well as end-use

Table 2 Australian domestic transport carbon dioxide emissions, 1987-88

	CO_2 emissions in megatonnes (Mt)	% Transport CO_2 emissions	% Australian CO_2 emissions
Road	59.7	86	22
Car	*37.5*	*54*	*14*
LCV	*8.5*	*12*	*3*
Truck	*13.4*	*19*	*5*
Rail	3.5	5	1
Air	4.3	6	2
Sea	1.6	2	1
Total	69.1	100	26

LCV Light commercial vehicle
Notes 1. It is assumed all carbon in fuels is combusted to carbon dioxide.
2. Emissions are on a full fuel cycle basis
Source BTCE estimates

dioxide[4]. Methane and nitrous oxide make relatively minor contributions to total transport emissions and CFCs are to be phased out under Australia's commitment to the Montreal Protocol, and do not therefore present a greenhouse policy issue

Consistent with its share of energy consumption, domestic transport contributed an estimated 26 per cent of 1987-88 Australian carbon dioxide emissions; close to 70 megatonnes (Mt) on a 'full fuel cycle' basis. Estimates of total emissions of carbon dioxide from Australian transport are shown in table 2.

The main single source of transport emissions is the private car, being responsible for around 54 per cent of total CO_2 emissions from domestic transport. The usage of cars in urban areas currently accounts for around 39 per cent of total transport CO_2 emissions. In all road transport accounts for 86 per cent of emissions of CO_2, rail 5 per cent, air 6 per cent, and sea 2 per cent

In terms of the primary transport tasks: urban passenger transport accounted for 45 per cent of 1987-88 CO_2 emissions; non-urban passenger transport, 24 per cent; non-urban freight, 19 per cent; and urban freight, 12 per cent.

It is estimated that transport accounted for about 14 per cent[5] of total Australian greenhouse gas emissions, in terms of radiative forcing. A large proportion of the strongly radiative greenhouse gases, such as methane and nitrous oxide, were emitted from other sectors Carbon dioxide and carbon monoxide accounted for over 96 per cent of all Australian transport greenhouse gas emissions, in terms of CO_2 equivalents (the amount of CO_2 which would produce the same warming effect as the greenhouse emissions mix).

4 Carbon monoxide is not then treated separately. Some recent evidence, however, suggests that this procedure could underestimate the indirect contribution to the greenhouse effect of carbon monoxide (Zillman 1990).

5. The contribution was probably between 14 and 16 per cent depending on the extent to which transport is responsible for the national level of chlorofluorocarbon release.

Fuel economy in cars

Improving the fuel economy of the car fleet would appear to be of major importance in reducing greenhouse gas emissions, given its 54 per cent contribution to 1987-88 Australian transport CO_2 emissions. Fuel economy however is only one of many factors influencing choice of car, while the effective lowering of the marginal cost of driving, resulting from improved fuel economy, would have some offsetting effect on emissions if it were to lead to an increase in the kilometres driven per car (see later section on the effect of fuel prices). Such an effect could be neutralised by adjusting fuel prices. Within the EEC, for example, the fuel excise is already much higher than in Australia, and a further greenhouse tax on fuel is under consideration.

New cars

In 1979 the average fuel economy rating of new cars was 10.9 litres per 100km in Australia and about 11.6 in the United States (see table 3).

By 1988 the new car average in Australia had fallen to 9.1 litres per 100km. This was a slower rate of improvement than occurred in the United States, where by 1988 the new car average was 8.2 litres per 100km). Some have argued that the switch in the US to LCVs (which now account for some 35% of the new passenger car market and are not covered by Corporate Average Fuel Economy [CAFE] standards) may have resulted in an underestimate of fuel economy in the US new car fleet.

There are a number of problems with these international comparisons: there are variations among countries in standards for emissions (eg nitrogen oxides and particulates), differences in factors determining vehicle requirements (topography,

Table 3 New car fuel economy

	Average L/100km				% Change over period
	1979	1983	1986	1988	
Australia	10.9	9.2	9.3	9.1	-16.5
Canada	11.4	8.5	8.4	8.1	-28.9
West Germany	9.6	8.1	7.5	7.9	-17.7
Italy	8.3	7.3	6.8	6.8	-18.1
Japan	8.6	7.8	8.3	8.6	0
Sweden	9.2	8.6	8.4	8.2	-10.9
U.K.	9.0	7.9	7.5	7.4	-17.8
U.S.A.	11.6	8.9	8.4	8.2	-29.2

Note: The US use of a harmonic mean to calculate its published average fuel economy rates (in miles per gallon) is consistent with the use of weighted arithmetic means to calculate average fuel intensities (in litres per 100km).
Figures for Australia prior to 1986 (obtained under AS 2077) have been adjusted to be comparable with those obtained under AS 2877.
na - not available

Sources: DPIE (personal communication). IEA (unpublished). US Energy Information Administration (1990).

average length of trips, total distance travelled, nature of trip and car ownership levels), and variation in the test driving cycles determining fuel economy ratings[6]

Car fleet average fuel economy

Table 4 Car fleet fuel economy

	Average L/100km				% change over period
	1979	1983	1986	1988	
Australia	12.7	12.5[c]	12.0[d]	11.8	-7
Canada	15.7	13.8	12.4	na	-25[b]
West Germany[a]	10.8	10.9	10.9	10.7	-1
Italy	9.1	8.0	7.8	7.6	-17
Japan	11.8	11.0	10.7	na	-9
Sweden	10.9	10.8	10.5	10.3	-6
U.K.	na	na	na	na	na
U.S.A.	16.3	13.7	12.9	11.8	-28

a Possibly based on erroneous data according to IEA.
b. Based on 1987 estimate of 11.84 litres per 100km
c. 1982 figure.
d 1985 figure.

na - not available.

Sources: DPIE (personal communication) IEA 1990 (unpublished). US Energy Information Administration (1990).

In Australia, the fleet average fuel economy improved from 12.7 litres per 100km in 1979 to about 11.8 in 1988. In the US, comparable figures were 16.3 litres per 100km in 1979 and 11.8 in 1988 (see table 4).

This comparative slowness of the improvement in the fleet average in Australia would have been influenced by the ageing of the car fleet. In 1971 around one-quarter of Australian cars were ten years or more old; in 1988 almost half. There may be a more rapid improvement of the fleet average in coming years, as these older vehicles reach the end of their design lives.

The potential for future fuel economy improvements in cars

Difiglio et al. (1989) explored the potential for further improvements in new car fuel economy in the United States. They concluded that "using technology already included in manufacturers' production plans and based on consumers' willingness to pay for fuel economy" a new car fuel consumption of 6.9 litres per 100km could be reached by the year 2000. A further improvement to 6.5 litres per 100km would be cost-effective based on fuel cost savings over the vehicle life, and could be achieved without significantly reducing average vehicle size and performance. The Difiglio study went on to argue that downsizing the mix of cars, by influencing consumer

6 In 1986, for example, Australia changed from test standard AS2077 to standard AS2877, which introduced a 2.75 per cent discrepancy between 'as measured' figures before and after this date. Under the old standard AS2077, the figure for 1988 would have been 9.35 litres per 100km

choice through subsidies and taxes on vehicles, could bring the average fuel consumption of new cars down to 5 litres per 100km.

Other overseas studies (e.g. Mellde et al 1989, Brosthaus in OECD/IEA 1990a, and to a lesser extent OECD/IEA 1990b) lend support to the Difiglio views. However there appears to be controversy in the US about the scope for improvements in automobile technology to affect fuel economy, particularly where many technological improvements to one vehicle are involved (Bussman 1989, McTague 1990). McTague (Ford US) estimated fuel economy improvements leading to 7 litres per 100km in US cars by 2005.

The conclusion of a recent international conference on 'Tomorrow's clean and fuel-efficient automobile: Opportunities for East-West cooperation' (sponsored by OECD/IEA/ECMT/CEC in Berlin, March 1991) was that while many automobile manufacturers had developed prototype 4/5 passenger vehicles with fuel consumption of 2-3 l/100km, and a top speed of over 150km/h, the vehicles were not likely to be available unless national governments altered current consumer purchase patterns through appropriate economic and regulatory measures.

The Australian motor industry has now proposed fuel economy targets of 8.2 litres per 100 km in the year 2000 and 8.0 litres by 2005, roughly equal to the current US average for new cars (FCAI 1990). The potential for, and costs of changes in energy efficiency in cars in Australia, and the dynamics through which improvements in new vehicle technology would influence the average fuel economy of the car fleet are the subject of a consultancy study by Nelson English, Loxton and Andrews (NELA), sponsored by the Commonwealth and Victorian Governments.

The choice and setting of alternative policy instruments - new vehicle design regulation, vehicle sales taxes, fuel tax, re-registration requirements, enforced scrapping of high emission vehicles - would influence the speed and the cost and the equity of change. However, if a substantial (and rapid) reduction of CO_2 emissions should be required by 2005 from the transport sector, it may be difficult to avoid reduction in motor car utilisation. This is the dominant transport mode, and the target date of 2005 may be too close for large changes in vehicle technology and/or vehicle size and power to penetrate the car fleet. Motor car utilisation in aggregate could, of course, be reduced through increased fuel taxes. However, there are other (non-greenhouse) reasons for targeting constraints on motor car use towards particular urban problems through urban traffic management or road pricing innovations.

Fuel economy in other transport vehicles

The potential for fuel economy improvements in ships and aircraft is discussed in another paper delivered to this forum (Kelso 1991). The conclusions from that paper are that the average fuel economy of the Australian coastal fleet could be expected to improve by around 40 per cent by 2005, while in air, the improvement for the domestic airline fleet would be likely to be between 16 and 30 per cent.

The BTCE has not as yet examined in detail the potential for fuel economy improvements in trucks. Some considerations include reported improvements over recent years of some 10% (which should penetrate the fleet before 2005), and possible reductions in vehicle power requirements of 25-30% through prudent component choice (Close 1991). Isuzu claim improvements of 30% will be available should plans for ceramic diesel engines bear fruit. Further positive effects will come from mandatory introduction of speed limiters, some substitution of B-doubles for semi-trailers, and possible adoption of improved driver habits. As opposed to this, stricter emission standards for diesel vehicles could worsen fuel economy. Overall, an improvement in truck fuel economy by 2005 of the order of 20 to 25% is probably a conservative estimate.

With respect to rail, advice from Australian National is that fuel economy of diesel engines improved by 10% from 1980 to 1990, and is likely to improve by around 8% between 1990 and 2000. Further improvements in fuel economy could be expected from improved wagon productivity and track upgrading.

Alternative transport fuels

Alternative fuels appear to be either limited in supply or range of application, or high-cost pending some significant technological breakthrough. Some indication of costs and relative greenhouse gas contribution is in table 5. Perhaps the most potential lies with CNG or LNG for commercial road transport (trucks and buses), where it appears to be low-cost in dedicated short-haul operations, and also delivers a positive external benefit in the context of urban air pollution. CNG is already entering commercial short-haul transport uses for buses and trucks in Australia. It has been estimated that CNG might substitute for almost 10 per cent of diesel fuel in road transport by 2005, and that this increased penetration of CNG into the truck fleet could reduce CO_2 emissions from all trucking by about 2.5 per cent (Walker 1990). Wide penetration of natural gas would require significant capital outlays in providing an infrastructure of gas distribution and compression on long-distance routes. This issue is currently being examined under an ERDC research grant. Further detail on the potential for use of alternative transport fuels is contained in BTCE (1991).

Table 5 Greenhouse emissions and fuel costs of alternative transport fuels

	% change in greenhouse emissions, CO_2 equivalent (a)	Overall fuel costs, 1987 $US per barrel gasoline equivalent (b)
Conventional gasoline	..	27
Synthetic gasoline (from gas)	0 to +30[c]	43-61
Synthetic diesel (from gas)	0 to +30[c]	69
Compressed natural gas (CNG)	-19[1]	20-46
Methanol from gas	-3[1]	30-67
Methanol from coal	+51	63-109
Methanol, ethanol from biomass	-100	64-126
Electric, hydrogen from non-fossil	-100	81-135[c]
Electric, from coal	+26[d]	na
Electric, from natural gas	-18[d]	na

1. Le Cornu (pers. comm., 1990) notes that DeLuchi's figures appear to assume natural gas is pure methane. Some Australian natural gas contains significant amounts of other hydrocarbons and naturally occurring CO_2

Sources

(a) DeLuchi et al (1988)
(b) IEA (1990)
(c) Le Cornu (1990). Le Cornu has nuclear-based electric and hydrogen as 3 to 5 times the cost of gasoline
(d) DeLuchi et al (1989)

Transport system improvements

In considering the potential for reducing greenhouse gas emissions through various strategies designed to increase the efficiency of transport operations, including possible modal shift, we have segmented the transport task into urban[7] and non-urban passenger transport, and urban and non-urban freight. Overall there appears to be limited prospect for reduction in emissions from modal shift.

The estimates of emissions per unit transport task from each mode given in the tables reflect actual performance, rather than technical capability. Increases in load factors, for example, or improved operating conditions or lower speeds, could change the achieved levels of emissions substantially.

Urban passenger transport

Approximate estimates of modal shares and associated emission levels are shown in table 6. Emission levels for each mode during peak and off-peak periods, and according to route travelled (eg radial or lateral), are likely to be quite different from the averages presented in the table.

Urban passenger transport accounts for the highest level of carbon dioxide emissions of any of the transport tasks, constituting 45 per cent of the total transport emissions. Cars were responsible for around 88 per cent of these urban CO_2 emissions.

When used for journeys to work, the car will usually have a much worse energy intensity and CO_2 emission rate per passenger kilometre than when used for other private purposes. This follows from the especially low average occupancy rate (about 1.2 persons per vehicle, compared with around 2 when used for other private purposes) and from the poor energy efficiency resulting from driving in congested conditions. However, journeys to work account for only about 35 per cent of urban automobile kilometres. In less congested conditions, and with the higher occupancy level, the energy intensity of automobile use may not be very different from that of off-peak public transport and its advantages in utility are usually considerable.

Electrified rail, in purely greenhouse terms, does not score as favourably as it might if energy security and urban pollution were also at issue, because of the low thermal efficiency of power stations and the losses in transmission. In Sydney, the ratio of primary to end-use energy is about 3 to 1; in Melbourne, with lignite as the primary energy source, this ratio is about 3.8 to 1. Recent information from the Electricity Commission of NSW suggests that modern alternating current traction systems (as opposed to the existing old direct current SRA traction network) could reduce energy consumption by electric rail by some 40 per cent.

Commuter railways would have significantly greater efficiencies during peak periods, given high (one-way) loadings for radial commuting to and from CBDs, and possibly other nodes of high employment density. However, public transport already commands a large share of such journeys in Sydney and some other cities. Buses will also average substantially lower emissions per passenger kilometre at peak times than cars with average occupancies.

During off-peak periods however, low occupancy often implies high energy intensities per passenger kilometre for public transport. For the bus fleet, the major part of energy use (and consequently, the major part of CO_2 emission) occurs during off-peak periods.

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7 In this paper, urban areas include all cities with populations above 40,000.

Table 6 Urban passenger transport, Australia, 1987-88

Task	Passenger kilometres (billions)	Energy consumption (PJ)	Energy consumption (MJ/pkm)	Rate of CO_2 emissions (grams/pkm)	Total CO_2 emissions (megatonnes)
Road					
Car	131.3	384	2.9	210	27.3
LCV[a]	6.8	26	3.8	270	1.8
Bus	4.5	7	1.6	120	0.5
Rail	7.0	11	1.6	150	1.0
Total[b]	151.5	433	..	..	31.1

a Light commercial vehicles
b. Totals may not add, since they include all transport vehicle types for example, ferries. These make very small contributions to total emissions.
.. not applicable

Note Figures relate to the full fuel cycle.

Sources BTCE estimates based on ABS (1987,1990) BTCE Transport Indicators database, ABARE (1989), RIC (unpublished data) Adena and Montesin (1988), and personal communication with S Eriksson (1991)

The dominance of the private car in urban passenger transport is such that to achieve substantial reductions in CO_2 emissions, by transfer from cars to public transit, enormous increases in the transit task and in infrastructure investment would be required. Without these, only a small part of the urban passenger transport market may provide scope for substitution between public transport and the car. A Melbourne survey (cited in MOT 1986) found that only 8 per cent of car drivers (and 10 per cent of car passengers) thought they had a convenient alternative, while only 18 per cent of public transport users *had* a car available. In any event, only a small percentage of urban passenger kilometres are car journeys to work to central areas, perhaps around 6 per cent.

While this is not to say that a lesser contribution from increased public transport patronage would not be useful in pursuing simultaneously, greenhouse, road congestion and urban pollution objectives, substantial new investments in urban public transport would raise questions which necessarily have to be analysed on a case-by-case basis. Greenhouse effects *per se* are very unlikely to dominate such decisions, but should be considered in cost-benefit analyses of UPT and other transport proposals on the basis of their contribution to achieving the Government's emission reduction target.

Because of the high emission intensity of car use for journey to work, greenhouse objectives would be fostered by State Government initiatives focused on this area. Less costly measures than UPT investment could include improving traffic control systems, promoting higher car occupancy, improving rail-bus-car interchange and park-and-ride facilities, priority bus lanes, restricting CBD car use, and encouraging residential and commercial location decisions which make less demands on the transport system, in particular, on car use.

Non-urban passenger transport

The private car is estimated to have been responsible for around 63 per cent of the 1987-88 non-urban passenger task carbon dioxide emissions (see table 7).

Table 7 Non-urban passenger transport, Australia, 1987-88

Task	Passenger kilometres (billions)	Energy consumption (PJ)	Energy consumption (MJ/pkm)	Rate of CO_2 emissions (grams/pkm)	Total CO_2 emissions (megatonnes)
Road					
Car	55.9	143	2.6	180	10.2
LCV[a]	5.2	19	3.6	250	1.3
Bus	11.8	9	0.8	60	0.7
Rail	2.3	4	1.6	120	0.3
Airline	13.3	50	3.8	260	3.5
Total[b]	90.3	232	..	..	16.5

a. Light commercial vehicles
b. Totals may not add since they include all transport vehicle types, including light aircraft.
.. not applicable

Note Figures relate to the full fuel cycle

Sources BTCE estimates based on ABS (1987, 1990), BTCE Transport Indicators database, ABARE (1989), RIC (1990), Adena and Montesin (1988).

The least greenhouse emission-intensive mode is the bus, reflecting high load factors and uncongested traffic conditions. Air transport is the most energy intensive mode. However, the long distances between major cities in Australia suggest limited scope for substitution between airlines on the one hand and the less emission-intensive modes, bus or rail, on the other. It appears that most inter-city passengers may be constrained by income or time towards one mode or the other. About 70 per cent of air travel between Sydney and Melbourne is for business purposes.

For travel other than between major cities, there may also be limited substitution possibilities, for similar reasons. The flexibility of the private car is likely to be more important for rural and inter-provincial town travel. If reduced non-urban speed limits for cars are unlikely to gain favour in Australia, further fuel economy improvements in vehicles and aircraft may be the only significant source of greenhouse gas emission abatement in the non-urban passenger area.

Non-urban freight

Non-urban freight accounts for around 19 per cent of total transport emissions (see table 8). While sea transport of bulk commodities is the most energy and carbon dioxide emission efficient of all modes, substitution possibilities between coastal bulk shipping and bulk rail are limited by the origin and destination of the different bulk tasks.

Non-bulk sea transport is comparable to non-bulk rail, and considerably better than trucks, in terms of emission efficiency. Much of the current non-bulk sea transport task involves Bass Strait crossings, though shipping may provide some scope for intermodal substitution in the case of cargo moving from Tasmania to, for

Table 8 Non-urban freight transport, Australia, 1987-88

Task	Tonne kilometres (billions)	Energy consumption (PJ)	(MJ/tkm)	Rate of CO_2 emissions (gms/tkm)	Total CO_2 emissions (megatonnes)
Bulk					
Rail					
Govt	37.1	15	0.4	29	1.1
Private	31.0	4	0.1	10	0.3
Sea	89.2	16	0.2	13	1.2
Non-bulk					
Rail	13.1	11	0.8	60	0.8
Sea	4.9	3	0.7	51	0.3
Air	0.2	9	44.5	3050	0.6
Road					
LCV	1.6	32	20.2	1443	2.3
Rigid	8.4	27	3.3	237	2.0
Artic	44.5	63	1.4	104	4.6
Total	230.0	181	..	..	13.3

LCV - Light commercial vehicle Rigid - rigid truck Artic - articulated truck .. not applicable Govt - government operated

Note Figures relate to the full fuel cycle.

Sources BTCE estimates based on ABS (1987, 1990) ABARE (1989) RIC (1990)

example, Brisbane. Non-bulk freight carried on government railways compares favourably with road transport in energy intensities and carbon dioxide emission rates. Emission levels per tonne kilometre are around 58 per cent of those for freight carried on articulated trucks. The non-bulk task is however carried predominantly by road vehicles, which account for over 70 per cent of non-bulk tonne kilometres

The amount of freight transported by road has increased rapidly, approximately doubling within the last decade This has prompted proposals to shift more long-haul freight by rail for energy conservation (given the differences in emission rates between trains and trucks), environmental and safety reasons (see for example, Laird 1990). To the extent that there is scope for substitution between modes in non-urban freight transport, it is probably largely limited to the inter-state segment of the non-bulk task, where there is some potential for rail to increase its share. Laird (1990) gives the level of inter-state freight on transport corridors as 13 billion tonne-kilometres for road and as 6.6 billion tonne-kilometres for rail, for 1987-88. The remaining non-urban road freight task of 40 billion tonne-kilometers is unlikely to be contested by rail.

Various reforms now under consideration, including the proposed National Rail Freight Corporation, the Inter-State Commission proposal for a restructuring of charges, including a levy for the external costs of road use, and the recent Special Premier's Conference decision on uniform road regulation may slow down the expansion of road freight in favour of rail freight on inter-city corridors, and lead to some abatement in the growth of greenhouse emissions. The requirement for heavy vehicles to be fitted with speed limiters set at 100 kilometres per hour should also have a favourable effect on fuel economy, as might an extension of the operating zones of B-Doubles if it were to be implemented

Urban freight

Emissions from urban freight are in table 9 Given the variation in the type of freight carried in the urban areas, from small high value products (including document carriage) to common bulk commodities, such as fuel, it appears unlikely that the task could be efficiently performed with a very different vehicle mix. Even if some substitution of articulated for rigid trucks were possible, this would have only a marginal impact on total transport emissions given the relatively small level of emissions from urban freight.

Table 9 Urban freight transport, Australia, 1987-88

Task	Tonne kilometres (billions)	Energy consumption (PJ)	Energy consumption (MJ/tkm)	Rate of CO_2 emissions (gms/tkm)	Total CO_2 emissions (megatonnes)
Road					
LCV	2.7	44	16.4	1168	3.1
Truck					
Rigid	13.1	52	4.0	290	3.8
Artic	15.2	24	1.6	118	1.8
Total	31.0	120	..	..	8.7

LCV - Light commercial vehicles Artic - articulated vehicle .. - not applicable
Note Figures relate to the full fuel cycle.
Sources BTCE estimates based on ABS (1987, 1990) ABARE (1989), RIC (1990)

Spatial efficiency

Though there are clearly many factors influencing car use, some recent research (Newman and Kenworthy 1989) has focused on the effect of low residential density (rather than central city job density) as the most important element underlying extensive use of private cars and high gasoline consumption. Collins and Taylor (1991), who also note a link between low residential density and heavy dependence on the private car, believe that low density suburbs are incompatible with good public transport.

Concentrating urban development upon corridors most readily served by public transport, and directing land use strategies towards intensifying residential densities may therefore tend to reduce growth in automobile-kilometres. While significant effects from increased density will be long-term, it should still be possible to achieve some short-term results through measures which limit further urban sprawl.

The effect of fuel prices on demand for transport fuels

A greenhouse tax on fuel consumption is sometimes discussed in the international debate on emission reduction strategies. The impact of such a tax depends on the price elasticity of demand for transport fuel.

There is some controversy over the magnitude of the long-term elasticity of demand The BTCE recently commissioned Professor Hensher (1991) to prepare a report on this and related issues Using a set of behavioural equations to represent the major influences on the derived demand for transport fuel, he estimated, for Australia, a five year price elasticity of demand for petrol in passenger cars of -0.66, incorporating responses of fleet size, vehicle kilometres travelled and average fleet fuel efficiency It is possible the own-price elasticity of demand for automotive gasoline could be as high as -1, in the very long term, when induced technology changes are taken into account

If we assume a constant price elasticity of -0.66, an increase of 100% in the fuel price would result in a 37% decrease in the quantity of fuel demanded However, it is unclear if, or how much, the elasticity would change if tax-induced price changes moved price well beyond the range of previously observed prices

Hensher also estimated the five year elasticity of demand for automotive diesel oil at -0.55

Conclusions

The foregoing discussion has reviewed some low-cost and some more difficult measures for reducing greenhouse gas emissions in transport. To conclude the paper the authors take a very speculative, and very approximate, look at the contribution that the low-cost options might make to achievement of the Toronto target. We have looked only at the low-cost options because of the Government's decision that responses should not have adverse effects on the economy in the absence of similar measures overseas, and the official view that response strategies should be cost-effective, and preferably be justifiable on broad grounds of efficiency, taking account of economic and environmental benefits besides greenhouse gas reduction

The results are shown in table 10. If the fuel efficiency improvements already built in to the ABARE forecasts are added back to those forecasts, a reduction of just over 50% in the level of emissions estimated for 2005 is required to achieve the Toronto target The 'low-cost' options in table 10 indicate a potential reduction of around 27%, and therefore a level of transport CO_2 emissions in 2005 of around 82 megatonnes, 19% above the 1988 level of 69 megatonnes

The results suggest that if the Toronto target is to be achieved, at least some of the more difficult options would have to be pursued These include:

- substantial fuel price increases to reduce discretionary travel, to encourage use of more fuel efficient vehicles, and encourage more efficient use of existing vehicles;
- downsizing and/or reducing performance of the car fleet;
- steps to increase the scrappage rate for older vehicles;
- urban development strategies for increased density, dispersed employment, improved residential mobility;
- urban traffic policies designed to reduce car use, but which require substantial investment in public transit improvements;
- pursuing further rail reform;
- infrastructure investment necessary if natural gas is to be widely available as a transport fuel

On the positive side, fuel economy improvements in new cars will make a greater contribution beyond 2005, as fleet fuel economy follows reductions in the new car average In the long-term, technological break-throughs may assist in

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On the positive side, fuel economy improvements in new cars will make a greater contribution beyond 2005, as fleet fuel economy follows reductions in the new car average. In the long-term, technological break-throughs may assist in lowering the cost of emission reduction in the transport sector, and it is also possible that the social cost to consumers of adapting to smaller cars has been overemphasised. At present, however, the conclusion appears to be that the costs of large emission reduction in transport by 2005 will be high. No simple or singular solution is available; achievement of the target will require a strategy involving an integrated package of measures. There does, however, appear to be a case for proceeding with the low-cost options where it is clear that they meet the conditions outlined above. Such a policy would bring us a substantial part of the way (around 70%) towards stabilising transport emissions at 1988 levels by 2005, as opposed to 2000.

Table 10 Speculative views on the potential contribution of some low-cost options to reducing the level of transport greenhouse gas emissions in 2005

Option	% reduction in 2005 transport CO_2 emissions
New car fuel economy improvement to 6.5 l/100km by 2005 (fleet average just under 10 l/100km) and assuming no increase in average VKT	7
Traffic management: smoother flows & reduced congestion (10% fuel saving for urban road)	5
Car occupancy on journey-to-work increased from average 1.2 to 1.5 persons.	2
Natural gas: heavy penetration in urban buses and freight	2
Modal shift: 10% of car task to urban transit	2
Increase in rail freight in major corridors (over 'no-NRFC' scenario)	1
Improvements in fuel economy of ships and aircraft	2
Fuel economy improvements in truck, LCV, bus and rail	8
Total: low cost options (netting out cross-product terms)	27
Estimated reduction required to meet the Toronto target in transport	51
Total for low-cost options as % of required reduction	53

Sources Views of the authors, NERDDC estimates quoted in Nelson English (1988)

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Abbreviations

ABARE	Australian Bureau of Agricultural Resource Economics
ABS	Australian Bureau of Statistics
AMEC	Australian Mineral and Energy Council
BTCE	Bureau of Transport and Communications Economics
IEA	International Energy Agency
NIEIR	National Institute of Economics and Industry Research
OECD	Organisation for Economic Cooperation and Development
RIC	Railway Industry Council
SMVU	Survey of Motor Vehicle Use

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