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Climate Change and Australian Coastal Shipping

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Table of contents

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The opinions presented and conclusions drawn in this paper remain the responsibility of its author.

Summary

This report was commissioned by the Maritime Union of Australia. The Union asked for an evaluation of the following.

- The nature of the threat posed by climate change and the policy response that will be necessary to minimise the risks associated with global warming.
- Greenhouse gas emissions from the Australian transport sector, with particular emphasis on freight emissions.
- How coastal shipping compares to the other major freight transport modes in terms of energy and emission intensity.
- The extent to which increasing shipping’s share of the domestic freight task could reduce Australia’s emissions.

The threat posed by climate change

It is now widely accepted that human-induced climate change poses a significant threat to the welfare of the international community and the natural environment. Between 1850-1899 and 2001-2005, the global average surface temperature increased by approximately 0.76°C, rising from around 13.7°C to 14.5°C. Much of this increase occurred over the last 50 years when the rate of warming was approximately 0.13°C per decade, nearly twice the rate of the last 100 years. According to the Intergovernmental Panel on Climate Change (IPCC), there is a greater than 90 per cent chance that most of the observed warming since the mid-20th century has been driven by the accumulation of greenhouse gases in the atmosphere, particularly carbon dioxide (CO_2). If the international community does not make a concerted effort to reduce greenhouse gas emissions, there is a risk that the global average surface temperature could rise by between 1.1 – 6.4°C on 1980 – 1999 levels by the end of the 21st century.

There is a considerable amount of support for the notion that the threshold for dangerous climate change is a rise in the global average surface temperature of 2 – 2.5°C above pre-industrial levels (or additional warming of 1.2 – 1.7°C). In order to prevent the increase in the global average surface temperature exceeding 2°C, the atmospheric concentration of greenhouse gases would have to be stabilised at a level below 400 parts per million (ppm) of carbon dioxide equivalents (CO_2-e). As the current concentration is 430 ppm CO_2-e, staying within the 2°C threshold is unlikely. Keeping the increase in the global average surface temperature below 2.5°C above pre-industrial levels would require the atmospheric concentration of greenhouse gases to be stabilised at around 450 ppm CO_2-e (roughly 400 ppm CO_2). Due to the persistent delays in initiating policy responses to climate change, even staying within this threshold now seems unlikely.

In order to keep CO_2 concentrations below 450 ppm (roughly 500 ppm CO_2-e), global emissions would have to be approximately 20 per cent below current levels in 2040 and more than 40 per cent below current levels in 2050. Making emission cuts of this

magnitude will require an unprecedented level of international cooperation and a willingness on behalf of governments, businesses and the broader community to accept the economic costs associated with the required greenhouse policy responses.

Transport and freight emissions

According to the National Greenhouse Accounts, the transport sector currently accounts for approximately 15 per cent of Australia's emissions. Between 1990 and 2005, transport emissions grew by 30 per cent, rising from 61.9 to 80.4 Mt CO_2-e. This was the second highest rate of emissions growth behind the stationary energy sector, which grew by 43 per cent (196 to 279 Mt CO_2-e). Increasing emissions from the stationary energy and transport sectors are expected to be the major drivers of emissions growth over the coming decades.

The majority of domestic transport emissions are related to passenger transport. According to the Bureau of Transport and Regional Economics (BTRE), approximately 64 per cent of direct domestic civil transport emissions were passenger-related and 36 per cent were freight-related in 2004. Although domestic freight emissions are less than passenger-related emissions, they still account for approximately six per cent of Australia's emissions.

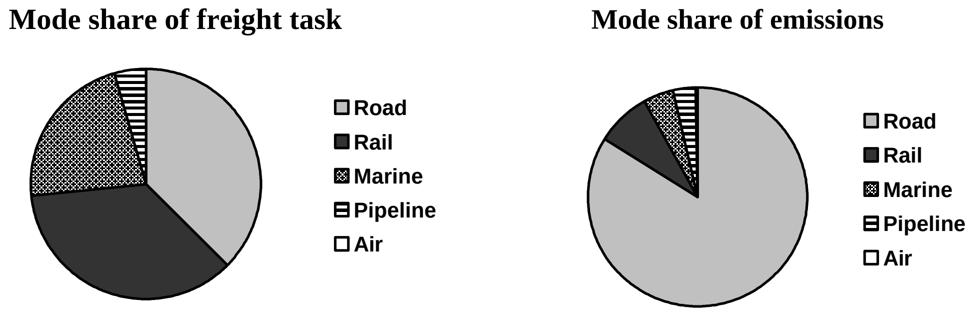
The government estimates of transport and freight emissions are incomplete as they do not account for all emission sources related to freight movements. In particular, they do not include the emissions associated with supplying the fuel that is used in freight movements, including the provision of electricity to electric trains (when combined with direct emissions, this approach is called 'full fuel cycle' accounting).

Data compiled by Apelbaum Consulting indicate that in 2005 total emissions from the domestic transport sector on a full fuel cycle basis were 101 Mt CO_2-e. The division of transport emissions between passenger and freight on a full fuel cycle basis is similar to that found under direct accounting methods. In 2005, 37 per cent of transport emissions on a full fuel cycle basis were freight-related and 63 per cent were passenger-related.

The overwhelming majority of freight emissions are attributable to road transport. In 2005, road transport was responsible for 31 Mt CO_2-e, 84 per cent of total freight emissions. This compares to 3.1 Mt CO_2-e from rail (eight per cent), 1.7 Mt CO_2-e from coastal shipping (four per cent), 1.3 Mt CO_2-e from pipelines (three per cent) and less than one per cent from aviation. The emission profile of the domestic freight market does not correspond neatly with the division of the freight task between the modes – see Figure S1.

In 2005, approximately 38 per cent of the domestic freight task was carried by road, 36 per cent by rail, 22 per cent by ship, four per cent by non-urban pipeline and less than one per cent by air, as measured in tonne-kilometres (tkm). Hence, road carries less than 40 per cent of freight, but is responsible for over 80 per cent of freight emissions. In contrast, shipping accounts for 22 per cent of the domestic freight task and only four per cent of freight emissions. These differences are due to the energy and emission intensities of the transport modes.

Figure S1 Modal share of domestic freight task (tkm) versus mode share of freight emissions (Mt CO_2-e), 2005



Comparative energy and emission intensity performance of freight transport modes

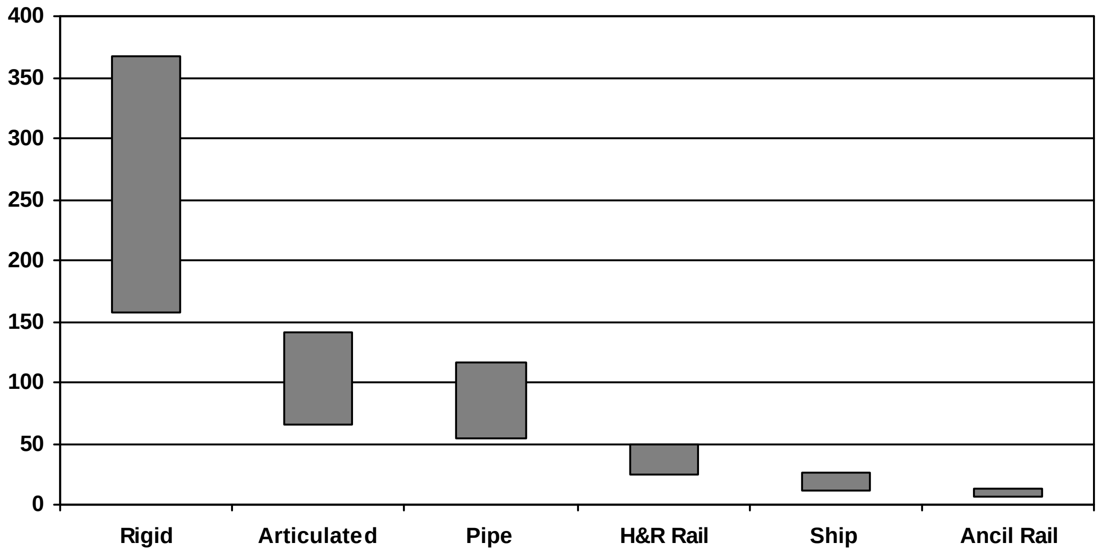
Of the major domestic freight transport modes, coastal shipping is the least energy and emission intensive, followed by rail, pipeline and road in ascending order. However, when the modes are broken into subgroups, shipping ranks second behind ancillary (or private) rail as the mode with the lowest energy and emission intensity – see Table S1.

Table S1 Energy and emission intensity of freight transport modes, 2005

Mode	Energy intensity (MJ-FFC/tkm)	Emission intensity (g CO_2-e/tkm)
Road transport		
Light commercial vehicles	21.07	1,532
Rigid trucks	2.95	209
Articulated trucks	0.98	71
Rail		
Hire and reward	0.32	24
Ancillary	0.09	6
Coastal shipping	0.17	15
Pipeline	0.89	54

Comparing the overall energy and emission intensity performance of the road transport modes against rail, pipelines and coastal shipping is arguably misleading as the modes operate in different markets. Rail, pipelines and shipping operate exclusively in non-urban markets, whereas the road modes operate in both urban and non-urban areas. Figure S2 shows the emission intensity ranges for rigid and articulated trucks, hire and reward and ancillary rail, pipelines and coastal shipping in non-urban markets over the period 2001 – 2005. The hierarchy of emission intensities between the modes in the non-urban market (excluding light commercial vehicles) is the same as the overall market. Rigid and articulated trucks have the highest emission intensities, the emission intensities of pipelines and hire and reward rail line in the middle, and coastal shipping and ancillary rail have the lowest emission intensities.

Figure S2 Emission intensity of non-urban freight, 2001 – 2005, g CO_2-e/tkm



The superior greenhouse performance of coastal shipping is achieved with an aging and outdated fleet. With fleet renewal and a more vibrant industry, the greenhouse performance of shipping could be considerably better, potentially rivalling ancillary rail.

Mode shifting to coastal shipping to reduce Australia's emissions

The greenhouse credentials of shipping have led many to propose mode shifting from road and rail as a means of cutting freight emissions. However, the trends in the domestic freight market over the past two to three decades have been away from shipping toward the land modes. These patterns have been a product of government policy and changing supply chains and freight flows, with the market increasingly shifting toward time-sensitive and urban and other inland freight.

To gauge what a mode shifting strategy could achieve, the market share patterns in non-urban freight between 1991 and 2005 were reversed. Had the market shares of articulated trucks, hire and reward rail and shipping remained at their 1991 levels over this period, the cumulative emissions from non-urban freight would have been four per cent lower. In 2005, the reversal of the mode share trends would have seen coastal shipping gain an additional 11 per cent of the non-urban freight market, yet the emission savings would have been modest; a two per cent saving in transport emissions and five per cent saving in freight emissions.

While modest, this saving is likely to prove difficult to achieve in reality. Coastal shipping does not compete with road and rail in a large enough portion of the domestic freight market to make mode shifting a viable option as a means of cutting freight emissions. Further, its major rivals in the markets where it does compete are relatively energy efficient, meaning any market share shipping is able to capture is unlikely to result in substantial emission savings.

The addition of a modest carbon price of around \$20 per tonne/CO_2 is unlikely to lead to substantial changes in coastal shipping's competitiveness. By and large, coastal shipping works in tandem with the land transport modes rather than competing with them for market share. In the small pockets where shipping does compete with the land modes (i.e. intercapital non-bulk and certain residual bulk flows), shipping is struggling to maintain market share due to the superior service characteristics of road and rail. Any increases in fuel costs triggered by a carbon price would have to be very large before it triggered a substantial change in the domestic freight market. Even then, the majority of the freight task would remain in the hands of the land modes because of the nature of the freight flows.

Optimistic mode shifting scenarios were modelled in the markets where coastal shipping is most likely to compete: the Eastern Capitals – Perth and Melbourne – Brisbane non-bulk markets. Favourable scenarios were also modelled for the interstate and non-urban intrastate bulk markets. Many of these scenarios are likely to be unachievable under market conditions. Yet even the most favourable scenarios result in modest emission savings. The combined saving in 2001 under the most optimistic scenarios for the four markets that were modelled was 145 Gg CO_2-e, which amounted to a reduction in total non-urban freight emissions (excluding pipelines and aviation) of around 0.9 per cent.

Actively pursuing mode shifting from land modes to coastal shipping as a means of reducing emissions is unlikely to be an effective or efficient greenhouse strategy. However, should mode shifting be pursued for other reasons, an additional benefit would be an improvement in the greenhouse performance of the domestic freight sector.

1. Introduction

It is now widely accepted that human-induced climate change poses a significant threat to the welfare of the international community. Over the past 100 years, the global average surface temperature has risen by approximately 0.74°C (IPCC 2007a). According to the Intergovernmental Panel on Climate Change (IPCC), there is a greater than 90 per cent chance that most of the observed warming since the mid-20th century has been driven by the accumulation of greenhouse gases in the atmosphere, particularly carbon dioxide (CO_2). If the international community does not make a concerted effort to reduce greenhouse gas emissions, there is a risk that the global average surface temperature could rise by between 1.1 – 6.4°C on 1980 – 1999 levels by the end of the 21st century. The science indicates that an increase in the global average surface temperature of more than 1.7 – 2.0°C on pre-industrial levels (i.e. additional warming of between 1.0 – 1.3°C) could have substantial adverse impacts, including greater water stress and lost agricultural productivity in some regions, the extinction of species and loss of unique ecosystems, and marked increases in sea levels.

For Australia to make a meaningful contribution to attempts to constrain global warming, it will have to reduce its emissions considerably over the next 40 years. The necessary emission reductions are likely to be greater in Australia than in most other developed nations. This is because Australia currently has one of the highest rates of emissions per capita in the developed world. If Australia is unable to make the necessary emission reductions, it is likely to have to rely on the acquisition of surplus emission permits from other countries to meet its international obligations. The viability and costs associated with this strategy will depend on the price and availability of emission permits. In the event that other nations struggle to meet their emission reduction commitments, purchasing surplus permits may be expensive and place considerable pressure on the economy.

Given the magnitude of the task facing Australia, significant emission abatement is needed in all sectors of the economy. Of particular importance will be Australia’s capacity to reduce emissions from the transport sector. In 2005, transport accounted for 15 per cent of Australia’s total greenhouse gas emissions, as calculated in accordance with the guidelines under the United Nations Framework Convention on Climate Change (UNFCCC) (DEWR 2007).[1] Since 1990, the transport sector has experienced the second highest rate of growth behind the stationary energy sector, rising from 62 million tons (Mt) of carbon dioxide equivalent (CO_2-e) to 80 Mt CO_2-e in 2005. The increasing emissions from transport have primarily been a product of economic growth. The challenge in the coming years will be for Australia to devise a strategy by which to decouple transport emissions from economic prosperity.

Around a third of domestic civil transport emissions are associated with freight movements (BTRE 2005; Apelbaum Consulting 2007a). Hence, in devising strategies to reduce emissions from transport, careful consideration will have to be given to the domestic freight market, including the emission intensity of the available transport modes and the capacity for substitution between the modes. In 2005, approximately

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[1] Australia’s greenhouse and freight accounts are done on a financial year basis. Unless otherwise stated, all references to years refer to the financial year ending. For example, the year 2005 refers to the financial year 1 July 2004 to 30 June 2005.

38 per cent of the domestic freight task was carried by road, 36 per cent by rail, 22 per cent by ship, four per cent by pipeline and less than one per cent by air, as measured by tonne-kilometres (Apelbaum Consulting 2007a).[2] While it currently has only around one fifth of the freight task, the emission intensity of coastal shipping is relatively low, particularly in comparison to its major competitors, road and rail. The greenhouse advantage offered by shipping is increased further when consideration is given to the embodied energy in the line-haul infrastructure associated with land transport. Due to these factors, shifting a proportion of the freight task from land modes to coastal shipping has been discussed at both domestic and international levels as a means of reducing greenhouse gas emissions. For example, the House of Representatives Standing Committee on Transport and Regional Services (2007, p. 235), recently stated that due to the relatively low energy and emission intensity of shipping:

> [i]t is logical … to argue that even a small modal shift in favour of domestic shipping should reduce transport sector energy consumption and emissions.

Similarly, in 2005, the former federal transport minister, Hon. Peter Morris, argued:

> [t]here is growing recognition across the Australian economy that sea transport is an essential mode of transport in the development of a national surface transport strategy. The greenhouse effect alone demands that domestic sea transport play a greater role in interstate freight transport (Morris 2005, p. 3).

The object of this report is to analyse the greenhouse benefits associated with shipping when compared to alternative freight transport modes and to evaluate what emission reductions could be achieved by increasing shipping’s share of the freight task. The report is set out as follows.

Section 2 provides an overview of relevant climate science and the policy challenges associated with global warming. Section 3 discusses the greenhouse performance of the transport sector and analyses the energy and emission intensity of the freight transport modes. Section 4 examines the nature of the pollutants emitted by ships and the shipping industry’s contribution to climate change. Section 5 looks at what increasing shipping’s share of the domestic freight task could achieve by calculating the emission savings that would have arisen if mode shares in the non-urban freight market were frozen at 1991 levels over the period 1991 – 2005. Section 6 evaluates where coastal shipping could draw market share from road and rail. Section 7 analyses whether mode shifting is a viable policy option in light of the evidence on the competitiveness of coastal shipping. Section 8 provides a conclusion.

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[2] The Bureau of Transport and Regional Economics (BTRE) (2007) gives a slightly different division of the domestic freight task in 2005: 35 per cent by road, 40 per cent by rail and 25 per cent by ship.

2. The greenhouse challenge

2.1 The greenhouse effect and global warming

The earth's radiation balance is a function of three factors:

- the amount of solar radiation that reaches the earth;
- the amount of solar radiation that is reflected back into space by the atmosphere and the earth's surface; and
- the amount of infrared radiation emitted from the earth into space.

The greenhouse effect describes the process whereby infrared radiation emitted from the earth's surface is absorbed by the atmosphere and re-radiated by greenhouse gas molecules. The energy that is absorbed and re-emitted by this process heats the atmosphere and the earth's surface, and in doing so effects the operation of the climate system. This process occurs naturally. Without the greenhouse effect, the global average surface temperature would be well below zero. However, human activities have enhanced the greenhouse effect by increasing the concentration of greenhouse gases in the atmosphere.

The most important greenhouse gases are water vapour, CO_2, methane (CH_4) and ozone (O_3). Other greenhouse gases include nitrous oxide (N_2O), sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and chlorofluorocarbons (CFCs). Human activities have also resulted in an increase in the presence of aerosols, or fine particles, in the atmosphere. Some aerosols reflect solar radiation (sulphur is an example), which has a cooling effect on the earth's climate. Other aerosols like black carbon (BC) have a warming effect by trapping and re-radiating infrared radiation and reducing the albedo of ice and snow.[3]

There are naturally large exchanges of the major greenhouse gases between sources and sinks. For example, CO_2 is naturally emitted into the atmosphere from sources including wildfires, decomposition of organic matter, respiration, volcanoes and evaporation from oceans. The processes by which CO_2 is naturally removed from the atmosphere (i.e. sinks) include absorption by oceans, utilisation for photosynthesis in aquatic and terrestrial plants, and chemical weathering. There are similar natural exchanges of other greenhouse gases, although they primarily involve chemical rather than biological processes. The climate system is normally able to achieve a degree of stability because the sinks roughly absorb the same amount of the relevant gases as are emitted from natural sources.

Although there tends to be a balancing of sources and sinks over time, this is not to say the atmospheric concentration of greenhouse gases has not fluctuated in the past. Over the earth's history, the atmospheric concentration of greenhouse gases has varied considerably. There has also been significant variation in the earth's climate, driven by a number of factors including changes in the earth's orbit, solar irradiance and atmospheric concentrations of greenhouse gas. However, the earth's climate has

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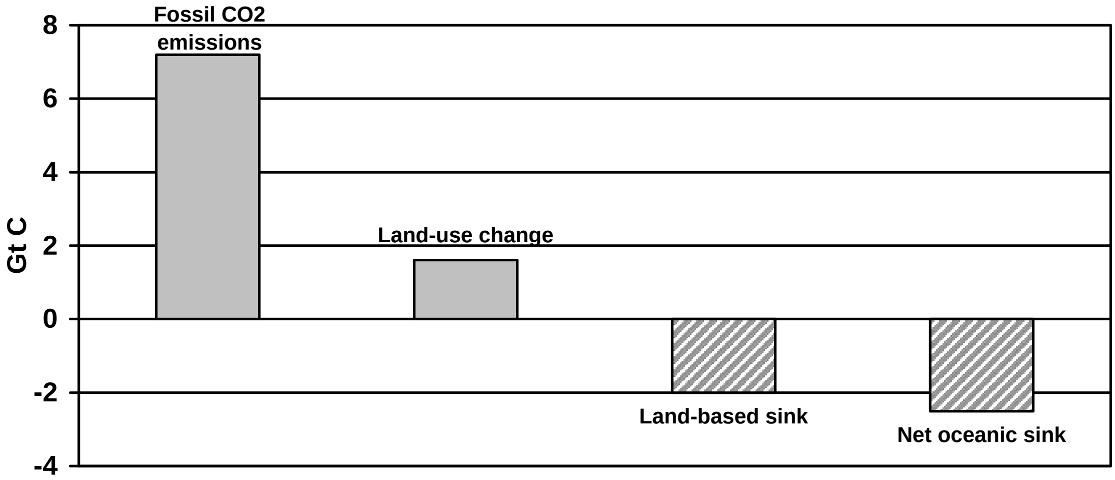
[3] Albedo refers to the reflection of solar radiation, in this case from the earth's surface into space.

been relatively stable for the last few millennia, which has allowed civilisation to flourish. The concern is that human activities are now disturbing the balance, causing rapid climate change that could adversely affect human interests and the health of the natural environment.

Human activities have resulted in an increase in greenhouse gas emissions, in most cases, well in excess of the absorptive capacity of existing sinks. Further, human activities, most noticeably land clearing, have reduced the size of natural sinks. The extent of the current imbalance in the CO_2 cycle is shown in Figure 1. Annual fossil CO_2 emissions are currently approximately 7.2 billion tonnes of carbon (Gt C) (26.4 Gt CO_2) and emissions associated with land use change are 1.6 Gt C (5.9 Gt CO_2), giving total anthropogenic emissions of approximately 8.8 Gt C (32.3 Gt CO_2). By comparison, the net land-atmosphere and ocean-atmosphere flux (i.e. difference between sources and sinks) is around -4.5 Gt C (-16.5 Gt CO_2) (IPCC 2007a).[4]

Figure 1 Sources and sinks of carbon dioxide, gigatonnes of carbon (Gt C)



Source: IPCC (2007a).

The imbalance between sources and sinks due to human activities has resulted in a marked increase in the atmospheric concentration of many greenhouse gases – see Table 1. Since 1750, the atmospheric concentration of CO_2 has increased by 35 per cent, CH_4 by 60 per cent and N_2O by 18 per cent. The atmospheric concentration of CO_2 in 2005 (379 ppm) was 20 per cent higher than the concentration at any time in the past 650,000 years (180 to 300 ppm) (IPCC 2007a). The rising concentration of greenhouse gases is acting like a blanket, trapping and re-radiating infrared radiation thereby increasing global temperatures.

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[4] See also IPCC (2001) and Schimel *et al.* (2001).

Table 1 Increase in atmospheric concentration of major greenhouse gases

Greenhouse gas	Pre-industrial concentration*	2005 concentration*	Change (%)
Carbon dioxide (CO_2)	280 ppm	379 ppm	35
Methane (CH_4)**	715 ppb	1774 ppb	60
Nitrous oxide (N_2O)	270 ppb	319 ppb	18

Source: IPCC (2007a).
* ppm = parts per million, ppb = parts per billion.
** Methane concentrations have remained relatively stable since the 1980s.

The main human drivers for the increasing atmospheric concentration of greenhouse gases are outlined in Table 2.

Table 2 Main human causes of increasing concentration of greenhouse gases

Greenhouse gas	Main cause
Carbon dioxide (CO_2)	Burning fossil fuels Cement manufacture Deforestation (release of CO_2 and reduction in absorption by plants)
Methane (CH_4)	Burning fossil fuels Burning biomass Fossil fuel mining and distribution Waste disposal in landfills Animal husbandry (e.g. cattle and sheep) Rice agriculture
Nitrous oxide (N_2O)	Agricultural fertilisers Burning biomass Animal husbandry Industrial activities (e.g. nylon manufacture)
Tropospheric ozone (O_3)	Burning fossil fuels Burning biomass Land use change
Halocarbons	Refrigerants Manufacturing processes
Aerosols	Burning fossil fuels Burning biomass Mining Industrial processes

Source: IPCC (2007a).

Increases in the atmospheric concentration of greenhouse gases have both direct and indirect influences on the earth's radiation balance and climate system. The direct impacts arise from their capacity to absorb and re-radiate infrared radiation. The indirect effects are a result of their ability to influence other components of the climate system through various feedback mechanisms.

An important feedback mechanism is the potential for climate change to increase the atmospheric concentration of water vapour. As the atmosphere warms, the concentration of water vapour should increase because warmer air is able to hold more water. The fourth assessment report of the IPCC (2007a) has confirmed that there has been an increase in the average atmospheric water vapour content over land, oceans and in the upper troposphere over at least the last 25 years. Due to the fact that water vapour is a greenhouse gas, its increasing concentration in the atmosphere is likely to exacerbate global warming.

Another feedback mechanism relates to the capacity of global warming to affect existing carbon sinks. As global temperatures increase, the science suggests the absorptive capacity of land-based and oceanic CO_2 sinks will decline. As a result, emission reductions to stabilise the atmospheric concentration of CO_2 at appropriate levels may have to be greater than initially believed.

To measure the direct impact of greenhouse gases, the concept of radiative forcing is often used. Broadly, radiative forcing is a measure of the impact of an agent (for example, a greenhouse gas) on the amount of incoming and outgoing radiation energy (i.e. the heat balance in the earth’s atmospheric system) (IPCC 2001; 2007a). It is used to assess the natural and anthropogenic drivers of climate change and is measured in watts per square metre (Wm^{-2}). Positive values suggest the agent has a warming effect and negative values imply a cooling effect.

As Table 3 shows, the IPCC has estimated that the net anthropogenic radiative forcing from the main agents is 1.6 Wm^{-2}, with a range of 0.6 to 2.4 Wm^{-2}. CO_2 is by far the largest human-induced cause of warming, followed by CH_4.

Table 3 Radiative forcing from anthropogenic forcing factors*

Agent	Radiative forcing Best estimate (Wm^{-2})	Radiative forcing Range (Wm^{-2})	Level of scientific understanding
Carbon dioxide (CO_2)	1.66	1.49 to 1.83	High
Methane (CH_4)	0.48	0.43 to 0.53	High
Nitrous oxide (N_2O)	0.16	0.14 to 0.18	High
Halocarbons	0.34	0.31 to 0.37	High
Tropospheric ozone (O_3)	0.35	0.25 to 0.65	Medium
Stratospheric ozone (O_3)	-0.05	-0.15 to 0.05	Medium
Stratospheric water from CH_4	0.07	0.02 to 0.12	Low
Surface albedo – land use change	-0.2	-0.4 to 0.0	Medium – low
Surface albedo – black carbon	0.1	0.0 to 0.2	Medium – low
Aerosols – Direct effect	-0.5	-0.9 to -0.1	Medium – low
Aerosols – cloud albedo effect	-0.7	-1.8 to -0.3	Low
Linear contrails	0.01	0.003 to 0.03	Low
Total net anthropogenic	**1.6**	**0.6 to 2.4**	

Source: IPCC (2007a).
* There are other anthropogenic forcing factors. However, they have very low levels of scientific understanding.

There has been a marked increase in the global average surface temperature over the past 150 years. Between 1850-1899 and 2001-2005, the global average surface temperature increased by approximately 0.76°C, rising from around 13.7°C to 14.5°C. Much of this increase occurred over the last 50 years when the rate of warming was approximately 0.13°C per decade, nearly twice the rate of the last 100 years. The observations from the instrumental record concerning the global average surface temperature are supported by a plethora of other data, including increasing temperatures in oceans and the lower- and mid-troposphere, reductions in snow cover and glaciers in both hemispheres, reduction in artic sea ice, sea level rise of approximately 1.8 mm per year between 1961 and 2003, and increases in the intensity and length of droughts and other extreme weather events. The warming has not been uniform. For example, relatively little change has been observed in temperatures in Antarctica, while temperatures in the Arctic have increased at almost twice the average global rate. Similarly, increases in average surface temperatures since the 1950s have varied between continents, with smaller increases in Australia and South America than those observed in Asia, Africa, North America and Europe. Yet on the basis of the available data, the IPCC has concluded that:

> … warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures,

> widespread melting of snow and ice, and rising global average sea level (IPCC 2007a, p. 5).

The earth's climate has been considerably warmer in the past than it is at present. There have also been periods of rapid climate change. However, the average temperatures in the Northern Hemisphere over the past 50 years are likely to have been the warmest of any 50-year period in at least the past 1,300 years (IPCC 2007a). There seems little doubt the 20th century was unusually warm in the context of the evolution of civilisation. Modern civilisation has also not experienced climate change at the speed at which it is currently occurring (DEH 2005; IPCC 2007a).

There is widespread consensus amongst the scientific community that the primary cause of the observed warming has been the increase in the atmospheric concentration of greenhouse gases, which has been caused by human activities. The fourth assessment report of the IPCC concludes that there is a greater than 90 per cent chance that 'most of the observed increase in global average temperatures since the mid-20th century … is due to the observed increase in anthropogenic greenhouse gas concentrations' (IPCC 2007a, p. 10). Uncertainties remain about the precise nature and magnitude of the human-induced forcings. However, overall there is little doubt amongst the vast majority of climate scientists that the increased concentration of greenhouse gases due to human activities is acting as a major driver of the warming of the earth's climate system.

Unless action is taken to reduce emissions, atmospheric greenhouse gas concentrations will continue to increase and lead to further warming. The IPCC has developed a range of emission scenarios (known as the SRES scenarios) for the 21st century that account for different economic, social and environmental factors. The six main 'marker' scenarios suggest that temperatures could increase by between 1.1 and 6.4°C over the 21st century, with best estimates ranging between 1.8 and 4.0°C.

On the basis of the available data, there are good grounds for suggesting that emissions and temperature increases over this century could be at the upper end of the SRES scenarios. Since the SRES scenarios were first developed in the late 1990s, global emissions have increased at an alarming rate. Between 1990 and 1999, annual fossil CO_2 emissions (i.e. emissions from fossil-fuel burning and industrial processes including cementing production) grew at a rate of around 1.1 per cent a year. This rate jumped to over three per cent a year over the period 2000 – 2004. On the basis of these data, Raupach *et al.* (2007, p. 2) conclude that:

> [o]bserved global emissions were at the upper edge of the envelope of IPCC emissions scenarios. The actual emissions trajectory since 2000 was close to the highest-emission scenario in the envelope … . More importantly, the emissions growth rate since 2000 exceeded that for the A1F1 scenario [the highest-emission scenario].

The extent of increases in the global average surface temperature will ultimately depend on the level at which the atmospheric concentration of greenhouse gases stabilise. Table 4 shows data from the IPCC's third assessment report concerning the increase in the global average surface temperature above pre-industrial levels that is likely to be associated with atmospheric CO_2 stabilisation levels ranging between 450 and 1,000 ppm.[5] The evidence suggests that if the atmospheric concentration of CO_2 is stabilised at 550 ppm, there is a significant risk the global average surface temperature will increase by more than 3°C above pre-industrial levels by the end of the 21st century and by more than 4°C in the long-term. Preston and Jones (2006) note that if the atmospheric concentration of CO_2 reaches 550 ppm, there is even a 10 – 20 per cent chance the global average surface temperature will increase by 5°C above pre-industrial levels at equilibrium.

Table 4 Temperature increase at 2100, 2300 and equilibrium associated with different CO_2 stabilisation levels

Stabilisation level (ppm CO_2)	Change by 2100 (°C)	Change by 2300 (°C)	Change at equilibrium (°C)
450	1.8 – 2.9	2.1 – 3.5	2.1 – 4.5
550	2.1 – 3.5	2.4 – 4.4	2.6 – 5.8
650	2.3 – 3.8	2.8 – 5.2	3.0 – 6.7
750	2.4 – 3.9	3.2 – 5.8	3.4 – 7.6
1,000	2.6 – 4.1	3.7 – 6.9	4.1 – 9.3

Source: IPCC (2001).

2.2 Dangerous climate change

The international response to climate change is coordinated under the United Nations Framework Convention on Climate Change (UNFCCC), which was adopted in 1992 and came into force in March 1994. Article 2 of the UNFCCC states that:

> [t]he ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve … stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure food production is not threatened and to enable economic development to proceed in a sustainable manner.

Despite fifteen years having passed since the adoption of the Convention, there is still no international consensus on what constitutes dangerous anthropogenic climate interference.[6] This is partly due to the extent of scientific uncertainty associated with the earth’s climate system and the impacts that could arise from increases in the atmospheric concentration of greenhouse gases.

Another major reason for the lack of agreement is the ambiguities associated with the Article 2 and the phrase ‘dangerous anthropogenic interference with the climate

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[5] Table 1 is based on the IPCC (2001) estimates, which evaluate the likely increase in the global average surface temperature above 1990 levels. These estimates were adjusted to provide an approximation of the likely increase on pre-industrial levels by assuming a global mean temperature increase to 1990 of 0.6°C.

[6] For further discussion on the threshold for dangerous climate change, see Preston and Jones (2006), Harvey (2007a; 2007b); and Kriegler (2007).

system'. While the wording is less than ideal, the final sentence in Article 2 effectively provides a three part definition of dangerous climate change:

- change that does not allow ecosystems to adapt naturally;
- change that threatens food production; or
- change that prevents economic development from proceeding in a sustainable manner.

This three part definition reduces the scope for uncertainty. However, in order to translate these criteria into clear policy targets, including in relation to the appropriate atmospheric concentration level, normative decisions must be made about acceptable climate risks. While science can play a key role in informing the decision-making process, prescribing the thresholds for dangerous climate change involves value judgments that go beyond the reach of science. The inability of science to define dangerous climate change means there is considerable scope for legitimate debate about where the policy boundaries should be set.[7]

The other major reason for the lack of consensus on the thresholds for dangerous climate change is the reluctance of political leaders to address global warming. Without the commitment to take decisive action, governments in both developed and developing countries have been willing to postpone debate on the thresholds for dangerous climate change.

Although there is no international consensus on its meaning, a number of governments, institutions and scientists have sought to define thresholds for dangerous climate change on the basis of the available evidence on the potential impacts of global warming. Examples of some of the suggested thresholds are outlined in Table 5.

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[7] See, for example, Patwardhan *et al.* (2003), Dessai *et al.* (2004), Schneider and Mastrandrea (2005), Lorenzoni *et al.* (2005), Oppenheimer (2005), Harvey (2007a; 2007b), and Kriegler (2007).

Table 5 Suggested thresholds for dangerous climate change

Source	Temperature threshold (°C)[a]	Atmospheric concentration threshold[b]
Stern (2007)		450 – 550 ppm CO_2-e
Harvey (2007a)[c]		<410 ppm CO_2
Hansen (2005; 2007) and Hansen *et al.* (2007a; 2007b)	1.7	<450 ppm CO_2
European Union[d]	2	<550 ppm CO_2-e
German Advisory Council on Global Change (2007)	2	<450 ppm CO_2-e
Scientific Expert Group on Climate Change (2007)	2 – 2.5	~450 ppm CO_2-e
International Climate Change Taskforce (2005)	2	400 ppm CO_2
French Government (2004)	2	<450 ppm CO_2
European Climate Forum (2004)	2 – 3	
Ott *et al.* (2004) and den Elzen *et al.* (2007)	2	<450 ppm CO_2-e
Government of The Netherlands (2004)	2	
German Advisory Council on Global Change (2003)	2	<450 ppm CO_2
Swedish Government (2003)		<550 ppm CO_2-e
Climate Action Network (2002)	2	<450 ppm CO_2
Royal Commission on Environmental Pollution (UK) (2000)		<550 ppm CO_2
Azar and Rodhe (1997)	2	375 ppm CO_2

a. Increase in global average surface temperature above pre-industrial levels.
b. CO_2-e is carbon dioxide equivalents, a measure of the concentration of the six main direct greenhouse gases (CO_2, CH_4, N_2O, SF_6, PFCs and HFCs).
c. Based on climate sensitivity (i.e. global average surface warming from a doubling of CO_2 concentration) 95th percentile of 4.5°C. Also assumes an overshoot. Without the overshoot, the limit is reduced to around 370 ppm CO_2.The fourth assessment report of the IPCC states that the climate sensitivity is likely (>66 per cent chance) to be between 2 – 4.5°C, and it is very unlikely (<10 per cent chance) to be less than 1.5°C (IPCC 2007a).
d. See European Parliament (2005; 2007), European Commission (2005; 2007), European Council (2007).

As Table 5 shows, there is a considerable amount of support for the notion of limiting the increase in the global average surface temperature to 2°C above pre-industrial levels and/or to ensure the atmospheric concentration of greenhouse gases does not exceed levels ranging between 450 and 550 ppm CO_2-e.[8] These goals are not consistent, as the scientific evidence indicates that keeping the increase in the global average surface temperature to 2°C above pre-industrial levels will require greenhouse gas concentrations to be stabilised at levels below 400 ppm CO_2-e. This is shown in Table 6, which contains data from the IPCC's fourth assessment report on the likelihood of staying within various warming thresholds for a given greenhouse gas stabilisation level.

If greenhouse gas concentrations stabilise at 550 ppm CO_2-e, it is unlikely that the global average surface temperature will increase by less than 2°C above pre-industrial levels. At this concentration level, there is even a significant risk that the global average surface temperature will increase by more than 3°C, and possibly 4°C, above pre-industrial levels. In order to have a high likelihood of staying within the 2°C threshold, the atmospheric concentration of greenhouse gases would have to be stabilised at a level significantly below the current concentration, which is approximately 430 ppm CO_2-e. The fourth assessment report of the IPCC states that:

> [s]tabilisation of atmospheric greenhouse gases below about 400 ppm CO_2 equivalent is required to keep the global temperature increase likely less than 2°C above pre-industrial temperature (IPCC 2007a, p. 828).[9]

Table 6 Likelihood of staying within 2°C, 3°C and 4°C warming thresholds (above pre-industrial) at given greenhouse gas stabilisation concentrations

Greenhouse gas stabilization level (ppm CO_2-e)	**2°C***	**3°C***	**4°C***
350	Likely	Very likely	Very likely
400	Moderate	Likely	Likely
450	Moderate	Likely	Likely
500	Unlikely	Moderate	Likely
550	Unlikely	Moderate	Likely
600	Very unlikely/ unlikely	Moderate	Moderate

Source: IPCC (2007a), derived using BERN2.5D EMIC.
* Very likely = >90% chance of staying below threshold; Likely = >66%; Moderate = 33 – 66%; Unlikely = <33%; Very Unlikely = <10%.

Attempts to define thresholds for dangerous climate change typically involve an evaluation of relevant climate risks, particularly in relation to ecosystems, food production and human health. Table 7 presents illustrative examples of the likely global and Australian impacts of increases in the average surface temperatures ranging from 0 – 5.5°C over the 21st century (global impacts relate to increases in the global average surface temperature, Australian impacts to increases in average Australian temperatures). The position of the left hand side of the text or line indicates the onset of the relevant impact.

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[8] The complex nature of the process involved in defining thresholds for dangerous climate change is explored in detail in Mastrandrea and Schneider (2004) and Schneider and Mastrandrea (2005).
[9] 'Likely' in this context refers to a greater than 66 per cent chance of occurring.

Table 7 Climate risks associated with temperature increases over the 21st century[a]

	0 — 1 — 2 — 3 — 4 — 5°C
Water	Increased water availability in moist tropics and high latitudes → Decreased water availability/increasing drought in mid-latitudes and semi-arid low latitudes → Hundreds of millions of people exposed to increased water stress → — *>12% decrease in flow in Murray-Darling Basin (MDB)* → — *>7% decrease in Melbourne's water supply* →
Ecosystems	Increasing species extinction risk → Increased coral bleaching — Widespread coral mortality → Increasing wildfire risk → — *40% of core habitat lost for Eucalypts* → *Increasing bleaching of Great Barrier Reef* → *Declining snow cover in Australian Alps* → *Significant reduction in montane tropical rainforest area in Nth Australia* → — *Complete loss of Acacia species in SW Australia* → *80% loss of freshwater wetlands in Kakadu* →
Food	Complex, localised negative impacts on small holders/subsistence farmers/fishers → Decreasing cereal productivity in low latitudes → Variable impacts on cereal productivity in mid- to high-latitudes → *Declining natural pasture growth* → *Decreasing wheat production* → *Increasing tick-related cattle losses* →
Coasts	Increasing damage from floods and storms → 30% of coastal wetlands lost → Millions more exposed to annual coastal flooding →
Health	Increasing burden from malnutrition and infectious diseases → Increased mortality and morbidity from heat waves, floods and droughts → Changed distribution of some disease vectors → *Southward spread of malaria receptive zones* → *Significant increase in population at risk of dengue fever* → *100% increase in no. people exposed to flooding* → *Increasing temperature-related mortality amongst elderly* →
Large-scale discontinuities	Risk of irreversible loss of Greenland ice sheet → Risk of irreversible loss of WAIS[b] → Risk of THC[c] collapse →

Sources: IPCC (2007b), Preston and Jones (2006) and Schneider and Lane (2006).

a. Examples of global and Australian impacts associated with increases in average surface temperature over the 21st century (Australian impacts are in italics). The left hand side of the text or line indicates the onset of the relevant impact.

b. WAIS is the West Antarctic Ice Sheet.

c. THC is the global ocean thermohaline circulation (also called the meridional overturning circulation).

As Table 7 shows, climate change will have negative impacts even if average temperatures rise by less than 1°C over the 21st century. In fact, global warming is already associated with a number of adverse effects, including water stress, drought and other extreme weather events and biodiversity losses. The negative impacts intensify as the temperatures increase. With temperature increases of between 1 – 3°C above existing levels, there is a risk of the irreversible melting of the Greenland and West Antarctic ice sheets, which could lead to sea levels rising by several metres a century (Schneider and Lane 2006; Hansen *et al.* 2007; Harvey 2007a; 2007b). In the last interglacial period (approximately 125,000 years ago), average polar temperatures were 3 to 5°C above current levels, and global average sea level is thought to have been four to six metres higher than the levels seen in the 20th century (IPCC 2007a). If temperature increases exceed 4°C, there is a risk of the collapse of the global ocean thermohaline circulation.

The negative impacts associated with global warming will not be uniformly distributed across the globe. Some regions will experience net benefits and others net losses if temperature increases are at the lower end of the projected scale. The most acute impacts are likely to be felt in poorer regions, many of which are susceptible to the effects of climate change and have relatively little capacity to adapt. However, as the IPCC (2007b, p. 16) has explained:

> [i]t is very likely that all regions will experience either declines in net benefits or increases in net costs for increases in temperature greater than about 2 – 3°C [above 1990 levels].[10]

Given the degree of uncertainty associated with the available climate projections and the extent of the potential impacts, there are good grounds for asserting that the threshold for dangerous climate change should be set at levels around 2 – 2.5°C above pre-industrial levels, or below 450 ppm CO_2-e (roughly 400 ppm CO_2). Yet the failure of the international community to take early action in response to global warming has made achieving these targets unlikely. The atmospheric concentration of greenhouse gases is rapidly approaching 450 ppm CO_2-e and preventing it from crossing this threshold would require an unprecedented level of political commitment, international cooperation and community support.

Figure 2 shows the type of trajectory that global emissions would have to follow in order to keep CO_2 concentrations to 450 ppm (roughly 500 ppm CO_2-e).[11] Possible trajectories for developed and developing countries are also shown, which assume the global CO_2 budget is allocated on a per capita basis on 2000 population levels, developed country emissions peak in 2015, developing country emissions peak in 2025, and global emissions peak in 2019 and ultimately stabilise at approximately 6 Gt CO_2. This trajectory suggests global emissions would have to be approximately 18 per cent below 2004 levels in 2040 and 42 per cent below 2004 levels in 2050. The cuts in developed countries would have to be more severe; 69 per cent below 2004 levels by 2030 and 90 per cent below by 2040. Developing country emissions would have to be approximately 13 per cent below 2004 levels by 2050.

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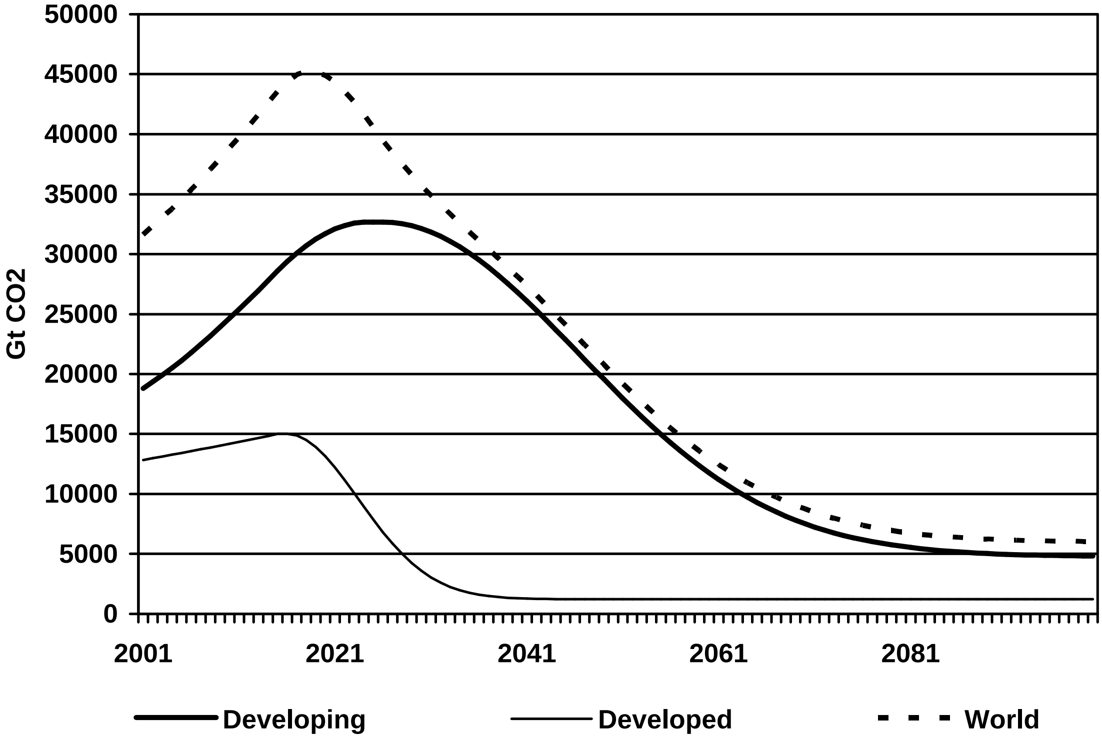
[10] This equates to approximately 2.6 – 3.6°C above pre-industrial levels.

[11] The trajectory was calculated using the 21st century CO_2 budgets generated by the BERN2.5CC carbon cycle EMIC, and discussed in the IPCC's fourth assessment report (IPCC 2007a).

The trajectory for global emissions shown in Figure 2 is relatively conservative. Some climate models suggest the emission reductions may have to be more radical in order to stabilise the atmospheric concentration of CO_2 at or below 450 ppm. Notwithstanding this, even staying within this 450 ppm CO_2 trajectory appears ambitious.

Although stabilising the atmospheric concentration of CO_2 at 450 ppm is likely to be difficult, there are significant risks associated with this concentration level. However, due to the difficulty in meeting a 2°C or 450 ppm CO_2 target, it now appears likely that higher thresholds will have to be set. To avoid impacts at the more serious end of the scale, governments will have to act urgently to reduce greenhouse emissions from all sectors and start to put in place strategies for adapting to global warming.

Figure 2 Trajectory of global, developed country and developing country emissions to stabilise atmospheric concentration of CO_2 at 450 ppm



Sources: IPCC (2007a) and The Australia Institute.

3. Transport emissions

In order to adequately address the threat posed by global warming, it is essential that Australia adopts ambitious emission reduction targets and governments put in place the policy frameworks that are necessary to ensure these targets are met. The Federal Government is yet to adopt an emissions reduction target. However, in June 2007, the Prime Minister announced that the Government would 'set a long term aspirational goal for reducing carbon emissions' in 2008 and introduce an emissions trading scheme by no later than 2012 (Howard 2007).

The federal ALP has proposed a national target of reducing Australia's emissions by 60 per cent below 2000 levels by 2050 (Rudd 2007). The Labor Governments in New South Wales, South Australia and the Australian Capital Territory have already adopted similar emission reduction targets for their respective jurisdictions (NSW Greenhouse Office 2005; ACT Government 2007).[12] The Governments of NSW and the ACT have also adopted a medium-term target of returning emissions to 2000 levels by 2025. Further, the states and territories have collectively undertaken to introduce a national emissions trading scheme in 2010 if the Federal Government fails to do so (Council for the Australian Federation 2007).

The science suggests the targets proposed by the ALP are likely to be too conservative if the object is to avoid dangerous climate change. If the international community resolves to keep the increase in the global average surface temperature below 2 – 3°C above pre-industrial levels, it seems likely Australia will be allocated a more restrictive emission budget than that proposed by the ALP. To deal with the smaller budget, Australia could either pursue a more ambitious emission reduction target or rely on purchasing surplus emission permits from other countries. A risk associated with the latter strategy is that there could be a shortage of surplus permits, meaning their price could be extremely high and purchasing a sufficient quantity of permits could place considerable pressure on the economy.

Irrespective of the strategy that is ultimately adopted, it will be important for emission reductions to be aggressively pursued in all sectors. One of the greatest challenges will be reducing emissions from the transport sector.

3.1 Profile of Australia's transport emissions

According to the National Greenhouse Accounts, the transport sector currently accounts for approximately 15 per cent of Australia's emissions (DEWR 2007). Between 1990 and 2005, it experienced the second highest rate of emissions growth of all sectors behind the stationary energy sector – see Figure 3. Over this period, transport emissions grew by 30 per cent, rising from 61.9 to 80.4 Mt CO_2-e. By comparison, between 1990 and 2005, Australia's total emissions grew by four per cent (499 to 522 Mt CO_2-e) and emissions from the stationary energy sector grew by 43 per cent (196 to 279 Mt CO_2-e) (DEWR 2007).

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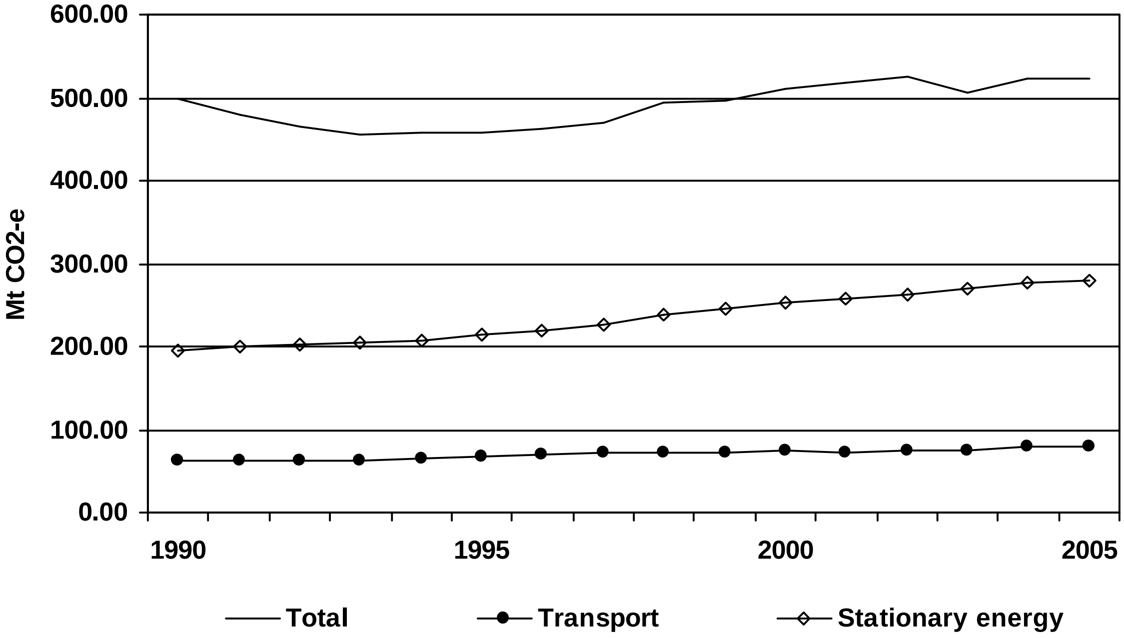
[12] *Climate Change and Greenhouse Emissions Reduction Act 2007* (SA).

Figure 3 Growth in greenhouse gas emissions, total, stationary energy and domestic civil transport, 1990 – 2005, Mt CO_2-e



Source: DEWR (2007).

Under the UNFCCC accounting guidelines, transport emissions are confined to direct emissions from domestic civil transport activities. Emissions associated with military activities are not reported and emissions from international aviation and maritime activities are not included in national totals, but they are reported as separate memo items. The trends in emissions from international aviation and maritime activities are similar to those seen in the domestic civil transport sector, only the growth rate has been higher. Between 1990 and 2005, international aviation and maritime emissions grew by 56 per cent and 46 per cent respectively (DEWR 2007).

Emissions from transport are projected to grow strongly over the coming decades – see Figure 4. The Bureau of Transport and Regional Economics (BTRE) has projected that between 2004 and 2020, domestic civil transport emissions will increase by 28 per cent, rising from 85 to 108 Mt CO_2-e (BTRE 2005).[13] The majority of the increase in emissions is expected to come from road transport (73 to 93 Mt CO_2-e). Aviation emissions are also expected to grow strongly, but off a much lower base (5.6 to 8.7 Mt CO_2-e). Smaller increases in emissions are projected for the rail (3.8 to 4.7 Mt CO_2-e) and marine sectors (2.05 to 2.12 Mt CO_2-e).

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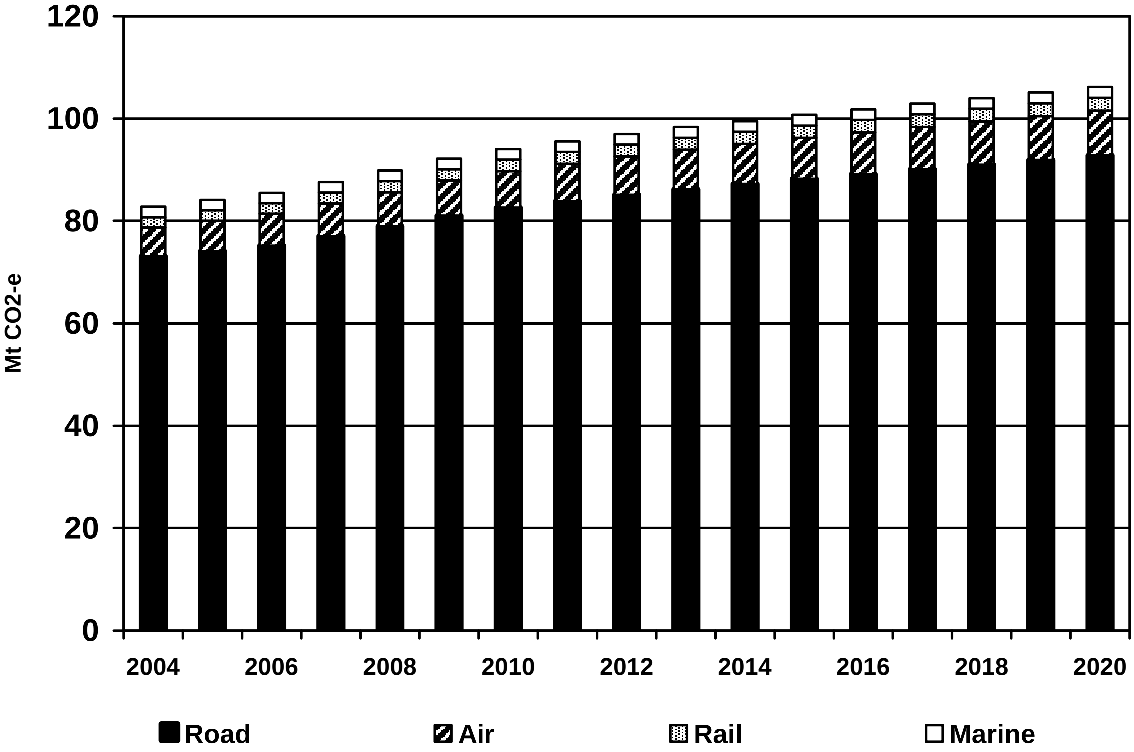
[13] Different methods were used to compile the DEWR (2007) and BTRE (2005) datasets. Caution should be taken when comparing data from the two sources.

Figure 4 Projected growth in domestic civil transport emissions, 2004 – 2020



Source: BTRE (2005).

As shown in Figure 4, the road sector is responsible for the majority of transport emissions. In 2004, 88 per cent of transport emissions were from the road sector. The remainder was divided between aviation (seven per cent), rail (two per cent) and marine (two per cent).

Direct emissions from domestic passenger transport are also significantly higher than domestic freight emissions. In 2004, approximately 64 per cent (53 Mt CO_2-e) of direct domestic civil transport emissions were passenger-related and 36 per cent (29 Mt CO_2-e) were freight-related (BTRE 2005).[14] This ratio is not expected to change substantially over the period 2005 – 2020. Data from the BTRE suggest that by 2020, direct freight-related emissions are likely to increase to approximately 41 per cent of total domestic civil transport emissions, with passenger-related emissions falling slightly to 59 per cent (BTRE 2005).

Although domestic freight emissions are less than passenger-related emissions, they still accounted for approximately six per cent of Australia's emissions in 2004. The above estimates of direct freight-related emissions are also incomplete as they do not account for all emission sources related to freight movements. In particular, they do not include the emissions associated with supplying the fuel that is used in freight movements, including the provision of electricity to electric trains (when combined with direct emissions, this approach is called 'full fuel cycle' accounting). Further, the estimates do not account for the embodied energy in transport equipment and

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[14] This estimate excludes emissions related to pipelines and electric railways and assumes freight-related emissions from aviation constitute one per cent of total aviation emissions.

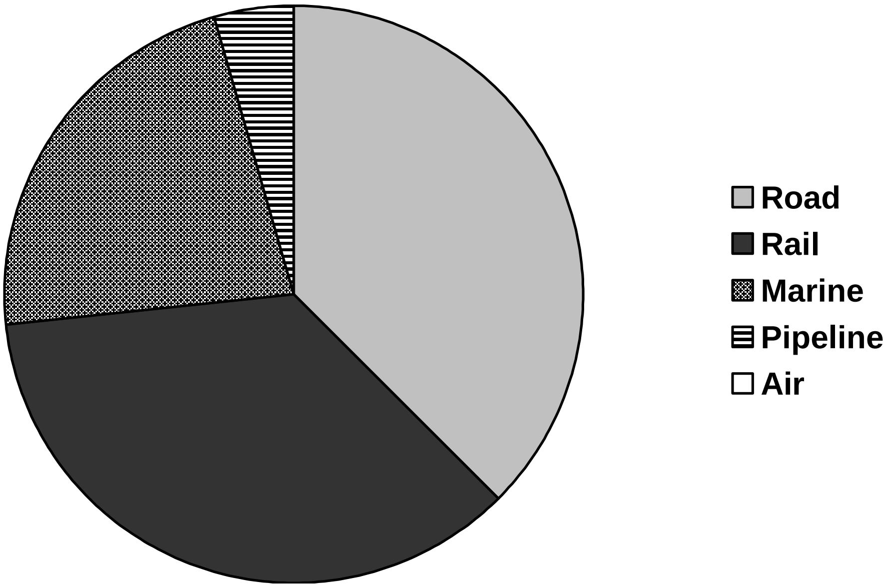
infrastructure (when added to full fuel cycle estimates, this is called ‘full system cycle’ accounting).

The BTRE has estimated that full fuel cycle emissions would add an additional 15 to 20 per cent to direct transport emission estimates and full system cycle emissions would raise the estimates by an additional 15 per cent. These estimates are roughly consistent with analysis by Apelbaum Consulting (2007a), which suggests that full fuel cycle domestic freight emissions in 2004 were approximately 36 Mt CO_2-e, 22 per cent above the BTRE estimates of direct freight emissions. When all relevant factors are accounted for, freight transport constitutes a significant source of domestic emissions. Therefore, reducing emissions from freight transport will be important in meeting Australia’s greenhouse obligations.

3.2 Breakdown of freight emissions

In 2005, approximately 38 per cent of the domestic freight task was carried by road, 36 per cent by rail, 22 per cent by ship, four per cent by non-urban pipeline and less than one per cent by air, as measured in tonne-kilometres (tkm) – see Figure 5 (Apelbaum Consulting 2007a).

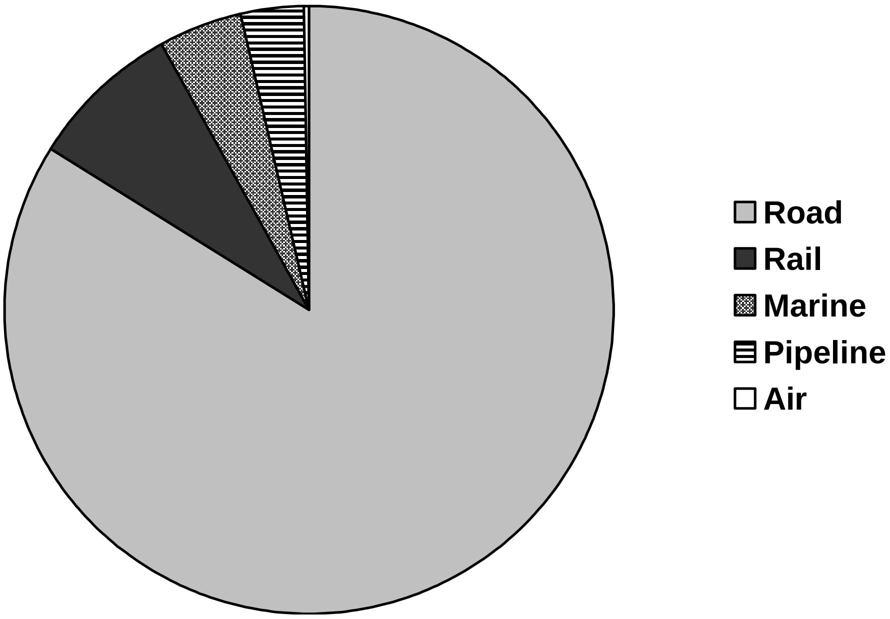
Figure 5 Modal shares of domestic freight task, 2005, tkm



Source: Apelbaum Consulting (2007a).

The division of the domestic freight task does not correspond neatly with the sources of domestic freight emissions – see Figure 6. Data compiled by Apelbaum Consulting suggest that total domestic freight emissions in 2005 on a full fuel cycle basis were approximately 37 Mt CO_2-e, which was compromised of 31 Mt CO_2-e from road transport (84 per cent), 3.1 Mt CO_2-e from rail (eight per cent), 1.7 Mt CO_2-e from coastal shipping (four per cent), 1.3 Mt CO_2-e from pipelines (three per cent) and less than one per cent from aviation (Apelbaum Consulting 2007a).

Figure 6 Emissions from freight transport (full fuel cycle), by mode, 2005



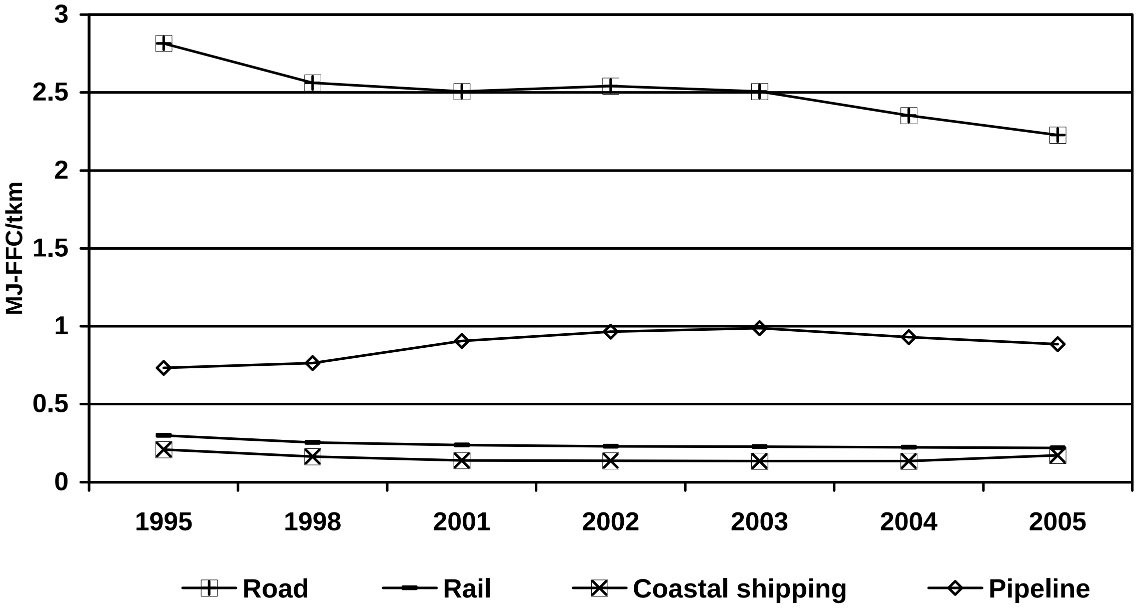
Source: Apelbaum Consulting (2007a).

The differences between the modal share of the freight task and the modal share of freight emissions are due to the relative energy and emission intensity of the transport modes. In general, moving freight by ship uses less energy and emits less greenhouse gases than if the same mass of freight was moved by rail, and moving freight by rail uses less energy and emits less greenhouse gases than if the same mass of freight was moved by road. Hence, the hierarchy of energy and emission intensity of the three main freight transport modes in ascending order is ship/rail/road. However, the market share of the domestic freight task in descending order is road/rail/ship, meaning the majority of the freight task is being undertaken by the modes with the highest energy and emission intensity. This apparent anomaly, and similar situations in other countries, has led a number of people to propose mode shifting as a potential means of lowering emissions from freight transport (Australian Shipowners Association 2005; Friedrich *et al.* 2007).

3.3 Energy and emission intensity of freight transport modes

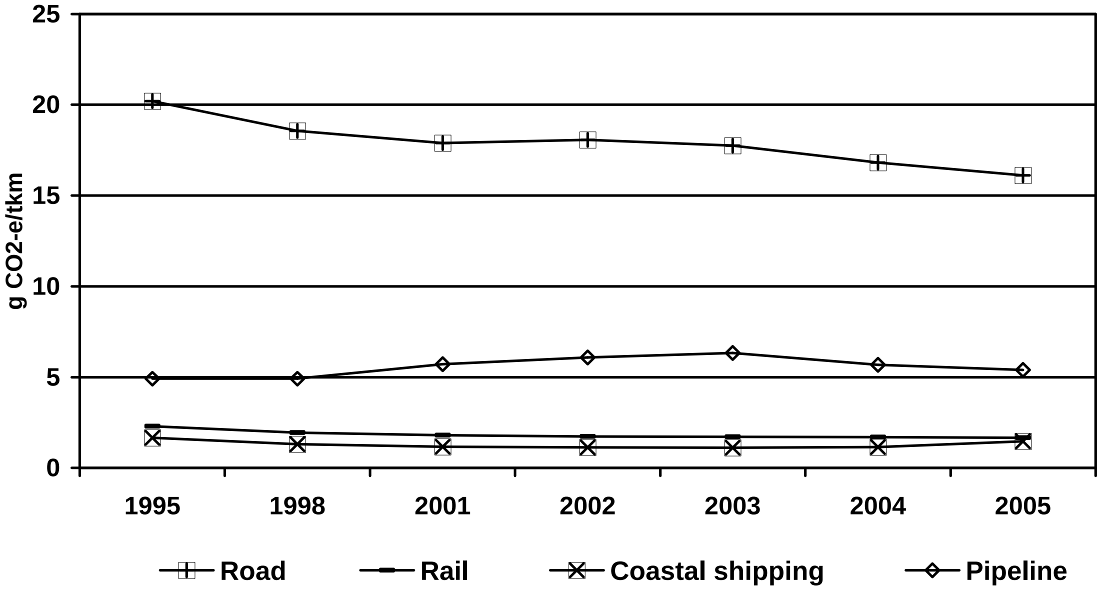
The notion of a ship/rail/road energy and emission intensity hierarchy is supported by a considerable amount of evidence. Figures 7 and 8 show data from Apelbaum Consulting (2007a) on the energy and emission intensity of the main freight transport modes over the period 1995 to 2005, calculated on the full fuel cycle basis.

Figure 7 Energy intensity of freight transport modes, 1995 to 2005, MJ-FFC per tonne-kilometre



Source: Apelbaum Consulting (2007a).

Figure 8 Emission intensity of freight transport modes, 1995 to 2005, g CO_2-e per tonne-kilometre



Source: Apelbaum Consulting (2007a).

Of the major domestic freight transport modes, coastal shipping is the least energy and emission intensive, followed by rail, pipeline and road in ascending order.[15] This has been the case throughout the period 1995 to 2005. As Figures 7 and 8 show, there

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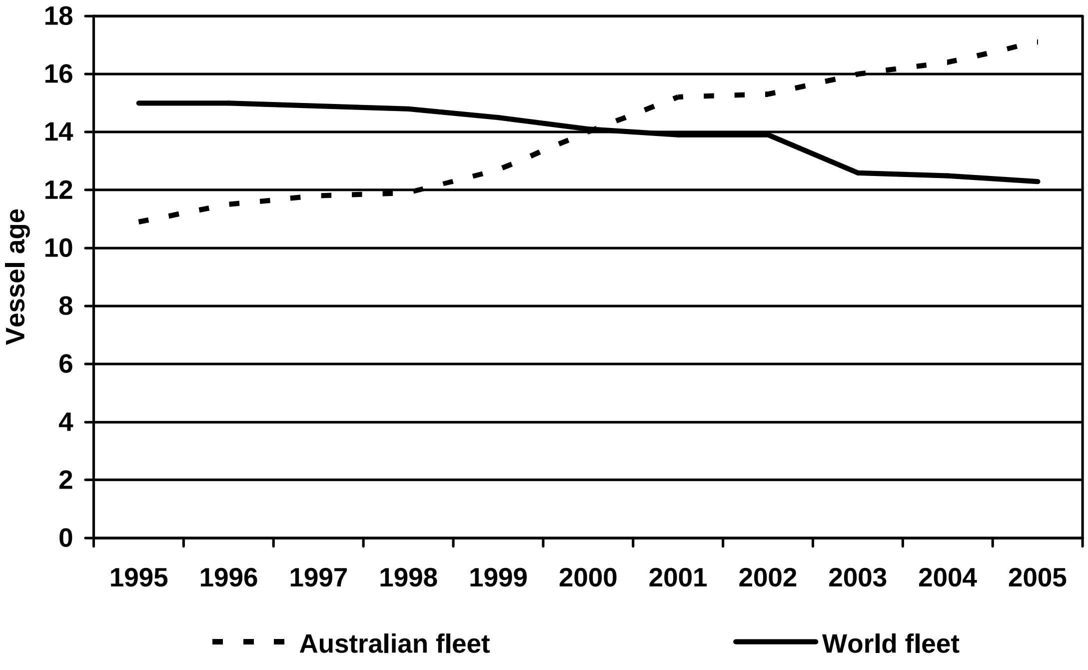
[15] Pipelines do not include slurry unless otherwise stated.

have been changes in the relative energy and emission intensity of the major freight transport modes. The intensity of road and rail trended downward over the decade. The energy and emission intensity of pipelines increased between 1995 and 2003 before falling over 2004 and 2005. The energy and emission intensity of coastal shipping decreased in the first half of the decade, but has increased since the early 2000s. Despite these changes, the hierarchy of ship/rail/road has been maintained.

There are a number of reasons for the changes that have been witnessed in the energy and emission intensity of freight transport modes. Technological innovation and capital replacement have undoubtedly played a part in lowering energy and emission intensity in some sectors, as have economies of scale and operational improvements that have arisen from increasing demand and changes in market share. The fluctuations witnessed in the energy and emission intensity of coastal shipping are likely to have been influenced by declining patronage and the reduction in the size, and increase in the average age, of the domestic fleet. The average age of vessels in the Australian commercial trading fleet in 2005 was 17.1 years, compared to the world fleet average of 12.3 years. This is a reversal of the situation that existed in the mid-1990s, when the average age of the Australian fleet was significantly below the world fleet average – see Figure 9.

Figure 9 Average age of Australian and world fleets, 1995 to 2005



Source: Apelbaum Consulting (2006).

Analysis of the energy and emission intensity of the major freight transport sectors hides differences within each mode. Table 8 shows a more detailed breakdown of the energy and emission intensity of freight transport modes in 2005.

Table 8 Energy and emission intensity of freight transport modes, 2005

Mode	Energy intensity (MJ-FFC/tkm)	Emission intensity (g CO_2-e/tkm)
Road transport		
Light commercial vehicles	21.07	1,532
Rigid trucks	2.95	209
Articulated trucks	0.98	71
Rail		
Hire and reward	0.32	24
Ancillary	0.09	6
Coastal shipping	0.17	15
Pipeline	0.89	54

Source: Apelbaum Consulting (2007a).

Ancillary (or private) rail has the lowest energy and emission intensity of the freight transport modes in Australia, followed closely by coastal shipping then hire and reward (or public access) rail. Approximately 54 per cent of rail freight by tonnes, and 57 per cent by tonne-kilometres, is carried on hire and reward railways. As a result, the energy and emission intensity of the railway sector as a whole is higher than the average in the coastal shipping sector.

Lying in the middle range are pipelines and articulated trucks, which have emission-intensities that are between 3.6 and 4.7 times higher than the emission intensity of coastal shipping. The transport modes with the highest energy and emission intensity are rigid trucks and light commercial vehicles (LCVs). The emission intensity of rigid trucks and LCVs is between 14 and 102 times higher than the emission intensity of coastal shipping.

Comparing the overall energy and emission intensity performance of the road transport modes against rail, pipelines and coastal shipping is arguably misleading as the modes operate in different markets. Rail, pipelines and shipping operate exclusively in non-urban markets, whereas the road modes operate in both urban and non-urban areas. Figure 10 shows the emission intensity ranges for rigid and articulated trucks, hire and reward and ancillary rail, pipelines and coastal shipping in non-urban markets over the period 2001 – 2005.[16] The hierarchy of emission intensities between the modes in the non-urban market is the same as the overall market. Rigid and articulated trucks have the highest emission intensities, the emission intensities of pipelines and hire and reward rail line in the middle, and coastal shipping and ancillary rail have the lowest emission intensities.

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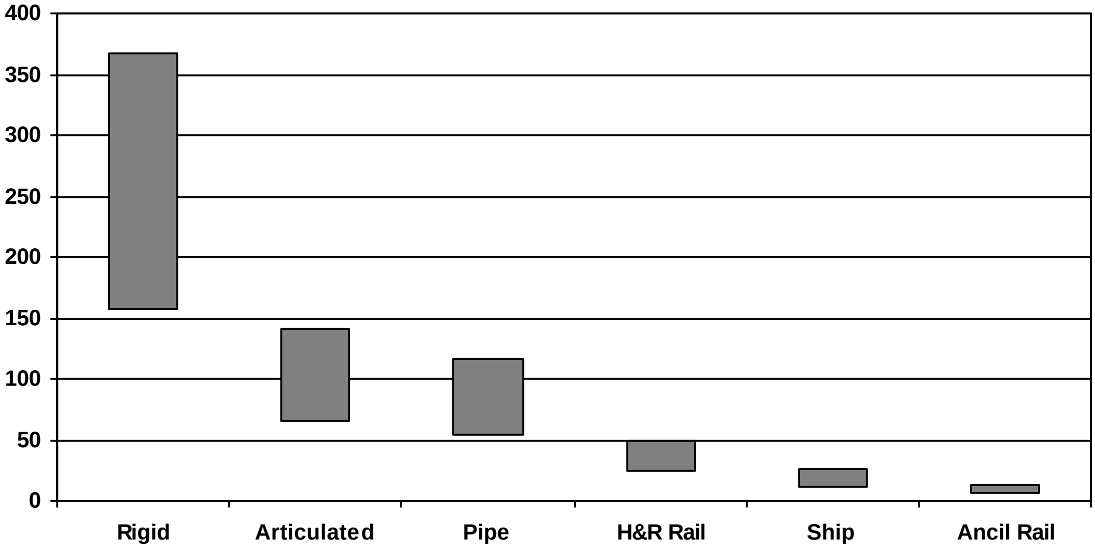
[16] LCVs were excluded as they account for only 0.5 per cent of the non-urban freight market. The emission intensity of non-urban LCVs is also significantly greater than all other modes. Over the period 2001 – 2005, it ranged between 1,555 and 2,067 g CO_2-e/tkm (Apelbaum Consulting 2007b).

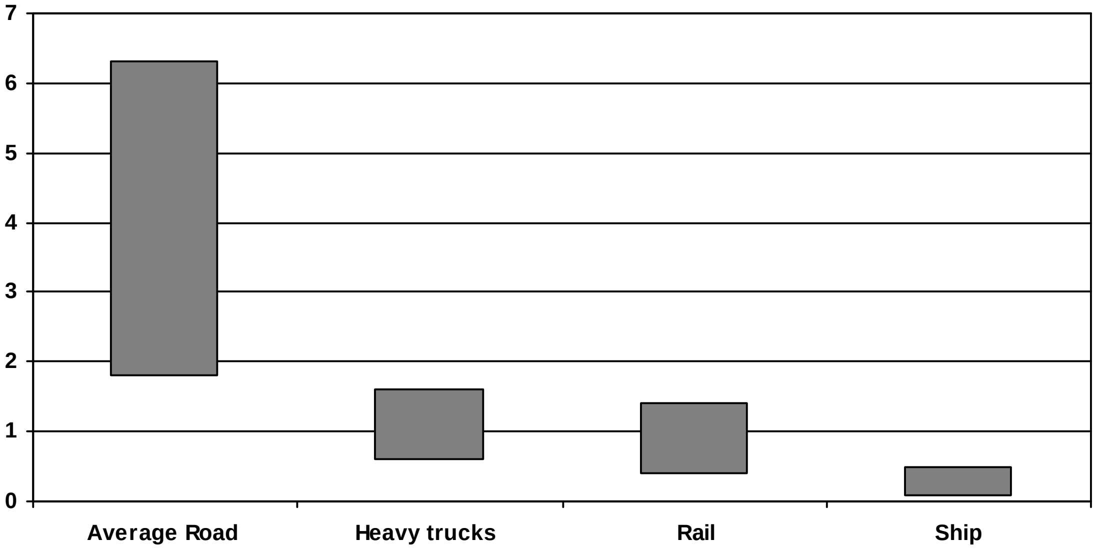
Figure 10 Emission intensity of non-urban freight, 2001 – 2005, g CO_2-e/tkm



Source: Apelbaum Consulting (2007a; 2007b).

The energy and emission intensity hierarchy of the major domestic freight transport modes is similar to that found overseas. This is shown in the seminal report on greenhouse gas emissions from ships prepared by Marintek *et al.* (2000) for the International Maritime Organization (IMO). Using national averages from the 1990s, they found clear evidence of the superiority of marine freight transport over road and rail in terms of energy intensity – see Figure 11.

Figure 11 Marintek *et al.* (2000) data on energy intensity of freight transport modes, MJ/tkm



Source: Marintek *et al.* (2000).

Marintek *et al.* (2000) also evaluated national averages on the emission intensity of freight transport modes – see Table 9. Shipping was found to have relatively high emissions per tonne-kilometre of nitrogen oxides (NO_x), which contribute to global warming.[17] However, its emissions of CO_2 per tonne-kilometre were significantly lower than those associated with road and rail.[18]

Table 9 Marintek *et al.* (2000) data on emission intensity of freight transport modes, g per tkm

Pollutant	Truck	Rail	Marine
Carbon dioxide (CO_2)	127 – 451	41 – 102	30 – 40
Carbon monoxide (CO)	0.25 – 2.40	0.02 – 0.15	0.018 – 0.20
Hydrocarbon (HC)	0.30 – 1.57	0.01 – 0.07	0.04 – 0.08
Nitrogen oxides (NO_x)	1.85 – 5.65	0.20 – 1.01	0.26 – 0.58
Sulphur dioxide (SO_2)	0.10 – 0.43	0.07 – 0.18	0.02 – 0.05
Particulates	0.04 – 0.90	0.01 – 0.08	0.02 – 0.04
Volatile Organic Compounds (VOC)	1.1	0.08	0.04 – 0.11

Source: Marintek *et al.* (2000).

A weakness with average energy and emission intensity data is that it can hide issues that arise as a result of differences in cargo type, routes over which the cargo is transported and operational factors (for example, the capacity factors under which modes are operated). To address this issue, and provide greater detail on the efficiency of alternative types of shipping modes, Marintek *et al.* (2000) also included data from an idealised freight transportation model that evaluated the energy and environmental performance of different modes in carrying an equal tonnage of cargo over an equal distance. The study was focused primarily on international shipping, hence a baseline distance of 3,218 km was assumed, along with an annual modal cargo of 32.2 million tonnes.

When average capacity factors were used for trucks and rail, Marintek *et al.* (2000) found that trucks used more than twice the amount of fuel per tonne-kilometre of cargo than rail – see Figure 12. Further, the four ship types that were modelled (oil tanker, bulk carrier, container and general cargo) were found to be more fuel efficient than rail under most circumstances. Container and general cargo vessels were only less fuel efficient than rail operating at average capacity when their capacity factors fell below 50 per cent. Bulk carriers and oil tankers were generally twice as fuel efficient as rail.

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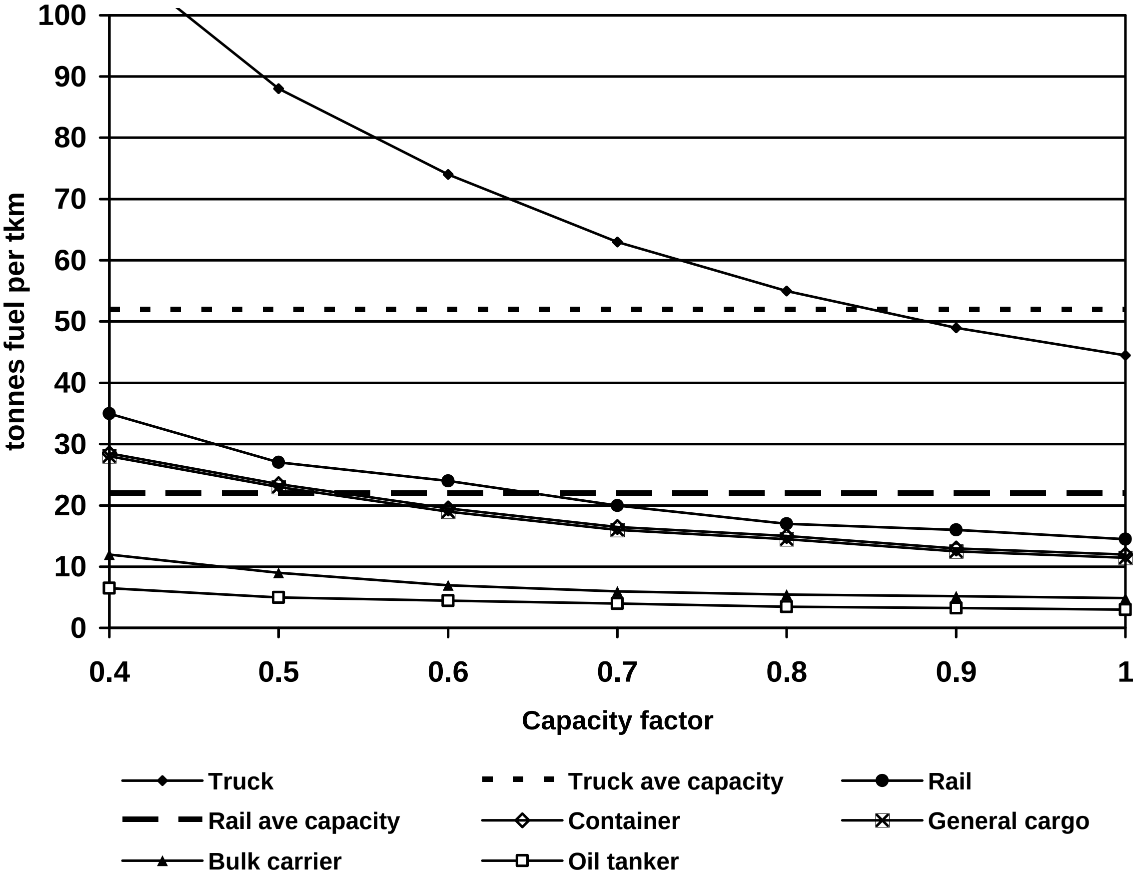
[17] See Section 4 for further details on the types of air pollutants that are emitted by ships.

[18] CE Delft *et al.* (2006) found a slightly higher range of CO_2 emission intensities for certain types of ships. RoRo and refrigerated cargo vessels were found to have CO_2 emission intensities that ranged between 95 and 124 g/ton nautical mile (roughly 50 to 70 g/tkm). However, as highlighted by the authors, the number of ships that were surveyed was too small to provide a representative sample of each ship category.

Figure 12 Fuel consumption by freight transport mode as a function of capacity factor from Marintek *et al.* (2000) idealised freight transport model, tonnes of fuel per tkm



Source: Marintek *et al.* (2000).

Similar results were found in relation to CO_2 intensity, only shipping did not perform as well against rail under certain operational assumptions concerning speed and vessel power. Consistent with the fuel-efficiency findings, heavy-duty trucks had substantially higher CO_2 intensity than all other freight transport modes. Bulk carriers and oil tankers also had lower CO_2 intensity than the other modes. However, the superior CO_2 intensity of container and general cargo vessels depended on operational factors. In most cases, when the capacity factor of container and general cargo vessels exceeded 50 per cent, they had significantly lower CO_2 intensity than rail. Yet when operating at higher speeds and with greater power, their CO_2 intensity could deteriorate, leading to rail outperforming them on a kg CO_2 per tonne-kilometre basis.

4. Shipping emissions

4.1 Types of air pollutants

Ships emit a number of different air pollutants. The ship emissions with the greatest relevance to climate change are carbon dioxide (CO_2), nitrous oxide (N_2O), nitrogen oxides (NO_x), carbon monoxide (CO), volatile organic compounds (VOCs), sulphur oxides (SO_x), and black carbon (BC) and other particulates (PM).

Carbon dioxide (CO_2) and nitrous oxide (N_2O)

Unlike some of the other pollutants associated with shipping, the atmospheric effects of CO_2 and N_2O emissions are relatively well understood. CO_2 and N_2O are long-lived direct greenhouse gases that mix well in the atmosphere.[19] Direct greenhouse gases are those that directly absorb and re-radiate infrared radiation. Indirect greenhouse gases are gases involved in processes that increase the concentration of direct greenhouse gases.

After water vapour, CO_2 is the most important direct greenhouse gas, accounting for approximately 10 – 25 per cent of the greenhouse effect. It is also the most important driver of anthropogenic climate change. N_2O's contribution to anthropogenic climate change has not been as great as CO_2, but it is a far more potent greenhouse gas. Global warming potentials (GWPs) are a measure of the atmospheric warming potential of a unit mass of a gas compared to the warming potential of same unit mass of CO_2. Table 10 shows the 100-year global warming potentials (GWPs) of the main direct greenhouse gases. The GWP of N_2O is 310 times that associated with CO_2. As a result, small increases in N_2O can have significant atmospheric consequences.

Table 10 Global warming potentials of the major direct greenhouse gases

Greenhouse gas	GWP	Greenhouse gas	GWP
CO_2	1	HFC-23	11,700
CH_4	21	HFC-125	2,800
N_2O	310	HFC-134a	1,300
CF_4*	6,500	HFC-143a	3,800
C_2F_6*	9,200	SF_6	23,900

Source: DEWR (2007).
* CF_4 and C_2F_6 are PFCs.

CO_2 and N_2O are two of the six direct greenhouse gases that are required to be accounted for under the UNFCCC and Kyoto Protocol. However, not all ship emissions of these six gases are included in national totals under the UNFCCC/Kyoto Protocol framework.

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[19] The atmospheric lifetimes of CO_2 and N_2O are approximately 5 – 200 years and 114 years respectively.

Emissions of these gases from vessels engaged in domestic navigation are included in national totals. However, emissions from fuel used by vessels engaged in international navigation are excluded from national totals and are only reported under the UNFCCC processes as a memo item (IPCC 2006). Due to the exclusion of international navigation emissions from national totals, the Kyoto Protocol requires that they be controlled through the IMO.[20]

In Australia, it is common for foreign vessels to perform domestic tasks, either under single or continuous voyage permits. Approximately 20 per cent of Australia's coastal freight by tonnes in 2004 was carried by foreign vessels under single and continuous voyage permits (BTRE 2006a). The IPCC Guidelines state that the division between domestic and international navigation should be determined on the basis of the 'port of departure and port of arrival, and not by the flag or nationality of the ship' (IPCC 2006, p. 3.48). Hence, emissions from fuel used by foreign vessels performing domestic freight tasks should ideally be included in estimates of Australia's total emissions. However, due to data limitations, the reports prepared under the UNFCCC/Kyoto Protocol framework by the Australian Government currently exclude emissions from fuels uplifted overseas by foreign vessels that perform domestic freight tasks.[21] This results in the underestimation of domestic shipping emissions.[22]

The national reports prepared under the UNFCCC/Kyoto Protocol framework also only account for transport emissions on a direct combustion basis rather than a full fuel cycle basis. As a result, emissions from the energy used in supplying transport fuels are excluded from transport totals and they will be excluded from a country's national total if the fuel was obtained from another country. Again, this leads to the underestimation of transport emissions. The use of direct combustion reporting also ensures that official UNFCCC/Kyoto Protocol data should not be used to compare the emission intensity of transport modes.

Nitrogen oxides (NO_x)

NO_x (NO plus NO_2) are an ozone precursor (i.e. indirect greenhouse gas), meaning they lead to the formation of ozone (O_3), which is a direct greenhouse gas. O_3 is formed primarily through a series of complex chemical reactions involving NO_x, VOCs and CO. The reactions involving NO_x that lead to O_3 formation are shown below.[23]

(R1) $NO + HO_2 \rightarrow NO_2 + OH$

(R2) $NO_2 + hv \rightarrow NO + O$

(R3) $O + O_2 + M \rightarrow O_3 + M$

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[20] Kyoto Protocol, Article 2(2).

[21] The data limitation is that the Australian Government does not have access to accurate data on the fuel uplifted overseas by foreign vessels performing domestic freight tasks. Mark Huntston, Australian Greenhouse Office, pers. comms. (7 September 2007).

[22] This weakness in the official greenhouse accounts has been raised on a number of occasions; see for example BTRE (2005).

[23] The discussion of atmospheric chemistry draws heavily on Endreson *et al.* (2003). Reaction two requires solar radiation (*hv*).

In contrast to CO_2, the lifetime of NO_x in the troposphere is short, ranging from hours to days. The short atmospheric lifetime prevents NO_x from being thoroughly mixed in the atmosphere, meaning the effects of NO_x emissions on ozone levels tend to be concentrated and localised and vary significantly over time. The extent to which NO_x emissions result in higher O_3 concentrations is also dependent on where they are released. For example, NO_x emissions in the upper troposphere from aircraft are more efficient in producing O_3 than NO_x emissions in the lower troposphere. The radiative effects associated with increases in O_3 are also spatially variable. The warming related to O_3 is greater near the tropopause (boundary region between the troposphere and stratosphere) than at the earth's surface.

Two critical factors in determining the efficiency of O_3 formation from NO_x emissions are the existing concentrations of NO_x and the presence of CO and CH_4. As the concentration of NO_x increases, the efficiency of O_3 formation declines. Because of this, when ships emit NO_x in remote ocean areas it can lead to significant increases in O_3 formation.

The role of CO relates to the production of HO_2 (hydroperoxyl radical). The oxidisation of CO leads to the production of HO_2 (see reactions R4 and R5), which participates in the formation of O_3 (see reactions R1 – R3).

(R4) $CO + OH \rightarrow CO_2 + H$

(R5) $H + O_2 + M \rightarrow HO_2 + M$

CH_4's role arises due to its reaction with OH. The loss of CH_4 from the atmosphere mainly occurs via the following reaction.

(R6) $CH_4 + OH \rightarrow CH_3 + H_2O$

By reducing the abundance of OH, CH_4 affects the oxidisation of CO, potentially lowering the rate of O_3 formation. Yet further oxidisation following reaction R6 will lead to the formation of O_3 through a series of reactions that are similar to reactions R1 – R3.

In addition, CH_4 is a direct greenhouse gas. As reaction R1 shows, NO_x can lead to the production of OH, which is involved in the removal of CH_4 from the atmosphere. Research has shown that international ship NO_x emissions increase global average OH levels by approximately three per cent and reduce CH_4 lifetimes by approximately 4.2 per cent (from around 9.6 to 9.2 years) (Lawrence and Crutzen 1999; Endresen *et al.* 2003). The local and regional changes in OH due to ship NO_x emissions vary, with the greatest increases likely to be in the northern hemisphere and along popular shipping lanes away from the coast. Due to these effects, NO_x emissions from ships can warm the atmosphere by increasing the concentration of O_3 in the troposphere, but they also have a cooling affect by lowering the concentration of CH_4.

Ship NO_x emissions may also contribute to atmospheric cooling by increasing particle formation. Elevated OH levels may lead to an increase in the oxidisation of SO_2 by OH, which in turn, may increase the concentration of particulates (Lawrence and Crutzen 1999). As is explained in more detail below, increases in particulates can increase the reflection of solar radiation.

Any assessment of the effects of ship NO_x emissions must take into account the different characteristics of the gases. CH_4 is a relatively well-mixed atmospheric gas, NO_x is not. As a result, the localised warming effects of NO_x-induced changes in tropospheric O_3 could exceed the equivalent localised CH_4 effects. Yet the effect of enhanced particle concentrations will also be concentrated, meaning the positive and negative local forcing from ship NO_x emissions may cancel each other out.

Carbon monoxide (CO)

CO is a very weak direct greenhouse gas. Its most important contribution to climate change arises as a result of its role as an indirect greenhouse gas. CO has two main indirect effects. Firstly, as discussed, the oxidisation of CO leads to the production of HO_2, thereby contributing to the formation of O_3 (see reactions R1 – 5). Secondly, the oxidisation of CO reduces the abundance of OH (see reaction R4). By reducing OH abundance, CO can extend the atmospheric lifetime of CH_4, which is also destroyed via a reaction involving OH (see reaction R6).

Volatile organic compounds (VOCs)

VOCs can be both direct and indirect greenhouse gases. Relevant VOCs associated with shipping include CH_4 and hydrocarbons. CH_4 is a reasonably potent direct greenhouse gas with a relatively short atmospheric lifetime of around 12 years. As discussed, it also indirectly leads to warming via its role in contributing to O_3 formation. Other VOCs like hydrocarbons can also lead to O_3 formation through a series of complex chemical reactions similar to reactions R1 – R3 above. Further, VOCs such as HFCs and PFCs are potent direct greenhouse gases with GWPs ranging between approximately 1,300 and 11,700 – see Table 10 above. According to Friedrich *et al.* (2007), certain HFCs and PFCs are still used on ships, primarily as cooling agents in refrigerated ships and fishing vessels. It is unclear whether this is the case in Australia, although it seems likely.

Sulphur oxides (SO_x)

SO_x emissions can have significant impacts on local and regional air quality. They also have direct and indirect effects on the climate. The direct climate impact of SO_x emissions is due to the role SO_2 in the formation of sulphur aerosols, which reflect solar radiation and thereby have a cooling effect on the atmosphere. The indirect effects are due to the increase in the number of particles resulting in increased cloud-droplet number densities and the formation of ‘ship tracks’; linear clouds that appear downwind of ships as a result of ship emissions (much like contrails behind aircraft). The rise in the cloud-droplet number densities and ship tracks increase the reflection of solar radiation and lead to atmospheric cooling (Capaldo *et al.* 1999; Schreier *et al.* 2007).

Black carbon (BC) and other particulates (PM)

Research has shown that BC has an important influence on the climate, both through direct radiative forcing and by changing the snow albedo (Hansen and Nazarenko 2004; Reddy and Boucher 2007; IPCC 2007a). The IPCC estimates the radiative forcing from global BC emissions to be between 0.0 and +0.2 Wm^2 (IPCC 2007a), although its warming effects are higher in certain regions (particularly eastern and southern Asia (Reddy and Boucher 2007)). Despite the fact that it has only a short atmospheric lifetime (typically four to seven days), the direct GWP of BC emissions on a global scale is thought to be approximately 480 for a 100-year time horizon, indicating it is a reasonably potent greenhouse gas. The indirect GWP of BC from its effects on snow albedo has been estimated to be 281 (Reddy and Boucher 2007).[24]

The relevance of PM to climate change is the same as the indirect effects of SO_x emissions. Research has shown that the primary cause of ship tracks is PM (Hobbs *et al.* 2000). Ship tracks and the increase in cloud-droplet number densities due to PM increase the reflection of solar radiation and have a negative forcing effect.

Summary

Table 11 below provides a summary of the direction of the forcings associated with shipping emissions. The evidence suggests the four major climate impacts associated with shipping are the increase in CO_2, the increase in O_3 from NO_x emissions, the decrease CH_4 from NO_x emissions and the increase in sulphur aerosols and PM.

Table 11 Direction of forcing due to ship emissions

Climate compound	Direction of forcing due to ship emissions
CO_2	+
N_2O	+
NO_x	
O_3	+
CH_4	–
PM	–
CO	+
O_3	+
CH_4	+
VOC (including CH_4)	+
O_3	+
CH_4	+
Sulphate aerosols and PM	–
BC	+

Sources: Marintek *et al.* (2000), Endresen *et al.* (2003), Corbett and Koehler (2003), Hansen and Nazarenko (2004), Eyring *et al.* (2005), IPCC (2007a) and Reddy and Boucher (2007).

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[24] While useful, it should be noted there is significant regional variation in the GWP of BC and the GWP estimates are subject to considerable uncertainty.

4.2 Net contribution of shipping to global warming

There are two main ways of evaluating shipping's contribution to global warming: the quantity of emissions and radiative forcing. There is currently uncertainty associated with the results from both approaches.

Emissions from shipping

In order to assist in policy formation, several studies have attempted to quantify fuel consumption and direct greenhouse gas emissions from international shipping. The most recent and comprehensive of these are Endresen *et al.* (2003), Corbett and Koehler (2003), Eyring *et al.* (2005) and Endresen *et al.* (2007).[25]

The estimates of fuel consumption and emissions derived by Endresen *et al.* (2003; 2007) are significantly lower than those in Corbett and Koehler (2003) and Eyring *et al.* (2005). These differences have given rise to a rigorous debate about the veracity of the methods and results in the respective studies.[26] The reasons for the discrepancies relate primarily to estimates of key variables, in particular the number of days vessels are assumed to spend at sea.

The results from Corbett and Koehler (2003), Eyring *et al.* (2005) and Endresen *et al.* (2007) are outlined in Table 12. In the case of Corbett and Koehler (2003) and Eyring *et al.* (2005), the estimates are of fuel consumption and direct emissions from the internationally registered fleet (civil cargo and non-cargo vessels greater than or equal to 100 gross tonnes (GT) and military vessels) in 2001,[27] including fuel use and emissions from main and auxiliary engines while at sea and in port. The estimates from Endresen *et al.* (2007) are confined to fuel use and emissions from the main engines of the non-military fleet in 2000.[28] Due to the differences in scope and time, caution should be taken when comparing the datasets. Data from Apelbaum Consulting (2007a) were used to calculate fuel consumption and emissions by domestic shipping in Australia (including military and fishing vessels, as well as international vessels performing domestic freight tasks). The results are included for comparison with the international totals.

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[25] See also Marintek *et al.* (2000), Endresen *et al.* (2005) and Corbett *et al.* (2007).

[26] See Endresen *et al.* (2003; 2004; 2007); Corbett and Koehler (2003; 2004); and Eyring *et al.* (2005).

[27] Eyring *et al.* (2005) limit military vessels to those around 300 GT and above, while Corbett and Koehler (2003) include all military vessels.

[28] Endresen *et al.* (2007) suggest their estimate of fuel consumption is likely to be between 12.5 and 17.5 per cent too low because of the exclusion of military vessels, auxiliary engines and vessels under 100 GT.

Table 12 Emissions from shipping, international and domestic (2000 and 2001)

Study	**Fuel** **Mt**	**CO_2** **Mt**	**CO** **Mt**	**NO_x** **Mt NO_2**	**SO_x** **Mt SO_2**	**PM** **Mt PM_{10}**	**VOC** **Mt**
International							
Corbett and Koehler (2003)	289	912	–	22.57	12.98	1.64	0.77
Eyring *et al.* (2005)	280	813	1.31	21.38	12.03	1.67	1.96
Endresen *et al.* (2007)	201	638			8.7		
Domestic							
Total[a]	0.399	1.04	0.002	0.02	0.01	0.001	0.002

Sources: Corbett and Koehler (2003), Eyring *et al.* (2005), Endresen *et al.* (2007) and Apelbaum Consulting (2007a).
a. Assumed density of fuels: automotive distillate = 850g/L; industrial diesel fuel = 880g/L; fuel oil = 900g/L; natural gas = 800g/m^3.

The results from Corbett and Koehler (2003) and Eyring *et al.* (2005) suggest that in 2001, the internationally registered fleet was responsible for approximately four per cent of world fossil fuel use, three per cent of fossil CO_2 emissions,[29] 30 per cent of fossil NO_x emissions and seven to nine per cent of global SO_x emissions.[30] The lower Endresen *et al.* (2007) estimates suggest the international non-military fleet accounted for less than three per cent of world fossil fuel use and 2.5 per cent of fossil CO_2 emissions in 2000.

Australian domestic shipping's contribution to the international totals is very small. Even if the higher estimates are adopted, fuel used for domestic shipping still only constituted around 0.14 per cent of total fuel used by the internationally registered fleet in 2001 and domestic emissions constituted less than 0.15 per cent of the international totals of all of the listed air pollutants.

The high levels of NO_x and SO_x ship emissions relative to fuel use is due to the low quality of marine fuel and relative lack of effort to control ship non-CO_2 emissions compared to other forms of transport (Friedrich *et al.* 2007). This can be seen by comparing the emissions per unit of fuel use between road, aviation and shipping on a global basis – see Figure 13.

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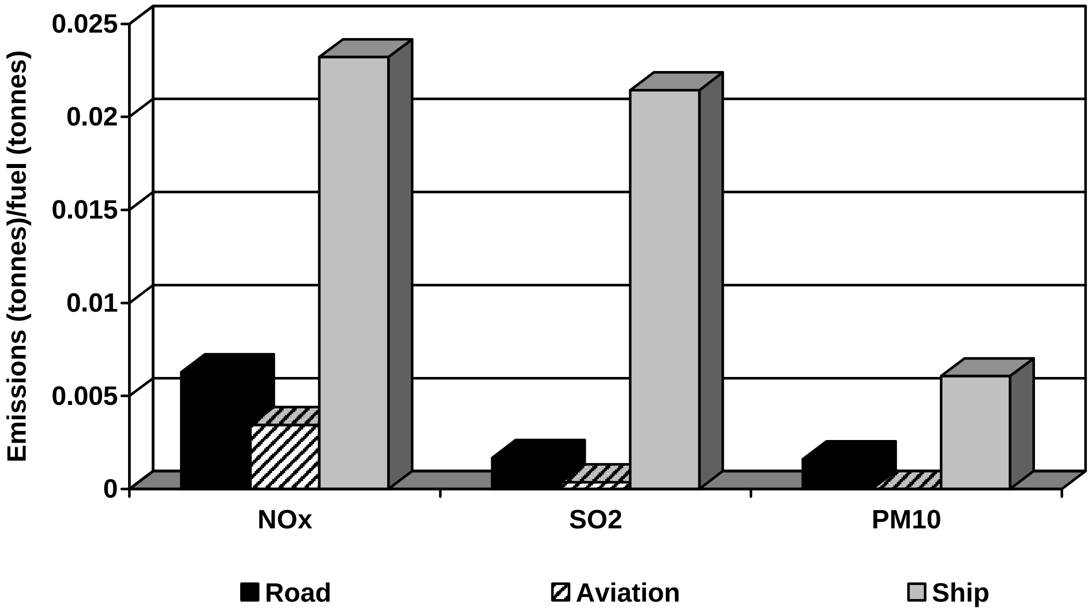
[29] Based on Marland *et al.* (2007) estimates of global fossil CO_2 emissions.

[30] See Corbett *et al.* (2007), Friedrich *et al.* (2007), Corbett and Koehler (2003) and Zhang *et al.* (2003).

Figure 13 Emissions per unit of fuel use, international road, aviation and shipping, 2000[a]

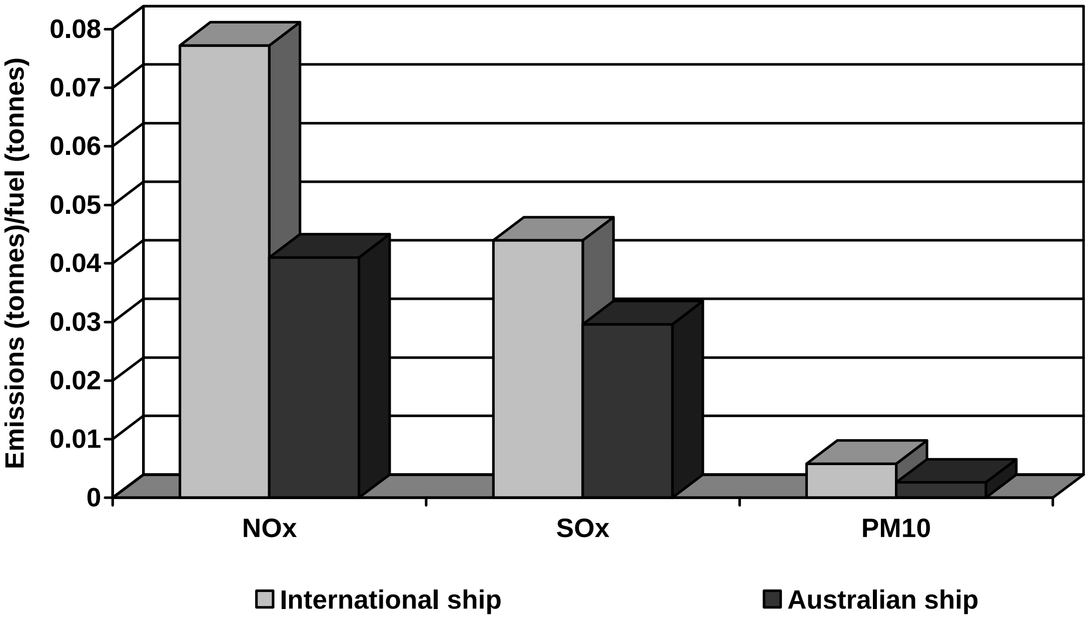


Source: Eyring *et al.* (2005).

a. Emissions of NO_x estimated in tonnes of nitrogen (N). Emissions of SO_x estimated in tonnes of sulphur (S). PM10 emissions from road transport include BC and organic carbon only.

As Figure 13 shows, the ratio between fuel use and NO_x, SO_2 and PM10 emissions is far higher for shipping than either road or air transport. Figure 14 compares the emissions per tonne of fuel of the international shipping fleet with those from Australia's coastal shipping industry. The data suggest the emissions of these pollutants per unit of fuel use from Australia's coastal shipping are significantly lower on average than the international fleet.

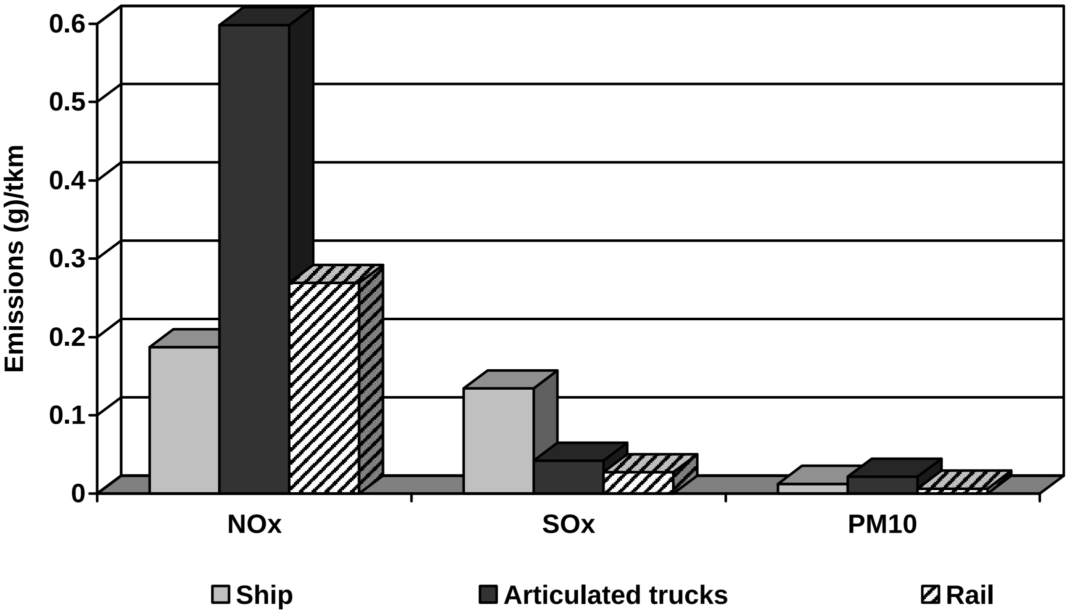
Figure 14 Comparison of emissions per unit of fuel use, international and domestic fleets, 2001[a]



Sources: Corbett and Koehler (2003), Eyring *et al.* (2005) and Apelbaum Consulting (2007a).
a. Estimated international ship emissions calculated as average from Corbett and Koehler (2003) and Eyring *et al.* (2005). Emissions of NO_x estimated in tonnes of NO_x. Emissions of SO_x estimated in tonnes of SO_x.

While Australia's coastal shipping industry may have lower NO_x, SO_2 and PM10 emission intensities per unit of fuel use than the international fleet, they are higher than those associated with the other domestic transport modes. However, due to the superior energy intensity performance of coastal shipping, its NO_x, SO_2 and PM10 emissions per tonne-kilometre on a full fuel cycle basis are similar to, or better than, those of its main competitors; articulated trucks and rail – see Figure 15. SO_2 is the only one of the major air pollutants where coastal shipping has higher emissions per tonne-kilometre than its competitors.

Figure 15 NO_x, SO_2 and PM10 emission intensities of domestic transport modes per tonne-kilometre on a full fuel cycle basis, 2005



Source: Apelbaum Consulting (2007a).

Measures are now being taken at an international and domestic level to lower NO_x, SO_x and PM emissions from shipping. A conundrum that may arise from these measures is that as SO_x and PM emissions decline, so will the cooling effects related to sulphur aerosols and PM. Consequently, there is a risk that the climate impacts of shipping may increase due to the efforts that are being taken to address non-CO_2 emissions.

Net radiative forcing from international shipping

There is currently considerable uncertainty associated with the net radiative forcing from ship emissions. The impact of ship CO_2 emissions is relatively well known. The uncertainty arises primarily in relation to the non-CO_2 emissions, particularly the effects due to changes in O_3 and CH_4 concentrations and the indirect impacts arising from sulphate aerosols, BC and other PM.

Marintek *et al.* (2000, p. 66) concluded that '[i]n total, the current net radiative forcing from ships (including CO_2, ozone, CH_4, and aerosols) is probably small or slightly negative'. However, this assessment was subject to the qualification that the estimate was 'highly uncertain' and that significant gaps in the science had to be resolved before definitive conclusions could be drawn.

Concentrating on the four major climate factors associated with shipping emissions (increase in CO_2, increase in O_3 from NO_x emissions, decrease CH_4 and increase in sulphur aerosols), Endresen *et al.* (2003, p. 20) estimated the net radiative forcing from shipping as 'small but positive, approximately 0.01 – 0.02 W/m^2'. This compares with the IPCC's (2007a) estimate of total anthropogenic radiative forcing of

1.6 Wm^2, and its estimate of the total radiative forcing associated with indirect aerosol effects of -0.7 Wm^2 (see Table 3). A summary of the results from Endresen *et al.* (2003) for the individual compounds is shown in Table 13.

Table 13 Endresen *et al.* (2003) estimate of radiative forcing from shipping

Climate compound	**Radiative forcing due to ship emissions (Wm^2)**
CO_2	0.030
O_3	0.029
CH_4	-0.020
Sulphate aerosols	-0.020
Net radiative forcing	**0.01 – 0.02**

Source: Endresen *et al.* (2003).

The Endresen *et al.* (2003) estimate of net radiative forcing from shipping emissions was based on their estimate of fuel consumption, which is approximately 40 per cent lower than the estimates by Corbett and Koehler (2003) and Eyring *et al.* (2005). It also excludes the negative forcing associated with the indirect effects of sulphur aerosols and PM and the positive forcing from CO, VOCs and BC. Other studies have estimated the radiative forcing from a number of these compounds. For example, Reddy and Boucher (2007) found the radiative forcing from ship emissions of BC was approximately +0.005 Wm^2 in all parts of the world. Similarly, Capaldo *et al.* (1999) evaluated the indirect effect of sulphur aerosols and PM from shipping and estimated the radiative forcing of these compounds to be -0.11 Wm^2, giving rise to the possibility that shipping may have a net cooling effect on the global climate. More recent evidence from Schreier *et al.* (2007) suggests the radiative forcing associated with ship tracks that are formed as a result of sulphur aerosols and PM is likely to be a great deal smaller than the amount estimated by Capaldo *et al.* (1999). They found that in some regions in the Northern Pacific Ocean and west of southern Africa the annual mean radiative forcing from ship tracks could be as high as -0.05 Wm^2. However, the global annual mean radiative forcing associated with this phenomenon was estimated at between -0.4 and -0.6 mWm^2.[31]

While the level of scientific understanding about the atmospheric impacts of shipping is growing, there remains a high level of uncertainty associated with a number of the pollutants. For example, the estimate of the global mean forcing from ship tracks in Schreier *et al.* (2007) is subject to uncertainties of ±40 per cent. The uncertainty associated with these issues makes it impossible to accurately estimate the net radiative forcing from shipping. However, the Marintek *et al.* (2000) conclusion that the evidence suggests the net forcing from shipping is likely to be small or even slightly negative remains valid.

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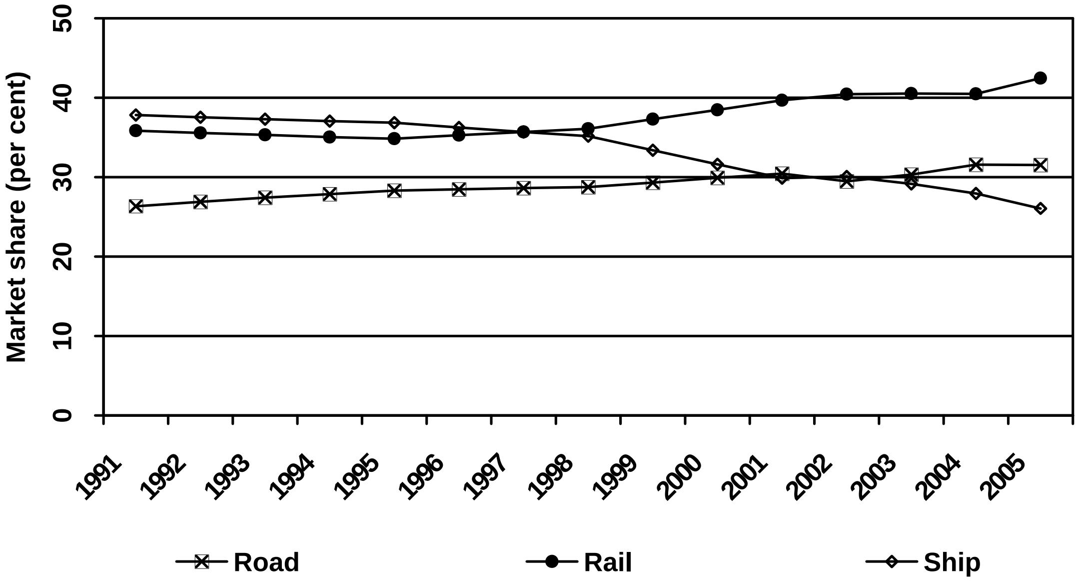
[31] mW = milliwatt, or 1/1000th of a watt.

5. Mode shifting to reduce greenhouse emissions

Throughout the early 1990s, coastal shipping had a greater than 37 per cent share of the non-urban freight market by tonne-kilometres. This has fallen away considerably over the last decade – see Figure 16. Coastal shipping now has 26 per cent of the non-urban market, compared to 32 per cent for road and 42 per cent for rail.

Figure 16 Mode shares of non-urban freight market, 1990 – 2005



Source: Apelbaum Consulting (2007a).

The changes in market share between the modes were due to a number of factors, including changes in freight flows, service demands and investments in road and rail infrastructure.

In order to demonstrate the impacts of mode shifting, a 'what if' scenario (called the 'WI1 scenario') was modelled that seeks to answer the question: what would have happened to non-urban freight emissions if the market share of the modes was frozen at 1991 levels over the period 1991 – 2005? This type of reversal of changes in mode shares is similar to what has been proposed as an option for reducing transport emissions in other countries. For example, in 2001, the European Commission proposed a strategy to deal with transport emissions that included a goal of bringing 'about a shift in transport use from road to rail, water and public passenger transport so that the share of road transport in 2010 is no greater than in 1998' (European Commission 2001a, p. 12).[32] On the basis of this proposal, the European Council now has a policy of encouraging member states to take measures, where appropriate, 'to effect a shift from road to rail, water and public passenger transport' (European Council 2006, p. 10).

To model the emission impacts of this scenario, the following assumptions were adopted.

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[32] See also the European Commission's White Paper on transport policy (European Commission 2001b).

- Road (articulated trucks, rigid trucks and LCVs), rail (hire and reward rail and ancillary rail) and coastal shipping retained the share of the non-urban freight market (i.e. proportion of tonne-kilometres) that they held in 1991 over the period 1991 to 2005. As shown in Table 14, the major changes in the market shares of the modes over this period has been a decline in the shares held by coastal shipping, LVCs and rigid trucks and an increase in the shares held by articulated trucks and rail. Hence, WI1 results in an increase in the shares held by coastal shipping, LCVs and rigid trucks and a decline in the shares held by articulated trucks and rail.

Table 14 Market shares of freight transport modes, non-urban freight, tonne-kilometres and per cent, 1991 and 2005

Mode	**1991 (tkm)**	**1991 (per cent)**	**2005 (tkm)**	**2005 (per cent)**	**Change in market share (per cent)**
LVCs	1.82	0.71	2.39	0.55	-0.17
Rigid trucks	9.61	3.76	11.71	2.68	-1.09
Articulated trucks	55.83	21.87	123.82	28.29	6.42
Total road	**67.27**	**26.35**	**137.92**	**31.52**	**5.17**
Hire and reward rail	53.22	20.85	106.30	24.29	3.44
Ancillary rail	38.32	15.01	79.35	18.13	3.12
Total rail	**91.54**	**35.86**	**185.65**	**42.42**	**6.57**
Shipping	**96.48**	**37.79**	**114.04**	**26.06**	**-11.73**
Total	**255.285**	**100**	**437.61**	**100**	**–**

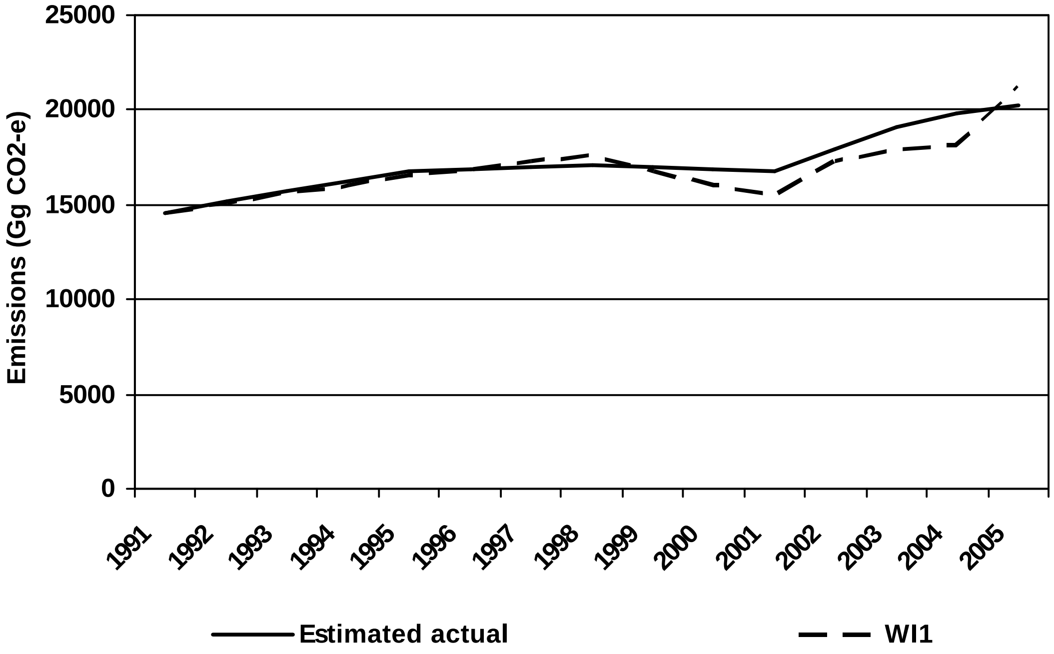
Source: Apelbaum Consulting (2007a).

- Changes in market share will often lead to changes in emission intensity. Modes that gain market share can experience falls in emission intensity due to increases in capacity factors and innovation prompted by investment. The reverse can be true of modes experiencing falling market shares; falling capacity factors and a lack of investment can increase the emission intensity of the mode. Despite this, the actual estimates of non-urban emission intensities of the modes from Apelbaum Consulting (2007a; 2007b) for the period 1991 – 2005 were used. This decision was made because of the access to accurate emission intensity data for this period and the lack of suitable data on which to make estimates of the changes that would have occurred if the market share remained static at 1991 levels. The adoption of this assumption is likely to result in an underestimate of the benefits of mode shifting to coastal shipping.

- Actual estimates of tonne-kilometres, emission intensity and total emissions were only available for the years 1991, 1995, 1998 and 2001 – 2005. To derive estimates for the years 1992 – 1994, 1996 – 1997 and 1999 – 2000, a linear trend in tonne-kilometres and emission intensity were assumed between the years where actual data were available. Total emissions for these years were then calculated by multiplying the emission intensity estimates by the estimated tonne-kilometres.

The estimated actual emissions and emissions under the WI1 scenario are shown in Figure 17. Further details of the magnitude of the impacts are provided in Table 15.

Figure 17 Actual versus WI1 emissions, 1991 – 2005, Gg CO_2-e



Sources: Apelbaum Consulting (2007a) and The Australia Institute.

Table 15 Cumulative emissions and savings, actual versus WI1, 1991 - 2005

Estimated actual cumulative emissions (Gg CO_2-e)	257,266
WI1 cumulative emissions (Gg CO_2-e)	252,676
Saving (Gg CO_2-e)	4,590
Saving (per cent)	1.8

Sources: Apelbaum Consulting (2007a) and The Australia Institute.

As shown in Figure 17 and Table 15, if the market shares of non-urban freight held by the major transport modes had been frozen at 1991 levels, emissions from non-urban freight transport would have been only slightly lower than they were. Over the entire period 1991 – 2005, cumulative total emissions would have been approximately two per cent (4,590 Gg CO_2-e) lower under the WI1 scenario. In certain years, the WI1 scenario results in higher emissions.

The small emission reductions achieved under the WI1 scenario are attributable to a number of factors, including the following.

- The scenario results in an increase in the market shares of LCVs and rigid trucks, which are the most emission intensive modes.

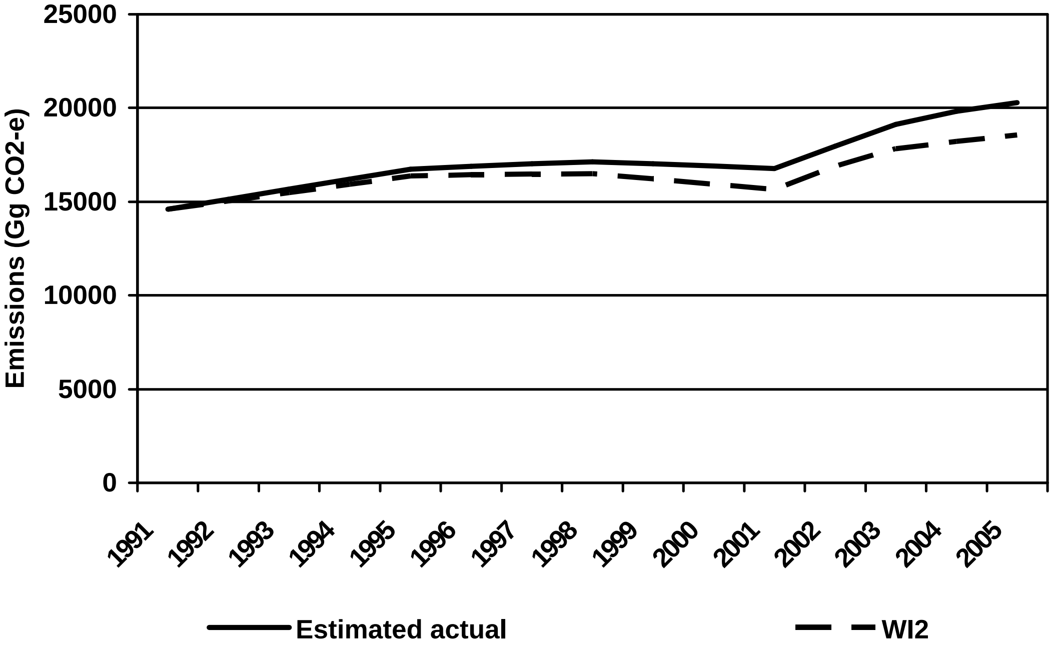
- The scenario results in a decrease in the market share of ancillary rail, which is the least emission intensive mode.
- The emission intensity of coastal shipping experienced a significant increase in 2005, rising to 15 g CO_2-e per tonne-kilometre. The average for the previous four years was 11 g CO_2-e per tonne-kilometre.

In order to provide a better insight into the potential greenhouse benefits associated with mode shifting toward coastal shipping, a second ‘what if’ scenario (called the ‘WI2 scenario’) was modelled on the basis of the following assumptions.

- The freight task carried by rigid trucks, LCVs and ancillary rail are their actual tonne-kilometres over the period 1991 – 2005. The market shares of rigid trucks and LCVs were not frozen because it is unlikely greenhouse policies would result in an increase in the market shares of the modes with the highest emission intensities. The market share of ancillary rail was not frozen because it has the lowest emission intensity of the modes, meaning any policy that resulted in ancillary rail losing market share would lead to worse greenhouse outcomes.
- Articulated trucks, hire and reward rail and coastal shipping retained the share of the non-urban freight market that they held in 1991 over the period 1991 to 2005. However, in calculating the market shares of these modes, the freight task carried by rigid trucks, LCVs and ancillary rail was excluded.
- The emission intensities of the modes are unchanged.

The results are presented in Figure 18 and Table 16.

Figure 18 Actual versus WI2 emissions, 1991 – 2005, Gg CO_2-e



Sources: Apelbaum Consulting (2007a) and The Australia Institute.

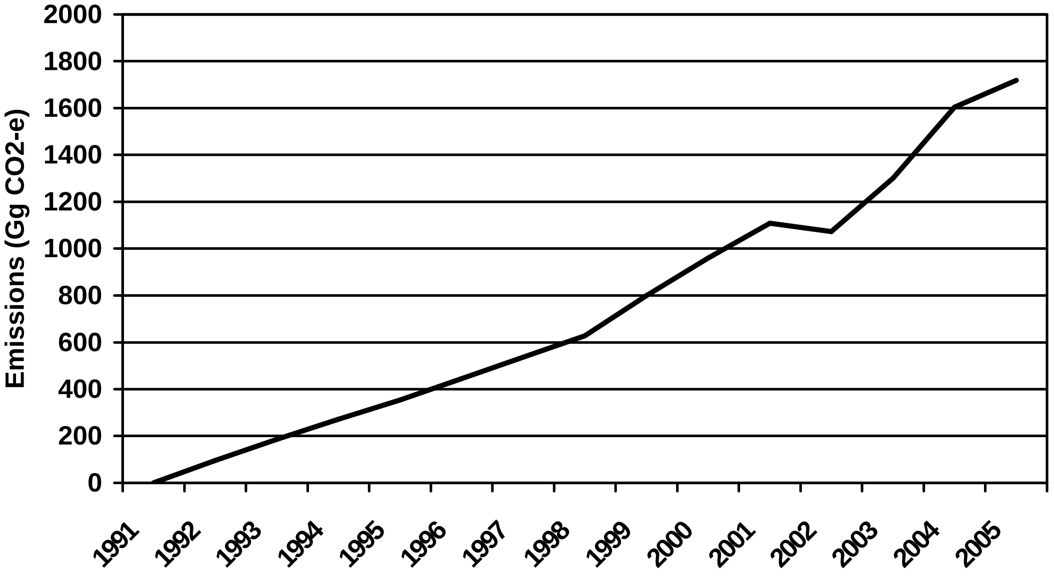
Table 16 Cumulative emissions and savings, actual versus WI2 emissions, 1991 - 2005

Estimated actual cumulative emissions (Gg CO_2-e)	257,266
WI2 cumulative emissions (Gg CO_2-e)	246,191
Saving (Gg CO_2-e)	11,075
Saving (per cent)	4.3

Sources: Apelbaum Consulting (2007a) and The Australia Institute.

The reductions under the WI2 scenario are more significant than those under the WI1 scenario. There is a cumulative saving of four per cent (11,075 Gg CO_2-e) over the period 1991 – 2005, which compares favourably to the WI1 scenario result of a two per cent (4,590 Gg CO_2-e) saving. There is also an upward trend in the size of the annual emission saving from the changes in mode shares – see Figure 19. This is a result of the growing size of the non-urban freight market and the ongoing decline of shipping's market share.

Figure 19 Annual savings under the WI2 scenario, 1991 – 2005, Gg CO_2-e



Sources: Apelbaum Consulting (2007a) and The Australia Institute.

Although the WI2 scenario produces significant emission reductions, two important points must be made.

Firstly, the size of the abatement is relatively small in comparison to the total emissions from the transport sector. Apelbaum Consulting (2007a) estimate that in 2005, total emissions from the domestic transport sector on a full fuel cycle basis (including pipelines) were 101 Mt CO_2-e, while domestic freight emissions were approximately 37 Mt CO_2-e. The saving achieved under the WI2 scenario in the same year was 1.7 Mt CO_2-e. Hence, the 11 per cent increase in shipping's share of the non-urban freight task in 2005 under the WI2 scenario resulted in a two per cent saving in transport emissions and five per cent saving in freight emissions. This is attributable to two main facts.

- The majority of transport emissions are passenger-related. Emissions from passenger vehicles and buses in 2005 amounted to 55 Mt CO_2-e. Further, around 40 per cent of freight emissions (16 Mt CO_2-e) are related to the urban freight task. Total emissions from the non-urban freight market (excluding pipelines and aviation) in 2005 were 20 Mt CO_2-e. As a result, proportional cuts in non-urban freight emissions must be large in order to result in substantial reductions in total transport and freight emissions.

- The WI2 scenario leaves a large proportion of the non-urban freight task in the hands of road transport, which has the highest emission intensity of the transport modes. This is illustrated by looking at the breakdown of the non-urban freight task and emissions by mode in 2005 – see Table 17. Total emissions under the WI2 scenario in 2005 are 19 Mt CO_2-e, of which 14 Mt CO_2-e are attributable to road transport. Hence, despite holding only a quarter of the non-urban freight market, road transport accounts for 73 per cent of non-urban freight emissions. Similar patterns are evident with the actual estimates and the WI1 scenario. Making substantial cuts to freight emissions requires a substantial reduction in the market share of road transport and/or a substantial reduction in the emission intensity of road transport.

Table 17 Breakdown of non-urban freight task and emissions, actual, WI1 and WI2 by mode, 2005

Mode	**Estimated actual**		**WI1**		**WI2**	
	Billion tkm	**Mt CO_2-e**	**Billion tkm**	**Mt CO_2-e**	**Billion tkm**	**Mt CO_2-e**
LVCs	2.4	4.9	3.1	6.4	2.4	4.9
Rigid trucks	11.7	2.5	16.5	3.5	11.7	2.5
Articulated trucks	123.8	8.1	95.7	6.3	93.5	6.1
Total road	**137.9**	**15.5**	**115.3**	**16.2**	**107.6**	**13.5**
Hire and reward rail	106.3	2.6	91.2	2.2	89.1	2.2
Ancillary rail	79.35	0.5	65.7	0.4	79.4	0.5
Total rail	**185.6**	**3.1**	**156.9**	**2.6**	**168.5**	**2.7**
Shipping	**114.0**	**1.7**	**165.4**	**2.4**	**161.6**	**2.4**
Total	**437.6**	**20.3**	**437.6**	**21.2**	**437.6**	**18.6**

Sources: Apelbaum Consulting (2007a) and The Australia Institute.

The second important point about the results from the WI2 scenario is that the capacity of mode shifting to bring about significant reductions in emissions is dependent on shipping’s ability to compete with the land transport modes under market conditions. If shipping is unable to compete and draw market share from other modes, any attempt to encourage mode shifting toward shipping is likely to be ineffective and inefficient. The WI2 scenario assumes shipping will be able to reverse the downward trend in its market share. However, the domestic freight market has changed considerably since 1991 and the characteristics of the market that made shipping competitive in the early 1990s may no longer be present. The changes in the domestic freight market and shipping's capacity to compete with the land transport modes are the subject of the following section.

6. Competition between shipping and other modes

This section analyses the extent to which coastal shipping can compete with road and rail. It is divided into two sub-sections:

- the ability of coastal shipping to compete with road and rail; and
- the effect of a carbon price on the competitiveness of coastal shipping.

6.1 Competitiveness of coastal shipping

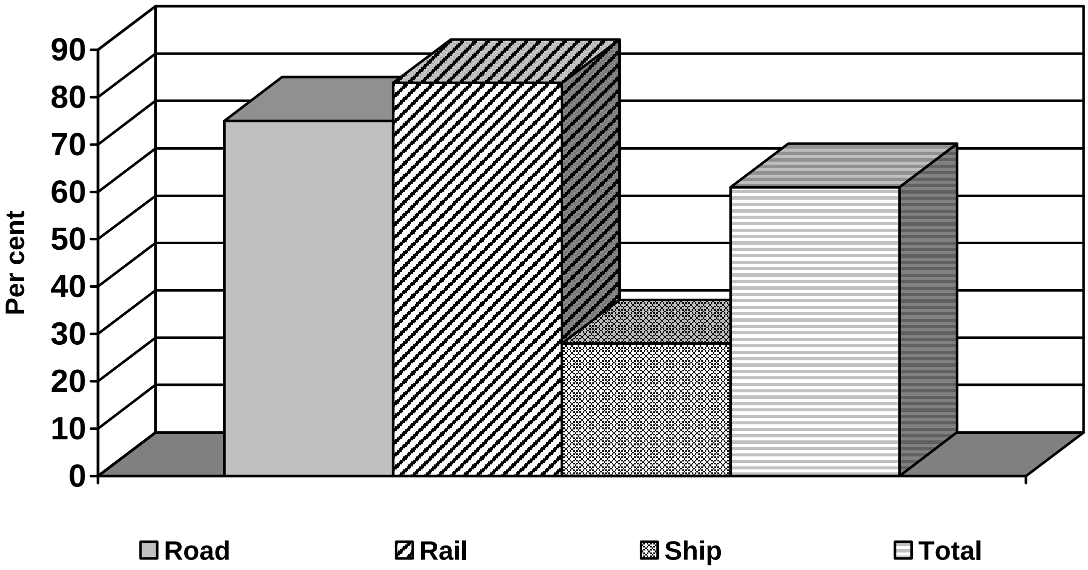
Australian freight market

The Australian freight market is comprised of a collection of distinct, albeit often overlapping, markets that are defined primarily by geography and product type. The geographic features of greatest relevance in the current context concern the divisions between urban and non-urban freight and intra and interstate freight.

In 2005, the domestic freight task amounted to 494 billion tonne-kilometres (excluding pipelines). Of this, 89 per cent was non-urban and 11 per cent was urban. The urban freight task is performed almost exclusively by road and most data sources assume that road performs the entire urban task (BTRE 2006b; Apelbaum Consulting 2007a). As a consequence, all of the freight transported by rail and coastal shipping is generally classified as non-urban.

While the majority of the domestic freight task is non-urban, much of it is intrastate (between an origin and destination within a single state/territory). In 2005, 67 per cent of freight carried by road, rail and coastal shipping by tonne-kilometres was intrastate (Apelbaum Consulting 2007a). However, only 28 per cent of sea freight was intrastate, compared to 75 per cent for road and 83 per cent for rail – see Figure 20. Much of the Australian domestic freight market is therefore concentrated on intrastate movements, while sea freight is mostly interstate.

Figure 20 Proportion of total freight movements that are intrastate, 2005



Source: Apelbaum Consulting (2007a).

In terms of product type, the main distinction is between bulk and non-bulk cargoes. Bulk cargo can be broadly defined as any unpacked or unbound cargo that is carried loose. Examples include grains, minerals and oil and other petroleum products. Non-bulk cargoes are cargoes that are not bulk (i.e. they are carried in a packaged or bounded rather than loose form), and include containerised and break-bulk cargoes.[33]

The BTRE has estimated that in 2003, approximately 66 per cent of the domestic freight task (excluding pipelines) was bulk freight and 34 per cent was non-bulk freight by tonne-kilometre (BTRE 2006b). The majority of the bulk freight task was performed by rail and shipping, while the majority of the non-bulk task was performed by road – see Table 18.

Table 18 Bulk and non-bulk freight, billion tonne-kilometres, 2003

	Bulk	Non-bulk	Total
Road	46.09	107.53	153.62
Rail			
Hire and reward	67.19	30.99	98.18
Ancillary	62.93	–	62.93
Total rail	130.12	30.99	161.11
Ship	107.24	7.56	114.80
Total	283.44	146.33	429.78

Source: BTRE (2006b).

In the interstate transport of bulk freight, shipping is dominant, accounting for 89 per cent of the market – see Table 19. However, it holds only nine per cent of the interstate non-bulk market. The majority of non-bulk sea freight involves the

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[33] Containerised cargoes are those carried in standardised large reusable containers. Break-bulk cargoes are cargoes shipped in smaller package units like crates, cases, bales, drums and pallets.

movement of cargoes between Tasmania and the mainland (BTRE 2006a). Road holds the majority of the interstate non-bulk market (66 per cent). Rail has 25 per cent of the interstate non-bulk market, but its major area of operation is in the intrastate transport of bulk cargoes.

Table 19 Interstate bulk and non-bulk freight, billion tonne-kilometres, 2003

	Bulk	Non-bulk	Total
Road	3.90	51.86	55.76
Rail			
Hire and reward	5.90	19.54	25.44
Ancillary	–	–	–
Total rail	5.90	19.54	25.44
Ship	76.69	7.33	84.02
Total	86.49	78.96	165.45

Source: BTRE (2006b).

The intrastate freight market is broken into two parts: urban and rest of state (or non-urban intrastate). Road is effectively the only carrier of urban bulk and non-bulk freight. It is also the dominant carrier of non-urban intrastate non-bulk freight (accounting for 69 per cent of the market), and is responsible for a moderate amount of non-urban intrastate bulk freight (16 per cent) – see Table 20. Rail is the dominant carrier of non-urban intrastate bulk freight (67 per cent) and a significant carrier of non-urban intrastate non-bulk freight (31 per cent). Coastal shipping carries a moderate amount of non-urban intrastate bulk freight (17 per cent), but virtually no non-urban intrastate non-bulk freight.

Table 20 Intrastate bulk and non-bulk freight, billion tonne-kilometres, 2003

	Bulk	Non-bulk	Total
Road			
Urban	12.91	30.12	43.03
Rest of state	29.28	25.55	54.83
Total road	42.19	55.67	97.86
Rail (Rest of state only)			
Hire and reward	61.29	11.45	72.74
Ancillary	62.93	–	62.93
Total rail	124.22	11.45	135.67
Ship (rest of state only)	30.55	0.23	30.78
Total	196.96	67.35	264.31

Source: BTRE (2006b).

Non-bulk freight is growing at a significantly faster rate than bulk freight. Between 1983 and 2003, bulk freight grew at an average of 3.5 per cent per annum. Over the same period, non-bulk freight grew at an average of over five per cent per annum. The superior growth of non-bulk freight is expected to continue into the foreseeable future. The BTRE has projected that bulk freight will grow at 2.3 per cent per annum between 2003 and 2020, compared to a 3.6 per cent annual growth rate for non-bulk freight (BTRE 2006b).

Of the domestic freight tasks, non-bulk interstate freight is the fastest growing. Between 1983 and 2003, the interstate non-bulk freight task grew at an average of 5.4 per cent per annum. Over the period 2003 – 2020, it is expected to grow at 4.1 per cent per annum. The urban freight task has also grown rapidly since 1983 and is expected to continue its fast growth through to 2020.

The above facts suggest the following about the domestic bulk freight market.

- Road is effectively the only carrier of urban bulk freight, it carries a moderate amount of non-urban intrastate bulk freight and a small amount of interstate bulk freight.

- Rail carries no urban bulk freight, is the dominant carrier of non-urban intrastate bulk freight and a small carrier of interstate bulk freight.

- Coastal shipping carries no urban bulk freight, a moderate amount of non-urban intrastate bulk freight and is the dominant carrier of interstate bulk freight.

- Bulk freight is expected to grow at 2.3 per cent per annum between 2003 and 2020.

The non-bulk market is characterised by the following facts.

- Road is effectively the only carrier of urban non-bulk freight and the dominant carrier of intrastate and interstate non-bulk freight.

- Rail carries no urban non-bulk freight, but is a significant carrier of both non-urban intrastate and interstate non-bulk freight.

- Coastal shipping carries no urban non-bulk freight, almost no intrastate non-bulk freight and a small amount of interstate non-bulk freight.

- Non-bulk freight is expected to grow at 3.6 per cent per annum between 2003 and 2020.

Competitiveness of coastal shipping

A literature review was conducted to evaluate the competitiveness of coastal shipping. To identify relevant papers, a search was conducted of relevant domestic environment and transport journals and websites of relevant industry groups and government institutions, including the BTRE and the National Transport Commission. Only papers on the Australian freight market were included. Research on the competitiveness of rail and the ability to encourage mode shifting from road to rail were included where the papers contained material that was relevant to the evaluation of the competitiveness of coastal shipping. Reports published before 1997 were discarded. Nineteen relevant papers were identified and analysed. The review is presented in Appendix A.

The literature review illustrates that relatively little research has been carried out on the competitiveness of coastal shipping. More research has been focused on the degree of competition between road and rail and the ability of rail to gain market share from road. Notwithstanding this, the research that has been undertaken suggests three main things.

Firstly, the most likely area of competition between coastal shipping and the land transport modes is in the interstate carriage of non-bulk freight. Competition for bulk freight between coastal shipping and road and rail is limited, being confined to certain residual flows. The relative incontestability of the bulk freight market is likely to be a product of the nature of the freight flows and the characteristics of the modes. One of the major issues is that many of the bulk flows are urban or from inland areas to capital cities and regional centres; routes which shipping cannot service. This is reflected in the data on intrastate bulk freight movements. Road accounts for all urban bulk freight movements and rail is responsible for almost 70 per cent of the non-urban intrastate bulk market, with all ancillary rail freight being non-urban intrastate bulk freight (see Tables 19 and 20). In addition, the bulk freight task has become more geographically dispersed in both origin and destination in recent times, which has led to a decline in the shares of the non-urban intrastate bulk market held by rail and coastal shipping (Productivity Commission 2006; BTRE 2006b).

Another factor that contributes to the incontestability of bulk flows is shipping’s dominance of the large interstate market. This is due to the economies of scale and distance associated with shipping, and the relatively low intermodal costs associated with bulk cargo vessels. Due to these factors, ships are able to transport large quantities of bulk goods over long distances at rates that land transport modes find difficult to match. Long-haul bulk freight also tends to be less time sensitive than other cargoes. As a result, where large quantities of bulk cargoes require movement over long distances on coastal routes, shipping is generally the preferred mode. The data on interstate bulk freight movements reflect these factors. Shipping accounts for almost 90 per cent of interstate bulk freight (see Table 19). Its dominance in this market has left very little to capture from the other modes.

The second issue to emerge from the literature is that coastal shipping is most likely to compete for non-bulk cargoes on long-haul routes. One of the major reasons for this is the relatively high intermodal (i.e. port charges and stevedoring costs) and pick-up and delivery costs associated with shipping. In order to move freight by ship, the cargo must be loaded and unloaded at the port of departure and port of destination, which is costly for non-bulk cargoes (less so for ro-ro vessels than container ships). The cargo must also be picked up and delivered at both ends. Where the freight routes are short, the resulting freight costs per tonne-kilometre are high. Over longer distances, intermodal and pick-up and delivery costs per tonne-kilometre fall, resulting in lower unit costs.

The third major issue identified in the literature is that service (or non-price) factors have a significant influence on the mode choice decisions of many shippers wanting to transport non-bulk freight. Price is a major determinant of mode choice for most shippers. However, service factors including reliability, availability and transit times often have a substantial influence on mode choice. This is attributable to two major issues: the significance of freight transport costs as a proportion of the costs of end products and changes in supply chain management.

Freight transport costs generally constitute a relatively small proportion of total production costs. Estimates derived by Sinclair Knight Merz and Meyrick and Associates (2006) suggest that on average, they amount to around five per cent of total costs. Similarly, the BTRE (2004, p. 5) has stated that:

> … the cost of transport and logistics as a percentage of final price … averages 10-20% overall but can range from less than 5% for high value goods (such as electronics) to more than 30% for low value goods (such as building materials).

These estimates suggest that for most shippers, higher freight transport costs do not have a large impact on their overall cost profile. For example, if freight costs constitute 10 per cent of final prices, a 20 per cent increase in freight costs will result in only a two per cent increase in price. As a result, shippers may be willing to trade higher freight prices for improved service.

Changes in supply chain management over recent years are likely to have contributed to shippers placing greater significance on the quality of service offered by the competing freight transport modes. In particular, there has been a concerted effort to reduce inventories and a shift toward built to order goods and just-in-time logistics.[34] To facilitate these changes, shippers have required freight to be moved in smaller quantities more frequently with greater reliability. These service qualities are better suited to road than rail or coastal shipping. Road does not have the large economies of scale associated with the other modes, meaning it is able to move smaller loads economically and frequently. Further, improvements in vehicle technology and capacity (for example, the introduction of B-doubles and B-triples) and substantial improvements in road infrastructure have ensured road is able to provide a reliable, frequent, timely and cost competitive service. Neither rail nor coastal shipping has been able to match the improvements in service quality offered by road. This has resulted in road dominating the non-bulk market on short- to medium-haul routes. On long-haul routes, cargoes are likely to be less time sensitive and rail and shipping are able to provide freight services at rates significantly below road. These trends are evident in the data on the non-bulk freight flows on the six major intercapital corridors: Melbourne – Adelaide, Melbourne – Sydney, Sydney – Brisbane, Sydney – Adelaide, Melbourne – Brisbane and Eastern Capitals – Perth.

Table 21 Melbourne – Adelaide, non-bulk freight flows

	Distance (km)	Estimated freight rate 2007 ($/tonne)	Task in 1991 (billion tkm	Task in 2001 (billion tkm)	Growth rate 1991 – 2001 (per cent)	Market share 1991 (per cent)	Market share 2001 (per cent)
Road	740	34	1.12	2.7	9.2	63	84
Rail	740	45	0.65	0.48	-3.0	37	15
Sea	740	<rail	0.00	0.02	n/a[a]	0.0	0.6

Sources: BTRE (2006b) and Meyrick and Associates *et al.* (2007).
a. n/a means not applicable.

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[34] See BTRE (2004), NIEIR (2007) and Meyrick and Associates *et al.* (2007).

Table 22 Melbourne – Sydney, non-bulk freight flows

	Distance (km)	Estimated freight rate 2007 ($/tonne)	Task in 1991 (billion tkm	Task in 2001 (billion tkm)	Growth rate 1991 – 2001 (per cent)	Market share 1991 (per cent)	Market share 2001 (per cent)
Road	930	44	4.35	7.05	4.9	78	86
Rail	930	48	1.20	1.11	-0.8	22	14
Sea	930	<rail	0.00	0.01	n/a[a]	0.0	0.1

Sources: BTRE (2006b) and Meyrick and Associates *et al.* (2007).
a. n/a means not applicable.

Table 23 Sydney – Brisbane, non-bulk freight flows

	Distance (km)	Estimated freight rate 2007 ($/tonne)	Task in 1991 (billion tkm	Task in 2001 (billion tkm)	Growth rate 1991 – 2001 (per cent)	Market share 1991 (per cent)	Market share 2001 (per cent)
Road	1,000	54	1.81	5.00	10.7	65	84
Rail	1,000	53	0.97	0.89	-0.9	35	15
Sea	1,000	<rail	0.01	0.03	11.4	0.4	0.5

Sources: BTRE (2006b) and Meyrick and Associates *et al.* (2007).

Table 24 Sydney – Adelaide, non-bulk freight flows

	Distance (km)	Estimated freight rate 2007 ($/tonne)	Task in 1991 (billion tkm	Task in 2001 (billion tkm)	Growth rate 1991 – 2001 (per cent)	Market share 1991 (per cent)	Market share 2001 (per cent)
Road	1,550	n.a[b]	1.07	1.97	6.3	63	78
Rail	1,550	n.a[b]	0.64	0.52	-2.1	37	21
Sea	1,550	n.a[b]	0.00	0.03	n/a[a]	0.0	1.2

Sources: BTRE (2006b) and Meyrick and Associates *et al.* (2007).
a. n/a means not applicable.
b. n.a means not available.

As Tables 21 – 24 show, road grew strongly on the short- to medium-haul intercapital routes between 1991 and 2001, taking market share from rail. Coastal shipping held a small but significant share of a number of these markets in the 1970s (for example, Sydney – Brisbane and Melbourne – Sydney). However, by the early 1990s, coastal shipping's share of these markets was negligible and it remained virtually unchanged over the period 1991 – 2001. Where it did experience growth, it was off a very low base and it is only on the longer Sydney – Adelaide route that it holds a greater than one per cent share of the market. Of note is the fact that freight rates for rail and coastal shipping on the medium-haul Melbourne – Sydney and Sydney – Brisbane routes are similar to those for road (data were not available for Sydney – Adelaide). Despite this, road has been able to increase its market share on these routes dramatically, which illustrates the importance of the higher quality service offered by road and changes in supply chain management. The trends on the long-haul routes are different – see Tables 25 and 26.

Table 25 Melbourne – Brisbane, non-bulk freight flows

	Distance (km)	Estimated freight rate 2007 ($/tonne)	Task in 1991 (billion tkm	Task in 2001 (billion tkm)	Growth rate 1991 – 2001 (per cent)	Market share 1991 (per cent)	Market share 2001 (per cent)
Road	1,850	84	2.29	3.54	4.5	76	65
Rail	1,850	83	0.72	1.79	9.5	24	33
Sea	1,850	<rail	0.00	0.09	n/a[a]	0.0	1.7

Sources: BTRE (2006b) and Meyrick and Associates *et al.* (2007).
a. n/a means not applicable.

After losing market share to road on the Melbourne – Brisbane route between 1970 and 1990, rail reversed these trends in the 1990s, increasing its market share by nine per cent and experiencing an average annual growth rate of over nine per cent. This has been attributed to improvements in rail service, including the introduction of non-stop trains on this route (BTRE 2006b). Coastal shipping also gained market share off road. However, in 2001 it held only 1.7 per cent of the market, which equates to 90 million tonne-kilometres (or 45,000 tonnes).

Table 26 Eastern Capitals – Perth, non-bulk freight flows

	Distance (km)	Estimated freight rate 2007 ($/tonne)[a]	Task in 1991 (billion tkm	Task in 2001 (billion tkm)	Growth rate 1991 – 2001 (per cent)	Market share 1991 (per cent)	Market share 2001 (per cent)
Road	3,500	189	2.92	3.18	0.8	41	25
Rail	3,500	118	4.09	7.36	6.1	58	58
Sea	3,500	<rail	0.06	2.16	43.1	0.8	17

Sources: BTRE (2006b) and Meyrick and Associates *et al.* (2007).
a. Calculated as the average on the Perth – Sydney and Perth – Melbourne corridors.

On the long Eastern Capitals – Perth corridor, the majority of the non-bulk freight task (75 per cent) is now performed by rail and coastal shipping. Road's market share on this route increased significantly over the 1970s and 1980s, rising from around five per cent to over 40 per cent by the early 1990s. This was a product of improvements in service that followed the sealing of the Eyre Highway in 1976 and the simultaneous decline in coastal shipping. Since the early 1990s, road's share of this market has fallen to the point where road now accounts for only a quarter of the task. The decline in road was due mainly to an increase in the competitiveness of coastal shipping that was triggered by changes in government policy that allowed more freight to be transported by foreign vessels under single and continuous voyage permits. These changes contributed to a 35 per cent decline in the real freight rates for coastal shipping on this route between 1991 and 2001. As a result, shipping non-bulk freight by sea is now at least 40 – 50 per cent cheaper than road on the Eastern Capitals – Perth corridor.

Despite the resurgence of coastal shipping on the Eastern Capitals – Perth corridor, rail has been able to retain its market share. This has been achieved by improvements in service quality and a reduction in real freight rates of almost 40 per cent. The BTRE (2006b) describes the improvements in rail service in the following terms.

> In recent years, there has been a well-planned centralisation of investment under the aegis of the Australian Rail Track Corporation (ARTC). Standardisation of the gauge in Victoria was completed in 1995. Earlier concrete sleepering was extended during the 1990s and early 2000s. The adoption of National Rail class locomotives was completed by the lengthening of passing loops – allowing larger train lengths. In-cab signalling and points control meant trains no longer had to stop. By these means rail has been able to maintain its share on the corridor in the face of growing sea traffic (BTRE 2006b, p. 70).

Both rail and coastal shipping have freight rates that are at least 40 per cent lower than the applicable rates for road. Notwithstanding the substantially lower freight rates, road still has 25 per cent of the non-bulk market on the Eastern Capitals – Perth corridor. This fact suggests this portion of the market is insensitive to price and places far greater importance on service issues.[35] Transit time is an example of the type of service factor influencing shippers that chose to continue to transport freight by road. As Table 27 shows, on the Eastern Capitals – Perth corridor, road freight is generally twice as fast as sea freight. Given just-in-time logistics and the importance that some shippers place on timeliness, rail and coastal shipping are likely to be seen to be incompatible with the needs of many shippers.

Table 27 Main domestic freight corridors, transit times, hours

Freight corridor	**Distance (km)**	**Transit time (hrs)**		
		Road	**Rail**	**Sea**
Brisbane – Perth	4,400	70	93	132
Sydney – Perth	4,100	55	72	106
Melb – Perth	3,400	43	58	84
Adelaide – Perth	2,700	34	45	67
Melb – Brisbane	1,850	33	36	55
Sydney – Adelaide	1,550	20	27	50
Brisbane – Sydney	1,000	15	21	26
Sydney – Melb	930	11	13.5	29
Melb – Adelaide	740	9	13	26

Source: Meyrick and Associates *et al.* (2007)

The data on the intercapital non-bulk freight flows is consistent with the major points that emerge from the existing studies on the competitiveness of coastal shipping and

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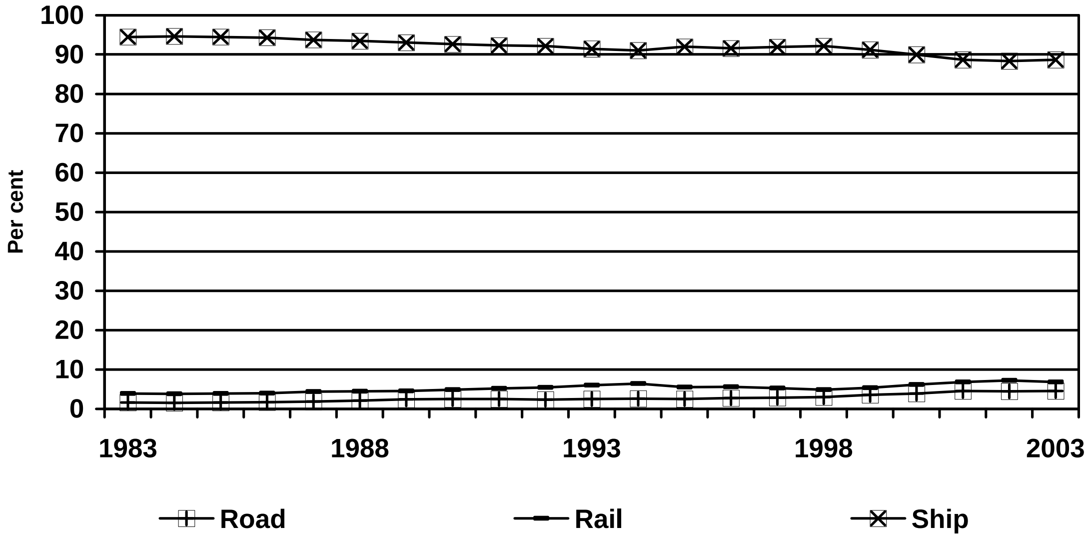
[35] The data on freight rates and market shares on the Eastern Capitals – Perth corridor are consistent with Maunsell Australia Pty Ltd's (2006, p. 32) assessment that 'even when rail freight is priced at 40% less than road freight … road freight sill wins approximately 30% of freight due to its superior service levels'.

extent of competition between the modes. In the non-bulk market, coastal shipping is most likely to compete on long-haul routes and service issues are an important contributing factor to its inability to draw market share away from road and rail.

Further insights into the competitiveness of coastal shipping can be gleaned from the BTRE (2006b) data on trends in the bulk and non-bulk markets. Figure 21 shows the trends in mode share of interstate bulk freight between 1983 and 2003. Over that time, road's share of the interstate bulk market rose from two to five per cent. Rail's market share experienced a similar trend, rising from four to seven per cent. The gains in road and rail have been at the expense of coastal shipping, which saw its share of the bulk interstate market fall from 95 to 89 per cent. These changes occurred against the backdrop of a market that grew at the relatively slow rate of 1.5 per cent per annum over this period.

Figure 21 Mode share trends in the interstate bulk freight market, 1983 to 2003

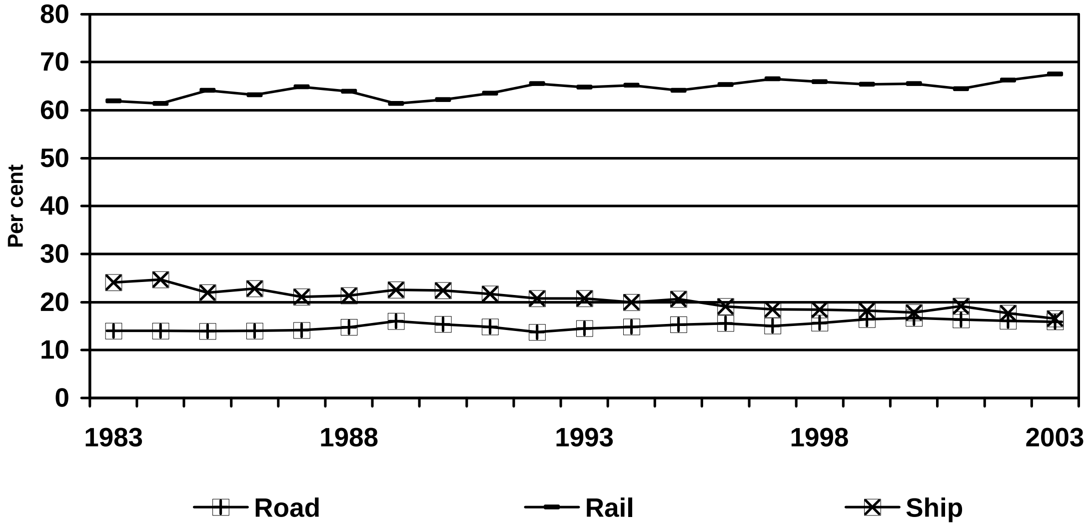


Source: BTRE (2006b)

Rail is the dominant mode in the non-urban intrastate bulk freight market and it has increased its dominance over recent years – see Figure 22. In 1983, rail held 62 per cent of the market. By 2003, this had reached 67 per cent. Road's share also grew, rising from 14 to 16 per cent. Shipping's share of the bulk non-urban intrastate market declined from 24 to 17 per cent.

The non-urban intrastate bulk freight market grew at 4.7 per cent per annum between 1983 and 2003, significantly faster than the interstate market. The differences in the growth rates reflect changes in the Australian economy; in particular, the decline in domestic manufacturing and increase in commodity exports.

Figure 22 Mode share trends in the non-urban intrastate bulk freight market, 1983 to 2003



Source: BTRE (2006b).

The gradual decline in coastal shipping's share of the non-urban bulk freight markets could give rise to the suggestion that shipping could increase its market share by reversing these trends, particularly where the freight flows are long-haul. Shipping already holds a significant proportion of these markets and by lowering price and improving service it could potentially increase its market share. This notion is arguably supported by the trends in the interstate market, where shipping lost 19 billion tonne-kilometres of its freight task and 3.5 per cent of its market share in the four years between 1998 and 2001. The sharp decline over this period is typical of the discontinuities associated with shipping. If more shipping services were made available, the downward trend in bulk sea freight could be quickly reversed, or so the argument goes.

While this is possible, the argument suffers from several weaknesses. Firstly, the rise in non-urban bulk road freight can partly be attributed to changes in the nature of the bulk freight task, whereby it is becoming more geographically dispersed (Productivity Commission 2006; BTRE 2006b). Road transport is best suited to service a more dispersed market because of the extensive road network and ability to access inland areas. Coastal shipping is unable to service the vast majority of this growing portion of the bulk freight market and it is one of the reasons why rail has been losing market share in many bulk commodity freight flows (the major exceptions being coal and other minerals) to road (BTRE 2006b).

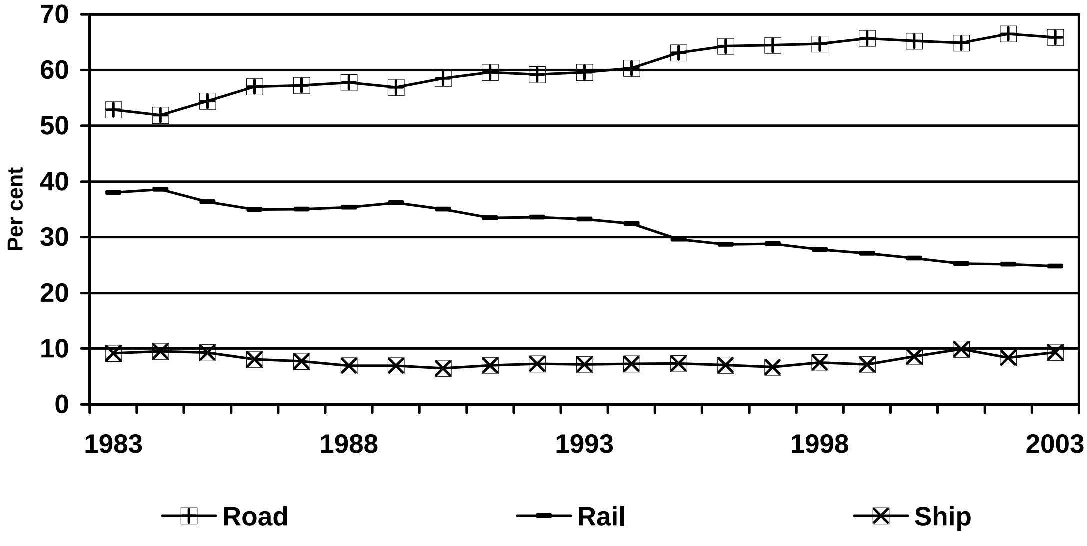
Secondly, the losses in interstate bulk sea freight in the late 1990s and early 2000s do not appear to have been transferred to the other modes. The reduction in sea freight led to an almost proportional reduction in total interstate bulk freight, offset slightly by the continuation of pre-existing growth trends in road and rail freight. It appears certain sea freight flows ceased rather than the flows being transferred to an alternative mode(s). These flows appear to have been primarily iron ore, petroleum products and crude oil movements (BTRE 2002a; 2006a). The reasons for the decline in these freight movements are unclear. The most likely cause is changes in the relevant commodity markets (for example, a reduction in domestic iron ore demand due to a fall in domestic steel manufacturing and a decline in the domestic petroleum industry). The restructuring of the domestic shipping industry that resulted in an increase in foreign vessels undertaking domestic freight tasks may also have played a part as it may have affected the accuracy of the data on sea freight movements.

A third flaw in the argument that shipping could recapture a large proportion of the non-urban bulk market is that bulk freight flows are often integrated with supply chains, making it unlikely there is open competition between the modes for these flows.

The preferred view is that the extent of competition between coastal shipping and the land transport modes in the non-urban bulk freight flows is limited. Coastal shipping's share of this market could change, but this is more likely to arise in response to changes in freight flows rather than an improvement or deterioration in shipping's competitive position relative to road and rail. In terms of the small proportion of the market that is contestable, coastal shipping faces threats from road and rail because of continual improvements in service quality triggered by investments in road and rail infrastructure.

Figure 23 shows the trends in mode share in the interstate non-bulk freight market between 1983 and 2003. This market grew at an average rate of 5.7 per cent per annum over this period, and road has been the major beneficiary of this growth. Its market share increased from 53 per cent in 1983 to 66 per cent in 2003. As Figure 19 shows, the rise in road's market share came at the expense of rail, which saw its market share decline from 38 to 25 per cent. Coastal shipping's share of the interstate non-bulk freight market fell from nine per cent in 1983 to six per cent in 1990, then recovered to reach nine per cent again in 2003. The return of coastal shipping in the 1990s was due to the increase in the use of single and continuous voyage permits, which enabled foreign operators to offer sea freight at low prices.

Figure 23 Mode share trends in the interstate non-bulk freight market, 1983 to 2003

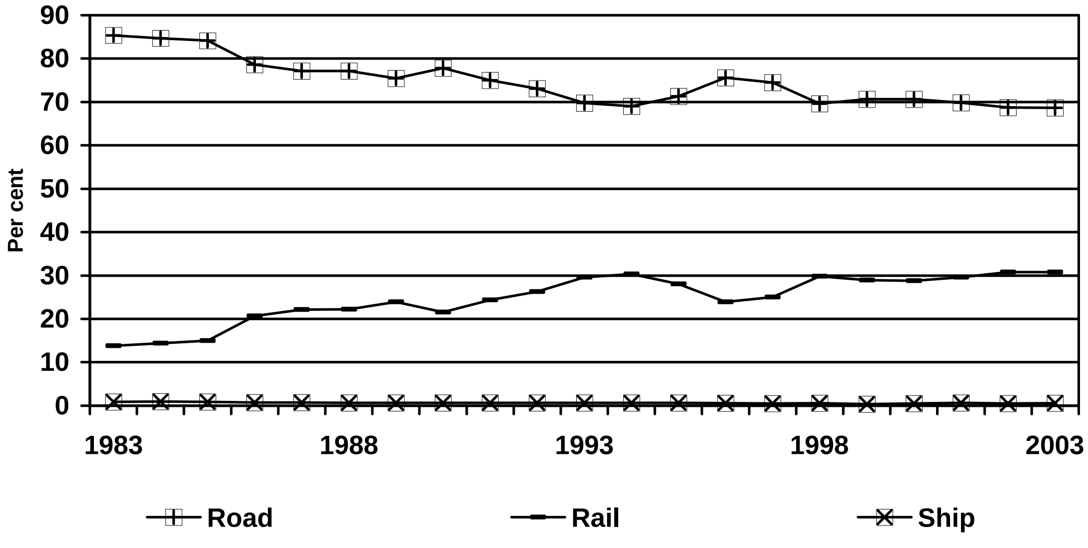


Source: BTRE (2006b).

The trends in the non-urban intrastate non-bulk freight market over the period 1983 – 2003 were significantly different to those in the interstate market – see Figure 24. Again, the market grew strongly, at an average rate of 4.8 per cent per annum. However, road lost market share to rail. Road's share of the non-urban intrastate non-bulk freight market fell from 85 to 69 per cent, while rail's share more than doubled, rising from 14 to 31 per cent. Coastal shipping's share of this market was negligible in 1983 (0.9 per cent) and it declined slightly over the period to reach 0.6 per cent in 2003.

The reasons for the declining market share of road in the non-urban intrastate non-bulk market are unclear. It is conceivable there are data errors that distort the trends. Alternatively, improvements in rail services between regional centres and capital cities may have allowed rail to capture market share. This assessment is consistent with the trends in the non-urban intrastate bulk market, where rail's task and market share increased between 1983 and 2003. Further, the average annual rate of growth in hire and reward rail in the non-urban intrastate bulk market was significantly higher than the rate of growth in ancillary rail in the same market over this period (5.7 per cent versus 4.7 per cent respectively), suggesting an improvement in intrastate public-access rail services. Yet, notwithstanding the twenty year trend, road still holds more than two-thirds of this market and this share was relatively stable over the period 1998 – 2003.

Figure 24 Mode share trends in the non-urban intrastate non-bulk freight market, 1983 to 2003



Source: BTRE (2006b).

The trends in the data on interstate and intrastate freight flows are consistent with the findings that emerge from the literature on the competitiveness of coastal shipping. The majority of the bulk market is not contestable between the modes. Coastal shipping dominates in the long-haul interstate bulk market and rail dominates in the shorter intrastate bulk freight market. The movement in both the intrastate and interstate bulk markets has been away from coastal shipping over the past twenty years, but the shift has been gradual and relatively small and appears to have been prompted by changes in the nature of the freight flows. In the non-bulk market, coastal shipping struggles to compete because of service issues and cost factors on shorter routes.

Conclusions on the competitiveness of coastal shipping

In a recent House of Representatives Standing Committee on Transport and Regional Services inquiry, the Australian Shipowners Association commented that:

> [i]n most instances, freight moved by sea is incapable of effectively being moved by road or rail. That is either because of the absence of infrastructure between remote locations, because the volume of freight is sufficient to render sea transport the only practical means available or because geographical barriers such as in the case of freight moved out of Tasmania for mainland markets or for transhipment to overseas markets (Australian Shipowners Association 2005, p. 2).

This assessment of the competitive position of coastal shipping matches the available evidence. Coastal shipping's capacity to compete with rail and road for additional market share under existing conditions is limited. Shipping's natural advantage lies in long-haul bulk freight. However, it already holds the majority of this market. In 2003, coastal shipping held almost 90 per cent of the interstate bulk freight market. The interstate bulk freight task performed by road and rail combined only amounted to approximately 9.8 billion tonne-kilometres. Given the cost advantages of coastal shipping for long-haul bulk freight movements, it is likely that the choice of road and rail for these freight flows is because coastal shipping is not suited to the task. In the intrastate bulk freight market, the nature of the freight flows renders much of the market incontestable by coastal shipping. It is conceivable coastal shipping could capture additional intrastate bulk freight, but only a small proportion of the market is contestable and there is strong competition from both rail and road. Any gains in this market are likely to be relatively small.

A number of recent studies have concluded that coastal shipping's greatest opportunities lie in the intercapital non-bulk markets, particularly the Eastern Capitals – Perth and Melbourne – Brisbane routes (Sinclair Knight Merz and Meyrick and Associates 2006; Meyrick and Associates *et al.* 2007). This conclusion is consistent with the evidence, although any increases in these markets are likely to be relatively small in comparison to shipping's existing task and the total domestic freight task.

The potential gains on the Melbourne – Brisbane route are likely to be minor. Despite increased use of single and continuous voyage permits, coastal shipping's share of the Melbourne – Brisbane non-bulk market in 2001 was less than two per cent and the total coastal shipping task on this route was only 90 million tonne-kilometres. The inability of coastal shipping to make inroads into the Melbourne – Brisbane non-bulk market over the past decade is likely to be due to improvements in the services offered by rail and road and the nature of non-bulk freight flows on this corridor. In particular, a significant proportion of this market is compromised of time-sensitive freight like food and live animals (Productivity Commission 2006). These characteristics will make it difficult for coastal shipping to make substantial gains in this market.

The Eastern Capitals – Perth corridor offers greater promise, but again the increases in coastal shipping's mode share and non-bulk freight task are likely to be relatively small. In 2001, the Eastern Capitals – Perth non-bulk market amounted to 12.71 billion tonne-kilometres (3.8 million tonnes), of which road held 3.18, rail 7.36 and coastal shipping 2.16 billion tonne-kilometres. Unlike some of the other intercapital non-bulk markets, the freight flows on the Eastern Capitals – Perth corridor are substantial. In 2001, they constituted almost nine per cent of the total domestic interstate freight market. However, it seems unlikely that coastal shipping will be able to dramatically increase its market share on this route under existing conditions.

As discussed, coastal shipping's share of the Eastern Capitals – Perth non-bulk market increased by 16 per cent between 1991 and 2001, all of which was gained at the expense of road. These gains were achieved via a 35 per cent reduction in real freight rates, which resulted in coastal shipping being 40 – 50 per cent cheaper than road on this route. The evidence suggests the remaining portion of the market held by road is likely to place considerably greater importance on service quality than price. Hence, future gains in coastal shipping's market share are more likely to come from rail than road. Yet, to date, rail has been able to respond to the increase competition from coastal shipping by lowering prices and improving service. Gaining market share on this route from rail is likely to prove difficult.

The BTRE (2006b) used data on the mode shares of the non-bulk market on the Eastern Capitals – Perth corridor over the period 1978 – 2001 to devise competitiveness indexes for road, rail and shipping. These historic indexes were then used in conjunction with projections on total non-bulk flows to estimate the freight task carried by each mode on this route over the period 2003 – 2020. Notwithstanding the fact that this method is unable to account for the prospect that a large portion of the market share held by road may be incontestable, the forecasts suggest coastal shipping's share of this market will increase from 17 to 21 per cent, a rise of only four per cent. The losses in market share are expected to be split relatively evenly between road and rail. This analysis by the BTRE (2006b) supports the contention that under existing conditions, any increases in coastal shipping's mode share and non-bulk freight task in the short to medium term are likely to be relatively minor, particularly in the context of mode shifting to reducing freight emissions.

Meyrick and Associates *et al.* (2007) provide further support for this conclusion. On the basis of the BTRE (2006c) analysis of non-bulk freight flows on the Eastern Capitals – Perth and Melbourne – Brisbane corridors, Meyrick and Associates *et al.* (2007) argue that the total potential contestable market between rail and coastal shipping, without taking into account cargo types, was approximately 2.4 million tonnes per annum in 1999. This was approximately five per cent of total sea freight at that time (BTRE 2006c). Using a simple choice model, and assuming certain improvements in the service offered by coastal shipping (100 per cent increase in availability, 25 per cent increase in reliability and 10 per cent reduction in transit times), the report concludes that coastal shipping could increase its freight task on these corridors by 25 per cent, or around 5,000 tonnes per annum on 1999 data from BTRE (2006c).[36]

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[36] Meyrick and Associates *et al.* (2007) state that the potential increase in coastal freight under optimal conditions on these long-haul routes is 4.9 million tonnes per annum. However, this appears to be a

The Meyrick and Associates *et al.* (2007) estimate is conservative. The report itself notes that the process followed is 'likely to understate the increase in mode share for coastal shipping' (Meyrick and Associates *et al.* 2007, p. 138) because of coastal shipping's small market share and the discontinuities associated with shipping. In addition, the estimates for 1999 from BTRE (2006c) that were relied on by Meyrick and Associates *et al.* (2007) are significantly lower than those in BTRE (2003a) and BTRE (2006b).[37] On the basis of the BTRE (2003a) and BTRE (2006b) data for 2001, which is the last year for which actual estimates are available, the proportional increases on the relevant routes suggested by Meyrick and Associates *et al.* (2007) would result in non-bulk sea freight increasing by approximately 157,000 tonnes on the Melbourne – Brisbane and Eastern Capitals – Perth routes (or roughly 476 million tonne-kilometres).[38] This would have equated to a 0.5 per cent increase in coastal shipping's total task and a six per cent increase in shipping's total non-bulk task in 2001 (BTRE 2006b). Hence, irrespective of which BTRE data are used, it appears the increases in sea freight on the Eastern Capitals – Perth and Melbourne – Brisbane corridors that arise from the Meyrick and Associates *et al.* (2007) simple choice model are likely to be small.

6.2 Impacts of a carbon price on the competitiveness of coastal shipping

The imposition of a moderate price on greenhouse gas emissions is unlikely to substantially change the competitive position of coastal shipping. This can be seen by looking at the impact of carbon prices on fuel prices.

The Federal Government and opposition are currently evaluating what set of policies to introduce to reduce greenhouse gas emissions. At this stage, it appears these policies are likely to result in a carbon price in the short- to medium-term that ranges between $5 and $20 per tonne of CO_2. With a carbon price of $20 per tonne/$CO_2$, the likely increase in the cost of automotive diesel oil per litre can be calculated as follows.[39]

Estimated CO_2 emissions per litre of automotive diesel oil = 2,664 grams

Carbon price = 0.002 cents per gram of CO_2

Increase in cost = 2,664 g x 0.002 = 5.3 cents per litre

The calculations for marine diesel oil are as follows.

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typographical error. The relevant units in BTRE (2006c), Table 2.16 are kilo-tonnes, but they seem to have been read as mega-tonnes.

[37] For discussion of the discrepancies in the data, see BTRE (2006c, pp. 174 – 175).

[38] The proportional increase for the Eastern Capitals – Perth corridor was calculated using an average mode change rate derived from the estimates for Adelaide – Perth and Melbourne – Perth in Table 48 in Meyrick and Associates *et al.* (2007, p. 137).

[39] Estimates of CO_2 emissions per litre of automotive and marine diesel oil were drawn from Apelbaum Consulting (2007a) and DEH (2006).

Estimated CO_2 emissions per litre of marine diesel oil = 2,740 grams

Carbon price = 0.002 cents per gram of CO_2

Increase in cost = 2,740 g x 0.002 = 5.5 cents per litre

As these calculations show, a $20 per tonne/$CO_2$ carbon tax is likely to increase the cost of automotive and marine diesel fuel by around five cents per litre. Assuming the increase in the cost of fuel is passed onto consumers in full, the carbon tax would lead to a four per cent increase in the price of automotive diesel oil and an eight per cent increase in the price of marine diesel oil (assuming prices of $1.33 and $0.70 per litre for automotive and marine diesel oil respectively).[40]

The impact of these relatively small changes in the price of fuel will depend on three main factors: the cost of fuel as a proportion of the total cost of road, rail and sea freight; the own-price and cross-price elasticities associated with road, rail and sea freight; and how freight operators respond to the changes in costs.

There is very little publicly available data on the cost of fuel as a proportion of the total costs of road, rail and coastal shipping operations in Australia. The most recent data on this issue are found in NIEIR (2007), which contains estimates of the cash and economic costs of non-bulk road, rail and sea freight on voyages of 450, 1,000 and 3,500 km. The estimates for road and rail freight were based on data from CRA International (2006), while the shipping data were drawn from a range of sources, including internal NIEIR analysis. Conveniently, NIEIR's estimates for road, rail and sea freight are broken down into cost components including fuel, enabling an evaluation to be made of the likely impact of the $20 per tonne/$CO_2$ carbon tax on the costs associated with the different modes.

Table 28 shows NIEIR's (2007) estimates of the fuel and total cash costs per tonne of non-bulk road, rail and coastal freight on the 1,000 and 3,500 km routes. To assess the likely impact of a $20 per tonne/$CO_2$ carbon tax, it is assumed there is no change in existing fuel taxes (and rebates) and that the tax is passed on in full to consumers. The assumptions adopted in NIEIR (2007) concerning fuel prices are retained. This results in the fuel costs of road rising by approximately 4.5 per cent and rail by 5.4 per cent for the two voyages. The impact of the carbon tax on the costs of coastal shipping will depend on the types of fuel used and time spent at sea and port. For simplicity, it is assumed that the carbon tax results in a six per cent increase in the fuel costs of sea freight. The results are shown in Table 28, below the NIEIR estimates.

The $20 per tonne/$CO_2$ carbon tax improves the relative cost position of coastal shipping. However, on a cash cost basis, it remains significantly more expensive than road and rail on the 1,000 km voyage. On the 3,500 km voyage, coastal shipping is cheaper both before and after the imposition of the carbon price, with the extent of the

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[40] The estimate of the automotive diesel oil price was drawn from Australian Institute of Petroleum (2007) after discussion with the Australasian Railway Association, pers. comms (21 August 2007). The estimate of the marine diesel oil price was obtained from the Australian Shipowners Association, pers comms. (21 August 2007).

difference being extended by the price on carbon. In both cases, the changes in total costs are relatively small. The cash costs of road increase by between 1.7 – 1.8 per cent, rail cash costs rise by between 0.6 and 1.0 per cent and sea freight costs rise by approximately 0.2 per cent.

Table 28 Effect of carbon price on price competitiveness of coastal shipping

		1,000 km voyage $/tonne			3,500 km voyage $/tonne		
		Road	**Rail**	**Sea**	**Road**	**Rail**	**Sea**
NIEIR (2007)	Fuel	21.38	8.24	2.05	80.49	10.90	3.66
	Total	54.06	43.90	68.85	208.84	98.00	92.63
With carbon price	Fuel	22.34	8.69	2.17	84.11	11.49	3.88
	Total	55.02	44.35	68.97	212.46	98.59	92.85

Source: NIEIR (2007) and The Australia Institute.

There is a possibility the NIEIR estimates are inaccurate. The area of greatest concern relates to the estimates of the intermodal costs (port charges and stevedoring costs) associated with coastal shipping. According to the data in NIEIR (2007), intermodal costs constitute 57 per cent of total sea freight cash costs per tonne for the 1,000 km voyage and 42 per cent for the 3,500 km voyage. The NIEIR estimates may overstate the intermodal costs and this could explain why the cash costs of sea freight are above road and rail on the 1,000 km voyage, while other evidence suggests sea freight prices on equivalent routes are below road and rail freight prices (Ernst and Young *et al.* 2006; Meyrick and Associations *et al.* 2007).[41] However, even if the intermodal costs have been overestimated, the effect on the analysis of the impacts of the carbon price will be marginal.

This can be demonstrated by looking at the estimated costs on the 1,000 km voyage. On the basis of the NIEIR estimates, the imposition of the $20 per tonne/$CO_2$ carbon tax results in a 1.57 per cent improvement in the cash cost of sea freight relative to the costs of road freight and a 0.83 per cent improvement in sea freight costs relative to rail costs. If intermodal costs are assumed to be 50 per cent lower than the NIEIR (2007) estimate, the carbon tax results in a 1.54 per cent improvement in sea freight costs relative to road freight costs and a 0.78 per cent improvement in sea freight costs relative to rail costs. The potential overestimation of intermodal costs by NIEIR (2007) has only a small effect on the relative position of the modes after the imposition of the carbon tax.

The imposition of a carbon price would not only increase fuel costs. Other relevant freight costs that would be affected by a carbon price include equipment capital and line-haul infrastructure costs. Increases in the cost of line-haul infrastructure capital and maintenance would further improve the competitive position of coastal shipping, assuming these costs are passed on to freight operators. However, with a small to moderate carbon price, the improvements are likely to be insubstantial and have little effect on the distribution of freight between the modes.

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[41] An alternative explanation could be that sea freight prices on these routes are based on marginal rather than average costs and that a significant amount of the freight is being carried by foreign vessels under single or continuous voyage permits.

Very little quantitative analysis has been undertaken on the elasticities of demand associated with sea freight. Based on a rail market evidence and BTRE data, Meyrick and Associates *et al.* (2007) estimated the own-price elasticity of demand for non-bulk sea freight at -0.23. Earlier research by the Bureau of Transport Economics (BTE) (1990) found the own-price elasticities for non-bulk sea freight on six major intercapital routes ranged between -0.13 to -1.68, with an aggregate of -0.83. No research was found during the literature review that contained quantitative analysis of the cross-price elasticities of sea freight relative to road and rail in Australia. In contrast, a number of papers were identified that contained information on the elasticities associated with road and rail. Details of some of these elasticity estimates are provided in Table 29.

Table 29 Elasticity estimates

	Own-price elasticity	**Cross-price elasticity**
Road		
Productivity Commission (2006)	-0.2 to -0.5	0.09 to 0.14
MM Starrs Pty Ltd (2005)		
Short haul	-0.5 to -0.7	4.03 to 7.54
Medium haul	-0.7 to -0.9	3.62 to 4.65
Long haul	-0.9 to -1.1	0.61 to 0.75
Kells (1997)	-0.77	
Rail		
Productivity Commission (2006)	-0.25	0.3
Meyrick and Associates (2006) – Victoria only	-0.7 to -0.9	
Ernst and Young *et al.* (2006) – North South corridor only	-1.2 to -2.5	
BTE (1999)		0.86
Kells (1997)		0.2 to 2.6

Sources: Productivity Commission (2006), Kells (1997), MM Starrs Pty Ltd (2005), Meyrick and Associates (2006) and BTE (1999).

Caution should be taken in interpreting Table 29 because the estimates are based on analysis of different freight markets and the data used to derive the estimates are of variable quality.

On the basis of the limited data that is available, it appears a carbon price in the order of \$20 per tonne/CO_2 is likely to have two main relevant impacts. Firstly, it could result in a reduction in the total size of the freight market. Secondly, sea freight may increase its share of certain markets, but any increase is likely to be small. Analysis conducted by the Productivity Commission (2006) on the impacts of increases in road charges indicates there is a good chance the overall impact of the carbon price will be to reduce sea freight relative to the business-as-usual situation because the losses that result from the contraction of the total market may be greater than the gains from mode switching.

To provide a rough guide as to the likely magnitude of the impacts associated with mode shifting prompted by a moderate carbon price, a simple partial equilibrium analysis was undertaken on the two freight markets where coastal shipping is most likely to compete; the non-bulk Eastern Capitals – Perth and Melbourne – Brisbane corridors. Three hypothetical scenarios using different cross-price elasticities were devised to gauge the possible impacts on these markets. The cross-price elasticity assumptions are set out below.

Scenario one

- Eastern Capitals – Perth route: assumes cross-price elasticities of demand for non-bulk sea freight with respect to the price of road and rail of 0.2 and 0.5 respectively, and a cross-price elasticity of rail with respect to road prices of 0.2.
- Melbourne – Brisbane route: assumes cross-price elasticities of demand for non-bulk sea freight with respect to the price of road and rail of 0.15 and 0.4 respectively, and a cross-price elasticity of rail with respect to road prices of 0.75.

Scenario two

- Eastern Capitals – Perth route: assumes cross-price elasticities of demand for non-bulk sea freight with respect to road and rail prices of 0.4 and 1.0, and a cross-price elasticity of rail with respect to road prices of 0.2.
- Melbourne – Brisbane route: assumes cross-price elasticities of demand for non-bulk sea freight with respect to the price of road and rail of 0.3 and 0.8, and a cross-price elasticity of rail with respect to road prices of 0.75.

Scenario three

- Eastern Capitals – Perth route: assumes cross-price elasticities of demand for non-bulk sea freight of 0.8 and 2.0 for road and rail, and a cross-price elasticity of rail with respect to road prices of 0.2.
- Melbourne – Brisbane route: assumes cross-price elasticities of demand for non-bulk sea freight with respect to the price of road and rail of 0.6 and 1.6, and a cross-price elasticity of rail with respect to road prices of 0.75.

The assumption of a cross-price elasticity of demand for sea freight with respect to the price of road of 0.2 in the first scenario on the Eastern Capitals – Perth route was based on rail market data for the Adelaide – Perth route drawn from Kells (1997). The same data provided the basis for the estimate of the cross-price elasticity of rail with respect to road prices of 0.2. The 0.5 estimate for the cross-price elasticity of demand for sea freight with respect to the price of rail is a best guess based on the data in Kells (1997) and MM Starrs Pty Ltd (2005) and the assumption that coastal shipping is more likely to compete with rail than road in this market.

The assumption of a cross-price elasticity of demand for sea freight with respect to the price of road of 0.15 in the first scenario on the Melbourne – Brisbane route is a best guess based on the characteristics of the market and the fact that coastal shipping has struggled to gain significant market share over the past decade. Kells (1997) did not evaluate cross-price elasticities on the Melbourne – Brisbane corridor and it was considered that the rail data for other north – south corridors did not provide insights into the competitive position of coastal shipping on this route. MM Starrs Pty Ltd (2005) estimated the cross-price elasticity of rail with respect to road prices for long-haul routes at between 0.61 and 0.75. While these data are useful, the difficulty shipping has had in increasing its market share despite falling sea freight rates suggests service factors rather than price are the major restricting factor on this route. The 0.4 estimate for the cross-price elasticity of demand for sea freight with respect to the price of rail is an optimistic best guess based on the assumption that coastal shipping is more likely to compete with rail than road in this market. The estimate of the cross-price elasticity of rail with respect to road prices of 0.75 was based on Kells' (1997) estimate on the Brisbane – Sydney corridor, which was considered most similar to the Melbourne – Brisbane route, and the data in MM Starrs Pty Ltd (2005) for long-haul routes.

The cross-price elasticities adopted under the second and third scenarios for non-bulk sea freight on both routes are multiples of the first scenario and were included to demonstrate that even under more favourable conditions, the gains for coastal shipping from mode shifting in response to a carbon price are likely to be small.

The nominal freight rates for the Eastern Capitals – Perth route were taken from BTRE (2006b). The nominal freight rates on the Melbourne – Brisbane route were derived from Meyrick and Associates *et al.* (2007). For road and rail on this route, the charge per tonne numbers in Table 40 in Meyrick and Associates *et al.* (2007) were divided by the average distance on the route (i.e. 1,850 km) to provide a cents per tonne-kilometre estimate. Based on the analysis in Ernst and Young (2006) and ratios between rail and sea freight prices on the Eastern Capitals – Perth corridor in BTRE (2006b), sea freight rates were assumed to be 25 per cent lower than rail freight rates on the Melbourne – Brisbane route.

There were insufficient data to accurately determine the impacts of the imposition of the \$20 per tonne/CO_2 carbon price on freight rates. To provide an approximation, the percentage increases in cash costs from Table 17 for the 1,000 km voyage were applied to the estimated price data for the Melbourne – Brisbane route, and the percentage increases in cash costs for the 3,500 km voyage were applied to the price data for the Eastern Capitals – Perth route. The relevant percentage increases in cash costs for the Eastern Capitals – Perth route were 1.7 per cent for road, 0.6 per cent for rail and 0.24 per cent for coastal shipping. For the Melbourne – Brisbane route, the increases were 1.8 per cent for road, 1.0 per cent for rail and 0.2 per cent for coastal shipping.

Using the above data and assumptions, an analysis was undertaken of the impact of the imposition of a \$20 per tonne/CO_2 carbon price on mode shares. No attempt was made to account for the overall reductions in demand that are likely to result from the imposition of the carbon price. The results of the analysis are presented in Tables 30 and 31.

Table 30 Impacts of a carbon price on non-bulk freight flows on Eastern Capitals – Perth route

	Road	Rail	Sea
Task (tonne-kilometres) 2001	3.18	7.36	2.16
Freight rate (cents per tonne-kilometre) 2001	5.66	2.75	2.08
Market share (per cent) 2001	25.02	57.91	16.99
Freight rate post carbon price (cents per tonne-kilometre)	5.76	2.77	2.08
Scenario 1 task (tonne-kilometres)	3.16	7.37	2.17
Scenario 1 market share	24.86	58.05	17.09
Scenario 2 task (tonne-kilometres)	3.15	7.37	2.18
Scenario 2 market share	24.81	58.02	17.17
Scenario 3 task (tonne-kilometres)	3.14	7.36	2.20
Scenario 3 market share	24.71	57.96	17.33

Sources: BTRE (2006b) and The Australia Institute.

As Table 30 shows, the changes in coastal shipping’s non-bulk freight task on the Eastern Capitals – Perth route under all three scenarios is small, ranging between 10 and 41 million tonne-kilometres. The changes in coastal shipping’s market share on this route range between 0.09 and 0.33 per cent. Rail’s market share and freight task experience very little change because the losses to shipping are offset by gains from road transport.

Table 31 Impacts of a carbon price on non-bulk freight flows on Melbourne – Brisbane route

	Road	Rail	Sea
Task (tonne-kilometres) 2001	3.54	1.79	0.09
Freight rate (cents per tonne-kilometre) 2001	4.54	4.49	3.37
Market share (per cent) 2001	65.31	33.03	1.66
Freight rate post carbon price (cents per tonne-kilometre)	4.62	4.53	3.38
Scenario 1 task (tonne-kilometres)	3.53	1.80	0.09
Scenario 1 market share	65.11	33.22	1.67
Scenario 2 task (tonne-kilometres)	3.53	1.80	0.09
Scenario 2 market share	65.11	33.21	1.68
Scenario 3 task (tonne-kilometres)	3.53	1.80	0.09
Scenario 3 market share	65.10	33.20	1.70

Sources: BTRE (2006b) and The Australia Institute.

The situation on the Melbourne – Brisbane route is similar, only the changes are even smaller – see Table 31. There is virtually no change in the non-bulk freight tasks performed by the modes and the market share is only slightly altered, with coastal shipping’s share rising from 1.66 per cent to between 1.67 and 1.70 per cent. The changes in shipping’s freight task range from 0.5 to 2.0 million tonne-kilometres.

Caution should be taken in interpreting these results. The assumptions underlying these scenarios are based on best guesses only and there are significant deficiencies in the available data. Further, no attempt was made to analyse the likely impacts of the carbon price on overall demand. As discussed, there is a strong possibility a carbon price would reduce the overall size of these markets relative to the business-as-usual situation. Notwithstanding the transfer of freight to coastal shipping triggered by the carbon price, the reduction in the size of the market could lead to a contraction rather than an expansion of coastal shipping's freight task. It could also result in coastal shipping's market share being larger than predicted here if there are significant reductions in road and rail freight.

Noting the caveats, the analysis suggests a \$20 per tonne/CO_2 carbon price would have a minor impact on the intercapital non-bulk markets. The price increases triggered by the carbon price are likely to be too small to drastically alter mode choice decisions.

The above discussion on the impact of a carbon price has centred on non-bulk freight flows. In terms of bulk freight, the likely impacts are unclear. There is insufficient data on bulk freight flows, prices and elasticities to make precise conclusions on this issue. However, the evidence that is available indicates that a moderate carbon price will not dramatically increase fuel costs and much of the bulk freight market is not contestable. On this basis, it seems that a moderate carbon price in the order of \$20 per tonne/CO_2 will not lead to a substantial increase in shipping's share of the bulk freight market. As in the case of the non-bulk market, the carbon price would probably reduce the overall size of the bulk market relative to business-as-usual. The net effect could be a reduction in the bulk freight task undertaken by coastal shipping.

The nature of the relevant freight markets suggests that a moderate carbon price is unlikely to significantly alter the competitive position of the major transport modes. A carbon price would have to increase fuel costs by a substantial margin to trigger extensive changes in the domestic freight market. In their assessment of the freight market, Sinclair Knight Merz and Meyrick and Associates (2006, p. 21) reached a similar conclusion, arguing that:

> [f]uel price changes would need to be measured in orders of magnitude (i.e. at least ten fold) to stimulate fundamental changes in the way goods are produced, raw materials sourced and finished goods are distributed.

In the longer-term (i.e. 2020 and beyond), large increases in fuel prices due to greenhouse policies or supply constraints may trigger a restructuring of the freight market and associated supply chains and manufacturing processes. However, the timeframe over which this is likely to occur and the number of variables involved makes it extremely difficult to predict the impact on coastal shipping. Technological advances could negate the impact of rising fuel prices, leaving supply chains and the freight markets relatively unchanged. Alternatively, the rising fuel prices could encourage a shift away from 'just-in-time' logistics towards warehousing, potentially benefiting shipping. There could also be a shift toward the regionalisation of economies, which could decrease dependence on long-haul freight. There are numerous possible outcomes and analysing the ramifications of these long-term impacts is beyond the scope of this study.

7. Implications for mode shifting

Coastal shipping's share of the domestic freight market reflects its competitive position. Under current conditions, coastal shipping is unable to compete effectively with land transport in most markets. Its share of the bulk cargoes arises because the relevant freight is effectively incapable of being moved by land transport. The area where it competes directly with land transport is confined primarily to non-bulk freight on long-haul routes. Coastal shipping may also compete for some residual long-haul bulk freight flows, although it already dominates this market and the capacity to increase shipping's market share on these routes via a carbon tax is limited.

The implication of these findings for the mode shifting strategy is that it seems unlikely it could result in a substantial reduction in greenhouse gas emissions from the domestic transport sector. The markets in which coastal shipping is competitive appear too small for the strategy to serve as an effective means of bringing about large reductions in emissions. Even if the Federal Government imposes a moderate price on greenhouse gas emissions via a carbon tax or emissions trading scheme, coastal shipping is unlikely to increase its share of the market by enough to see a large fall in freight transport emissions. Non-price factors mean that coastal shipping is not a viable substitute in most freight markets. Further, the differences in the emissions intensity of rail and shipping are unlikely to be large enough to make the relatively small potential shifts in freight produce substantial reductions in emissions. This is evident from the analysis in Section 5.1, which found that the 11 per cent increase in shipping's share of the non-urban freight task in 2005 under the WI2 scenario resulted in only a two per cent saving in transport emissions and five per cent saving in freight emissions.

This assessment is consistent with the BTRE's findings on the prospects of cutting transport emissions by encouraging mode shifting from road to rail (BTCE 1996; BTRE 2002b). The BTRE (2002b, pp. 58 – 59) argues:

> [o]pportunities to capture significant greenhouse gas emission reductions from shifting freight from road to rail are often quite limited because, generally, only a small proportion of total freight carried by road is contestable. This contestable area is long-distance non-bulk and residual bulk traffic. In addition, the degree of potential emission reductions that would result from any such switch are modest, because long-distance road freight movements are relatively fuel efficient compared to average road freight movements.

In its 1996 analysis, the BTRE (then called the Bureau of Transport and Communications Economics (BTCE)) concluded that if the four major rail corridors were upgraded the maximum emissions savings from shifting freight from road to rail would only amount to 0.5 per cent of total road freight emissions (BTCE 1996).[42] The BTRE's conclusions on rail shifting align well with the analysis on the environmental effectiveness of shifting freight to coastal shipping, only the emission savings in the sea shifting case are likely to be smaller because shipping competes in fewer markets

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[42] The four major rail corridors are Sydney – Melbourne, Sydney – Brisbane, Melbourne – Adelaide and Adelaide – Perth.

than rail and long-haul rail (shipping’s main competitor) is more efficient than long-haul road freight.

To further test the notion that mode shifting from land transport to coastal shipping is unlikely to produce significant emission savings, hypothetical emission scenarios for 2001 were developed for each of the non-bulk Eastern Capitals – Perth and Melbourne – Brisbane corridors, as well as the interstate and non-urban intrastate bulk freight markets. The Eastern Capitals – Perth and Melbourne – Brisbane non-bulk corridors are the markets in which coastal shipping has the greatest capacity to increase its market share. The interstate and non-urban intrastate bulk freight markets were included because they are markets in which coastal shipping is a major participant. As discussed, coastal shipping has also lost market share to road and rail in both of these markets over the past two decades and the imposition of a carbon price could help coastal shipping regain a small portion of the lost ground.

For the Eastern Capitals – Perth and Melbourne – Brisbane non-bulk markets, a base case and two hypothetical emission scenarios were modelled on the basis of the following assumptions.

For the base case scenario:

- the freight task and market shares for road, rail and shipping in the relevant markets were taken from BTRE (2006b);
- all rail freight was carried by hire and reward rail;
- based on the division of total non-urban road freight for 2001 from Apelbaum Consulting (2007a), adjusted to account for the long-haul nature of the routes, 95 per cent of road freight was assumed to be carried by articulated trucks and five per cent by rigid trucks; and
- the average non-urban emission intensities for the modes for 2001 from Apelbaum Consulting (2007a; 2007b) were adopted.

For the first hypothetical scenario:

- shipping increases its market share by two per cent;
- 80 per cent of the increase shipping’s market share comes from hire and reward rail,[43] 20 per cent from road, and the losses to road are distributed between articulated and rigid trucks according to their market shares in the base case (i.e. 95 per cent from articulated trucks, five per cent from rigid trucks); and
- the remaining assumptions from the base case scenario are applied.

For the second hypothetical scenario:

- Coastal shipping increases its market share by five per cent;

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[43] Ancillary rail does not carry non-bulk freight, nor does it operate on interstate routes.

- 60 per cent of the increase in shipping's market share comes from hire and reward rail, 40 per cent from road, and the losses to road are distributed between articulated and rigid trucks according to their market shares in the base case; and

- the remaining assumptions from the base case scenario are applied.

The analysis in Section 6 suggests a \$20 per tonne/CO_2 carbon price would result in coastal shipping increasing its market share by less than one per cent in both the Eastern Capitals – Perth and Melbourne – Brisbane non-bulk markets, even under favourable conditions. Hence the increases in market share assumed in the hypothetical scenarios are both optimistic. No attempt has been made to adjust the market size to account for the impacts of a carbon price on overall demand. This is likely to result in the overestimation of the emissions savings associated with mode shifting triggered by a carbon price. In addition, no adjustments have been made to account for the fact that a carbon price is likely to result in mode shifting from road to rail.

The assumption in scenario one that 80 per cent of the increase in shipping's market share comes from rail was made on the basis of the evidence regarding the nature of the non-bulk markets. The assumption that 40 per cent of the increase in shipping's market share would come from road under scenario two is very optimistic. It is unlikely that such a large shift from road to ship could be triggered by a moderate carbon price. However, this assumption was adopted to demonstrate that even if this is assumed, the emission savings that result are still relatively small.

The results of the analysis for the Eastern Capitals – Perth and Melbourne – Brisbane non-bulk markets are presented in Tables 32 and 33 respectively.

Table 32 Impact of sea shift in Eastern Capitals – Perth non-bulk market, 2001

	Base case	Scenario one	Scenario two
Freight task 2001 (billion tonne-kilometres)	12.7	12.7	12.7
Shipping's market share (per cent)	17.0	19.0	22.0
Emissions (Gg)	450.8	444.8	429.1
Emission saving (Gg)	–	6.0	21.6
Emission saving (per cent)	–	1.3	4.8

Sources: BTRE (2006b) and The Australia Institute.

The emission savings from the transfer of freight from road and rail on the Eastern Capitals – Perth corridor under both scenarios are relatively small. Under the first scenario, the two per cent increase in shipping's market share results in a 1.3 per cent emission reduction. The saving is approximately 6,000 tonnes CO_2-e, the equivalent of 0.04 per cent of emissions from the non-urban freight market (excluding pipelines and aviation) in 2001. The savings under the second hypothetical scenario are larger; 21,600 tonnes CO_2-e or five per cent lower than the base case. However, this still only amounts to 0.13 per cent of total non-urban freight emissions (excluding pipelines and aviation) in 2001.

Table 33 Impact of sea shift in Melbourne – Brisbane non-bulk market, 2001

	Base case	Scenario one	Scenario two
Freight task 2001 (billion tonne-kilometres)	5.4	5.4	5.4
Shipping's market share (per cent)	1.7	3.7	6.7
Emissions (Gg)	317.8	315.3	308.6
Emission saving (Gg)	–	2.6	9.2
Emission saving (per cent)	–	0.8	2.9

Sources: BTRE (2006b) and The Australia Institute.

Reflecting the size of the market and shipping's smaller market share, the emission savings under both scenarios on the Melbourne – Brisbane corridor are even smaller than those on the Eastern Capitals – Perth corridor. The first scenario results in a 0.8 per cent reduction in emissions (or 2,600 tonnes of CO_2-e). This is the equivalent of 0.02 per cent of total non-urban freight emissions (excluding pipelines and aviation) in 2001. Under the second scenario, there is a 2.9 per cent reduction in emissions, the equivalent of 9,200 tonnes of CO_2-e.

A base case and two hypothetical emission scenarios were modelled for the interstate and non-urban intrastate bulk markets on the basis of the following assumptions.

For the base case scenario:

- the freight task and market shares for road, rail and shipping in the relevant markets were taken from BTRE (2006b);
- drawing on the division of total non-urban road freight for 2001 from Apelbaum Consulting (2007a), 95 per cent of road freight was assumed to be carried by articulated trucks and five per cent by rigid trucks; and
- the average non-urban emission intensities for the modes for 2001 from Apelbaum Consulting (2007a; 2007b) were adopted.

For the first hypothetical scenario:

- shipping increases its market share by two per cent for the interstate market and one per cent for the non-urban intrastate market;
- 95 per cent of the increase in shipping's market share comes from hire and reward rail,[44] five per cent from road, and the losses to road are distributed between articulated and rigid trucks according to their market shares in the base case (i.e. 95 per cent from articulated trucks, five per cent from rigid trucks); and
- the remaining assumptions from the base case scenario are applied.

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[44] No market share was assumed to be lost by ancillary rail because it is the least emission intensive of the modes. Most ancillary rail freight is also likely to be incontestable.

For the second hypothetical scenario:

- Coastal shipping increases its market share by four per cent for the interstate market and two per cent for the non-urban intrastate market;
- 90 per cent of the increase in shipping's market share comes from hire and reward rail, 10 per cent from road, and the losses to road are distributed between articulated and rigid trucks according to their market shares in the base case; and
- the remaining assumptions from the base case scenario are applied.

As in the case of the non-bulk scenarios, the assumptions adopted under both bulk hypothetical scenarios are optimistic (some may argue unachievable without direct government intervention beyond a carbon price). Further, no attempt has been made to adjust the market size to account for the impacts of a carbon price on overall demand, nor have adjustments been made to account for the potential for mode shifting from road to rail.[45]

The results for the interstate and non-urban intrastate bulk markets are presented in Tables 34 and 35 respectively.

Table 34 Impact of sea shift in interstate bulk market, 2001

	Base case	Scenario one	Scenario two
Freight task 2001 (billion tonne-kilometres)	75.0	75.0	75.0
Shipping's market share (per cent)	88.7	90.7	92.7
Emissions (Gg)	1,152.9	1,129.5	1,098.1
Emission saving (Gg)	–	23.5	54.8
Emission saving (per cent)	–	2.0	4.8

Sources: BTRE (2006b) and The Australia Institute.

The hypothetical scenarios result in emission savings of between two and five per cent (24 to 55 Gg CO_2-e) in the interstate bulk market. This equates to between 0.14 and 0.33 per cent of total non-urban freight emissions (excluding pipelines and aviation) in 2001.

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[45] Theoretically, the imposition of a carbon price could even prompt a transfer of some freight from shipping to ancillary rail due to ancillary rail's superior emission performance. However, the nature of the freight tasks performed by the modes makes this unlikely.

Table 35 Impact of sea shift in non-urban intrastate bulk market, 2001

	Base case	Scenario one	Scenario two
Freight task 2001 (billion tonne-kilometres)	161.2	161.2	161.2
Shipping’s market share (per cent)	19.2	20.2	21.2
Emissions (Gg)	4,058.6	4,033.3	3,999.6
Emission saving (Gg)	–	25.3	59.0
Emission saving (per cent)	–	0.6	1.5

Sources: BTRE (2006b) and The Australia Institute.

In the non-urban intrastate market, the hypothetical scenarios result in emission savings of between 0.6 and 1.5 per cent (25 to 59 Gg CO_2-e). This equates to between 0.15 and 0.35 per cent of total non-urban freight emissions (excluding pipelines and aviation) in 2001.

The hypothetical scenarios for both the bulk and non-bulk markets show that even when optimistic assumptions about the potential for mode shifting are adopted, the emission savings are small. The combined saving under the most optimistic scenarios for the four markets is 145 Gg CO_2-e. The mode shifts to achieve this type of emission saving do not appear likely in the short- to medium-term. Yet even if they were achieved, the result would only be a reduction in total non-urban freight emissions (excluding pipelines and aviation) of around 0.9 per cent.

Despite coastal shipping’s greenhouse credentials, the evidence suggests it cannot compete for a large enough portion of the domestic freight market to make mode shifting a viable option as a means of cutting freight emissions. Further, its major rivals in the markets where it does compete are relatively energy efficient, meaning the transfer of market share to shipping is unlikely to result in substantial emission cuts. As a greenhouse policy option, encouraging mode shifting to coastal shipping does not offer great promise. There are likely to be more effective and efficient options.

8. Conclusion

Climate change poses a serious threat to the prosperity and wellbeing of current and future generations. It also puts at risk the health of the natural environment and, if left unaddressed, it could cause an extinction event the likes of which has not been witnessed since the evolution of humanity.

Persistent delay in initiating policy responses to climate change has already eliminated the opportunity of keeping the atmospheric concentration of greenhouse gases at levels the science suggests is safe. The weight of evidence indicates there is very little chance of avoiding certain key thresholds for dangerous climate change. Urgent efforts to abate anthropogenic greenhouse gas emissions are needed, as well as measures to ensure humans and the natural environment are given the best chances of adapting to what is now inevitable climate change.

To meet the challenges posed by global warming, emissions must be cut from all sectors of the economy over a relatively short time span. The transport sector is responsible for approximately one fifth of Australia’s greenhouse gas emissions and transport emissions are increasing rapidly in response to economic growth. Cutting emissions from the transport sector will be critical to meeting future emission reduction targets. In order to achieve significant cuts in transport emissions, it will be necessary to prompt reform in domestic freight markets.

Freight emissions make up nearly 40 per cent of total domestic transport emissions. Over 80 per cent of freight emissions are from road transport. Yet road freight accounts for only 38 per cent of the domestic freight task by tonne-kilometres. In contrast, coastal shipping carries 22 per cent of the freight task but is responsible for only four per cent of freight emissions. This is attributable to the fact that shipping is the most energy efficient and least emission intensive of the three major freight transport modes. When the modes are broken into subgroups, only ancillary rail has lower emission intensity. The emission intensity of coastal shipping is approximately 40 per cent lower than hire and reward rail and 80 per cent lower than the closest road mode, articulated trucks. The superior greenhouse performance of coastal shipping is achieved with an aging and outdated fleet. With fleet renewal and a more vibrant shipping industry, the greenhouse performance could be considerably better, potentially rivalling ancillary rail.

The greenhouse credentials of shipping have led many to propose mode shifting from road and rail as a means of cutting freight emissions. The notion of shifting freight to shipping to address greenhouse concerns is alluringly simple. However, the trends in the domestic freight market over the past two to three decades have been away from shipping toward the land modes. These patterns have been a product of government policy and changing supply chains and freight flows, with the market increasingly shifting toward time-sensitive and urban and other inland freight.

To gauge what a mode shifting strategy could achieve, the market share patterns in non-urban freight between 1991 and 2005 were reversed. Had the market shares of articulated trucks, hire and reward rail and shipping remained at their 1991 levels over this period, the cumulative emissions from non-urban freight would have been four per cent lower. In 2005, the reversal of the mode share trends would have seen coastal shipping gain an additional 11 per cent of the non-urban freight market, yet the emission savings would have been modest; a two per cent saving in transport emissions and five per cent saving in freight emissions.

While modest, this saving is likely to prove difficult to achieve in reality. Coastal shipping does not compete with road and rail in a large enough portion of the domestic freight market to make mode shifting a viable option as a means of cutting freight emissions. Further, its major rivals in the markets where it does compete are relatively energy efficient, meaning any market share shipping is able to capture is unlikely to result in substantial abatement.

The addition of a modest carbon price of around \$20 per tonne/CO_2 is unlikely to lead to substantial changes in coastal shipping's competitiveness. By and large, coastal shipping works in tandem with the land transport modes rather than competing with them for market share. In the small pockets where shipping does compete with the land modes, shipping is struggling to maintain market share due to the superior service characteristics of road and rail. Any increases in fuel costs triggered by a carbon price would have to be very large before it triggered a substantial change in the domestic freight market. Even then, the majority of the freight task would remain in the hands of the land modes because of the nature of the freight flows.

Optimistic mode shifting scenarios were modelled in the markets where coastal shipping is most likely to compete: the Eastern Capitals – Perth and Melbourne – Brisbane non-bulk markets. Favourable scenarios were also modelled for the interstate and non-urban intrastate bulk markets. Many of these scenarios are likely to be unachievable under market conditions. Yet even the most favourable scenarios result in modest emission savings. The combined saving in 2001 under the most optimistic scenarios for the four markets that were modelled was 145 Gg CO_2-e, which amounted to a reduction in total non-urban freight emissions (excluding pipelines and aviation) of around 0.9 per cent.

Actively pursuing mode shifting from land modes to coastal shipping as a means of reducing emissions is unlikely to be an effective or efficient greenhouse strategy. However, should mode shifting be pursued for other reasons, an additional benefit would be an improvement in the greenhouse performance of the domestic freight sector.

Appendix A Literature review - competitiveness of coastal shipping

Author	**Comment**
House of Representatives Standing Committee on Transport and Regional Services (2007)	House of Representatives Standing Committee report on freight transport policy and the best means to meet the challenges presented by the growing domestic freight task. The Committee noted that road and rail are the dominant modes, but acknowledged that coastal shipping 'has an important part to play' (p. 228). It states that: [c]oastal shipping particularly has a role to play in transporting freight between the Eastern States and Western Australia (p. 230). In a submission to the Committee, the Victorian Freight and Logistics Council argued that during peak times it was difficult to get rail slots from Adelaide and Perth, and that these bottlenecks had improved the attractiveness of shipping on east-west routes. The Committee states: [c]oastal shipping's potential lies in transporting less time critical freight. It represents an environmentally beneficial and cost effective alternative to rail and road modes, for bulk cargo shipped over long distances (p. 236). Yet it concludes: [o]verall, sea transport is not in a position to compete with road and rail. However, there is considerable potential for sea freight services to complement land transport networks (p. 237).
National Institute of Economic and Industry Research (NIEIR) (2007)	Report for the Maritime Union of Australia on the competitiveness of coastal shipping and its future. An analysis is provided of the cash and economic cost of road, rail and shipping on non-bulk freight routes of 450, 1,000 and 3,500 km. The author argues the cash costs of shipping are only lower than road and rail on the 3,500 km route. The economic costs of shipping are estimated to be lower than road and rail on all routes except the 450 km corridor. The author argues: … shipping and land transport are in competition over a fairly limited range of origin-destination flows … , principally long-distance transport in containers but also including long-distance transport of industrial inputs (such as fuels) and outputs (such as steel) (p. 51). The report argues that high intermodal costs (i.e. port and stevedoring costs) for coastal shipping and infrastructure access pricing practices for land transport are major reasons for the difficulties shipping faces in competing with road and rail.
Meyrick and Associates *et al.* (2007)	Report on international and domestic shipping for the Australian Maritime Group. It includes an assessment of the capacity to increase coastal shipping's share of the domestic freight task. The authors contend that: [l]ong-haul inter-capital non-bulk flows are the most contestable across the three modes (road, rail and sea) (p. 108). Later, the report states: [c]oastal shipping is most competitive on the longer distance inter-capital routes between the east cost capitals and Perth and between Melbourne and Brisbane. Within these corridors coastal shipping competes most strongly with rail (p. 133). On the shorter intercapital routes, coastal shipping is viewed as uncompetitive because of the extent of competition between road

	operators and superior service offered by road freight. Although the authors argue the non-bulk east-west and north-south freight routes are the most contestable for coastal shipping, they contend that: … there exists the opportunity for an innovative operator (entrepreneur) to create a market by combining domestic containerised flows (using domestic-sized equipment) with bulk and/or breakbulk cargoes using “combi/multi-purpose” vessels (p. 138). The authors emphasise the importance of both price and service factors in shipper’s mode choice decisions, arguing that many shippers are willing to pay a premium for superior transit time, availability and reliability. The trend toward service quality over price is viewed as a disadvantage to coastal shipping.
Productivity Commission (2006)	Report on the economic costs of freight infrastructure and efficient approaches to transport pricing. The object of the inquiry was to determine whether the current infrastructure access pricing arrangements are appropriate or whether they are leading to the subsidisation of road freight. The Commission found that due to the different service characteristics, only a small proportion of the freight market is contestable between road and rail (estimates range between 10 and 15 per cent). For many freight tasks, road and rail are more complements than substitutes. The report argues that road is flexible and well suited to time-sensitive freight, which has enabled it to capture the majority of the fast growth non-bulk market. Rail is seen as being best suited to bulk freight with regular, large volumes. Both rail and road have increased their market shares over the past 20 years at the expense of coastal shipping. The Commission found that the evidence does not support the contention that road is subsidised relative to rail on the intercapital corridors or in regional areas. Significant subsidies were found for both road and rail freight in regional areas, as well as on the use of rail infrastructure on the major corridors. As a result of the small amount of the market that is contestable between the modes, the Commission found that increasing road charges by over 40 per cent for articulated trucks and almost 30 per cent for non-articulated trucks would lead to only small changes in mode shares held by road and rail (e.g. 0.2 per cent decrease for articulated trucks) and that while rail’s share would increase, rail output would decline due to the contraction in the market caused by the higher prices. The Commission noted that ‘[i]nter-capital non-bulk freight carried by articulated trucks and public access rail is seen as the largest area of road-rail contestability’ (p. 26). It also contends that the mode shares of road and rail on the inter-capital routes partially reflect the types of freight on the routes. For example, on the Melbourne – Brisbane corridor, a third of the road freight is food and live animals, ‘whereas denser, usually containerised non-bulk freight is the most contestable between road and rail’ (p. 27). On the Eastern Capitals – Perth corridor, fewer time sensitive commodities are transported. The report evaluates price elasticities of domestic freight demand using the vector error correction model (VECM). It estimated the own-price elasticity of road at -0.25 and road at -0.2 to -0.5. The cross-price elasticity of rail freight with respect to the price of road freight was estimated at 0.286, suggesting the two modes are weak substitutes in this

	market. Significant cross-price elasticities were also found for non-urban and articulated trucks with respect to the price of rail freight (0.139 and 0.118 respectively). The Commission provides an overall estimate of the cross-price elasticity of road freight to the price of rail freight of between 0.09 and 0.14. The report states: [t]he low estimates of cross-price elasticities support the contention that only a small percentage of the aggregate freight task is contestable between road and rail (p. F.23). The Commission also presents evidence suggesting non-price factors play a significant role in mode choice.
Sinclair Knight Merz and Meyrick and Associates (2006)	Report for the National Transport Commission on policy responses to forecasts that the domestic land freight task will double between 2000 and 2020. The authors argue that: [t]here are opportunities for modal shift, particularly on longer corridors, with moves to rail for Melbourne – Brisbane and coastal shipping for eastern states to Perth. However, the forecasts conclude that road will carry the majority of increase on shorter inter- and intra-state corridors (p. 2). Later in the report, after reviewing international evidence, the authors contend that: … while programs to shift freight to rail may have some potential, they are largely a response to the idea that ‘rail is good, trucks are bad’; the benefits of any mode shifts will be marginal, except in particular local situations (p. 102).
Ernst and Young *et al.* (2006)	Report for the Commonwealth Department of Transport and Regional Services on the Melbourne – Sydney – Brisbane rail freight corridor and its future. The report includes an assessment of the freight market on this corridor, projections of future freight and an evaluation of alternative routes for the rail corridor. The report notes that rail’s market share in the corridor has been declining ‘because of improving road and truck design, congestion on the tracks, and the competitive time and cost of local PUD [pick-up and delivery]’ (p. 41). It also argues that rail’s share of the Melbourne – Brisbane route is higher than in the other markets because rail pick-up and delivery costs are reduced on a per unit basis on long haul journeys. The authors state: … the Melbourne to Brisbane route offers the greatest potential for competing with road and increasing the movement of freight by rail. At 1,954 km (the existing Coastal Corridor), it is of sufficient distance to enable rail to be performance and price competitive with road, since PUD costs are a smaller proportion of the total cost. By the same token, rail cannot be as competitive on the Melbourne to Sydney and Sydney to Brisbane routes as PUD charges form a much higher proportion of the door-to-door costs (p. 41). It is argued that rail is only a weak competitor with road for between 65 and 75 per cent of the manufactured freight market because of lower service quality. On the basis of surveys of customers, the authors contend that the most important factors in mode choice are price followed by reliability. Availability and transit time are also viewed as important. The ability of rail to compete is hindered by congestion in the Sydney metro network. With substantial improvements in rail infrastructure on the corridor (including re-routing the corridor inland), it is envisaged that rail could increase its market share in the Melbourne – Brisbane route to between 63 and 73 per cent. However, the report contains qualifications

	about the costs associated with the potential upgrades and the capacity to recover costs on the investment. The report also includes estimates of short-run own-price elasticities for rail that range between -1.2 and -2.5. Estimates were also provided for non-price factors: between -0.4 to -2.3 for transit time; 0.01 to 0.12 for reliability; 0.16 to 0.24 for availability; and 0.7 to 0.8 for monthly capacity.
BTRE (2006b)	Analysis by the BTRE of the domestic freight market. It includes estimates of historic freight flows and projections of trends in relevant markets to 2020. The report states that: The main area of competition between modes is in the interstate carriage of non-bulk freight. Road has been steadily gaining market share from rail on these routes … . There are possibilities for rail and sea to gain mode share on the interstate, especially intercapital, routes. However, the intercapital road freight task accounts for only about 15 per cent of the total road task. So in terms of the road freight industry in its entirety, the possibilities for substituting rail for road are clearly limited (p. 158). In the analysis of the trends in intercapital non-bulk freight markets, the report's authors argue that the major opportunities for intercapital rail lie on the longer east-west and Melbourne – Brisbane corridors, where the fixed costs associated with rail are able to be spread over longer distances. On the shorter intercapital routes, rail has been losing market share to road. In relation to coastal shipping, the authors note that: [n]on-bulk sea freight has declined on most corridors. However, since the mid 1990s it has increased strongly between the Eastern Capitals and Perth – largely at the expense of road (p. 68). Consistent with this finding, the forecasts devised by BTRE show coastal shipping's share of the major intercapital non-bulk freight flows stagnating or declining on all corridors except Eastern Capitals – Perth. Overall, the BTRE suggests coastal bulk freight will grow relatively slowly over the period 2003 – 2020, rising from 107 to 141 billion tonne-kilometres. Coastal non-bulk freight is expected to rise from 7.6 to 17.92 billion tonne-kilometres over the same period. Almost all of the growth in non-bulk freight is expected to come from interstate movements (most of which relates to Tasmanian trades).
BTRE (2006c)	Contains projections of changes in the total domestic freight task, interregional freight task and origin-destination movements on major AusLink corridors over the period 1999 – 2025. The report suggests that under existing conditions, shipping will struggle to maintain market share in most areas.
Meyrick and Associates (2006)	Report on rail freight price elasticities of demand in Victoria for the Victorian Essential Services Commission. In reviewing the literature, the authors suggest there is a 'consensus view that Australian rail services in bulk freight (largely minerals and grains) face relatively inelastic demand, while non-bulk freight (mostly containerised finished goods) is price elastic, due in large part to road transport being a close substitute' (p. 2). Further, the report states: .. the increasing mode share of rail on long-distance corridors and road on short-distance corridors over recent decades implies that a significant share of the total freight task is contestable (p. 3). The authors divide the Victorian freight market into three groups on the

	basis of the contestability between road and rail. Bulk commodities (mostly raw mineral and materials) are considered ‘generally uncontestable (i.e. with little probability of rail losing market share to road due to rail freight price increases)’ (p. 9). Grain and rice freight are assessed as having a ‘moderate level of contestability between rail and road modes’ (p. 9). Finally, ‘containerised elaborately transformed goods’ is assessed as ‘highly contestable from rail’s perspective’ (p. 9). If it is assumed that rail and shipping provide similar freight services at similar prices, this analysis suggests the major area of contestability for shipping is in relation to non-bulk freight. Bulk freight is generally uncontestable. In relation to grain and rice, like most agricultural produce, the relevant freight movements will generally involve movement of goods from inland to capital cities or major regional centres; movements for which shipping is unable to compete. Like Meyrick and Associates *et al.* (2007), this report emphasises the importance of service quality in mode choice, arguing that the evidence suggests rail service levels are an important element in explaining mode shares.
Maunsell Australia Pty Ltd (2006)	Review for the National Transport Commission of the report prepared by Port Jackson Partners Ltd and Access Economics (2005) (PJP Report) (see below). It argues there are significant errors in the PJP report, including in relation to cost estimates. The report suggests the costs of rail may have been underestimated and road costs overestimated in some instances. It also argues that notwithstanding the cost estimates, improvements in the services offered by rail are ‘much more critical to achieving the projected mode share gains than likely level of changes in costs/prices’ (p. 33). The report states: … it appears unlikely that any increase in real road prices, even of the magnitude that PJP consider appropriate, will have any significant on-going effect on rail mode share. The evidence emphasises the need for rail to reform its own offering so that it can better meet present day freight transport requirements and avoid having to cut prices to retain business (p. 36). After discussing internal structural reforms to improve rail proposed in the PJP report, the authors conclude: [r]eform is unlikely to significantly change rail’s inherent disadvantages compared with road in terms of catering for door-to-door movements and just in time delivery requirements, which have contributed to the increasing road mode share (p. 38).
Port Jackson Partners Ltd (PJP) and Access Economics (2005)	Report on the competitiveness of rail versus road for the Australasian Railway Association Inc. It concludes that rail is cheaper than road for intercapital non-bulk freight movements on all major corridors. The report also argues that the major reasons for rail’s declining or stagnated market share include lack of appropriate investment in rail infrastructure and infrastructure access pricing practices for road. It is suggested that rail operators need to improve service to capture market share. The authors argue shifting freight from road to rail will generate significant economic benefits.
MM Starrs Pty Ltd (2005)	Report on impact of pricing and cost recovery practices on modal choice between road and rail for the National Transport Commission. The report contains a review of domestic and international literature, which found that changes in supply chain management (for example, just-in-time logistics) have generally favoured road because of its superior service

	levels. It is argued that the evidence indicates that for most shippers, service levels are important and that only a minority of shippers make mode choice decisions solely on the basis of price. Based on elasticity estimates for intercapital freight market, the author suggests the own-price elasticity of demand for road freight is likely to be in the order of -0.5 for short haul routes (i.e. relatively inelastic) to -1.1 for long haul routes (i.e. near unitary elasticity or relatively elastic). Estimates of cross price elasticities between road and rail range between 7.54 (high substitutability) for short haul route to 0.61 (low substitutability) for long haul routes. Using the elasticity estimates, an analysis is provided of the impacts of 10 scenarios involving increases in road costs (for example, increases in registration charges and fuel costs). The author concludes that 'only relatively small changes in rail demand are likely to result from increases in truck charges unless the increases are very large indeed' (p. 18).
ACIL Tasman (2004)	Report for the Australian Trucking Association on the state of trucking industry and its competitive position with rail. The authors argue that approximately 15% of road freight is contestable by rail and most of this is on inter-city routes. The report remarks on the incontestability of a significant proportion of the domestic freight market because of geographic and economic considerations.
BTRE (2003b)	Report on rail infrastructure pricing that includes analysis on the competitiveness of freight transport modes. The authors note the improvements in road freight productivity brought about by changes in vehicle type and road infrastructure, which have facilitated the increase in road's share of the domestic freight task. The report also suggests that '[r]ail services in non-bulk freight face relatively elastic demand because road freight is a close substitute for non-bulk rail freight' and that 'the price elasticity for bulk freight movement is relatively inelastic' (pp. 25 – 26).
BTRE (2002b)	Report on greenhouse policy options for transport that includes an analysis of the practicality of mode shifting from road to rail. The report concludes: [o]pportunities to capture significant greenhouse gas emission reductions from shifting freight from road to rail are often quite limited because, generally, only a small proportion of total freight carried by road is contestable. This contestable area is long-distance non-bulk and residual bulk traffic (pp. 58 – 59). The report suggests that while there are policies that may disadvantage rail relative to road (i.e. infrastructure access pricing), the rectification of these problems is unlikely to result in a major change in mode shares.
BAH (2001)	Report for the Australian Rail Truck Association investigating rail market shares that are likely to be necessary to justify $500 million in infrastructure investment. The study estimated choice elasticities of demand for rail on short- and long-haul routes. The price elasticity for rail on both short- and long-haul routes was estimated at -1.1. Estimates were also derived for non-price factors: between -0.3 to -0.4 for transit time; 0.6 for reliability; and between 0.4 and 0.5 for availability.
BTE (1999)	Report on competition between rail and road freight and the likely impact of the new tax system introduced in 1999 (called 'ANTS'). The authors provide a history of the declining shares of coastal shipping and rail in the non-bulk market. Notes that by the late 1980s, 'non-bulk coastal shipping

	had basically fallen back to the more or less irreducible coastal trades – that is, to and from Tasmania, Western Australia and the Northern Territory' (p. 7). An analysis is also provided of the prospects of arresting the declining market shares of coastal shipping and rail. The authors suggest that changes in the relative prices between the modes are unlikely to significantly alter the trends in mode shares. They argue that '[t]he relative position of an existing mode is likely to be affected significantly only if a new technology is developed that extends its competitive 'life', or if a new technology emerges or achieves dominance' (p. 12). In reviewing the competitiveness of the modes, the report states: [i]n order to keep the analysis tractable, the main area of competition between road and rail was taken to be the interstate non-bulk freight sector. Bulk traffic, on the other hand, is generally better suited to specific modes such as sea and rail. Intrastate traffic is more likely to involve shorter distances – an area where rail has greater difficulty competing (p. 12). Although qualified, this statement is consistent with the notion that interstate non-bulk freight market is the area that is subject to the greatest amount of competition between the modes.
Kells (1997)	Report on the effect on road and rail demand of an increase in heavy vehicle mass limits for the National Road Transport Commission. The author provides an analysis of the price elasticity of demand and cross-price elasticities of road and rail freight on six major intercapital corridors. The author argues that a reduction in road freight rates will result in an increase in road demand from two sources: mode shift demand from rail and induced or new demand. The findings include that the price elasticity of demand for road on these corridors is approximately -0.77 (i.e. relatively inelastic). The cross-price elasticity estimates range between 0.14 (Adelaide – Perth) to 2.21 (Sydney – Melbourne) for the two preferred scenarios. The report notes that: … road and rail are far from perfect substitutes; rather, road and rail services supply different (but of course overlapping) markets, and there are numerous geographic, technological and logistic reasons for why road and rail freight services cannot often be easily substituted for each other (p. 16). The author critiques the Sinclair Knight Merz (1997) report (see below) on the basis that it assumed perfect substitutability between the transport modes, which results in an overestimation of the cross-price elasticities. It is also contended that Sinclair Knight Merz (1997) double-counted in calculating the overall change in road demand due to reductions in road freight rates.
Sinclair Knight Merz (1997)	Report on proposed changes to vehicle mass limits in New South Wales. The analysis includes estimates of the price elasticity of demand and cross-price elasticity for road and rail on the Sydney – Melbourne and Sydney – Brisbane freight corridors. The initial estimates in the report contained errors and revised estimates by Sinclair Knight Merz are published in an appendix in Kells (1997). The price elasticity of demand for road is estimated to be -0.5 for both corridors and the cross-price elasticity of rail is given as 3.43 for Sydney – Melbourne and 1.51 for Sydney – Brisbane. These estimates are based on the assumption that road and rail are perfect substitutes on these corridors.

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