

ACOLA Project 08

Securing Australia's Future: Sustainable Urban Mobility

Technology Study

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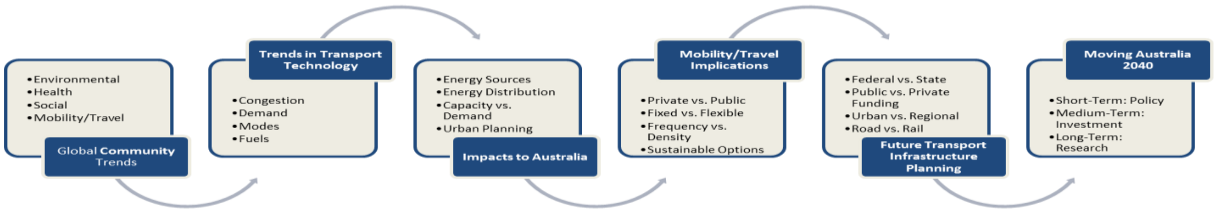
1 Transport Technology

1.1 Executive Summary

The linkages between current and future trends in community development and in transport technology provide rich potential to think about the options for a sustainable transport strategy for Australia.



In the period to 2061 and on ‘medium’ growth projections, the combined population in Australia's capital cities will grow by nearly 16 million and the proportion of Australians living in a capital city will significantly increase: from 66.0% in 2011 to 73.4% in 2061. Similarly, with rapidly changing social and economic circumstances, the demands on our transport systems will grow significantly. ‘Business as usual’ will not be sufficient; our mobility systems lack sustainability at present.

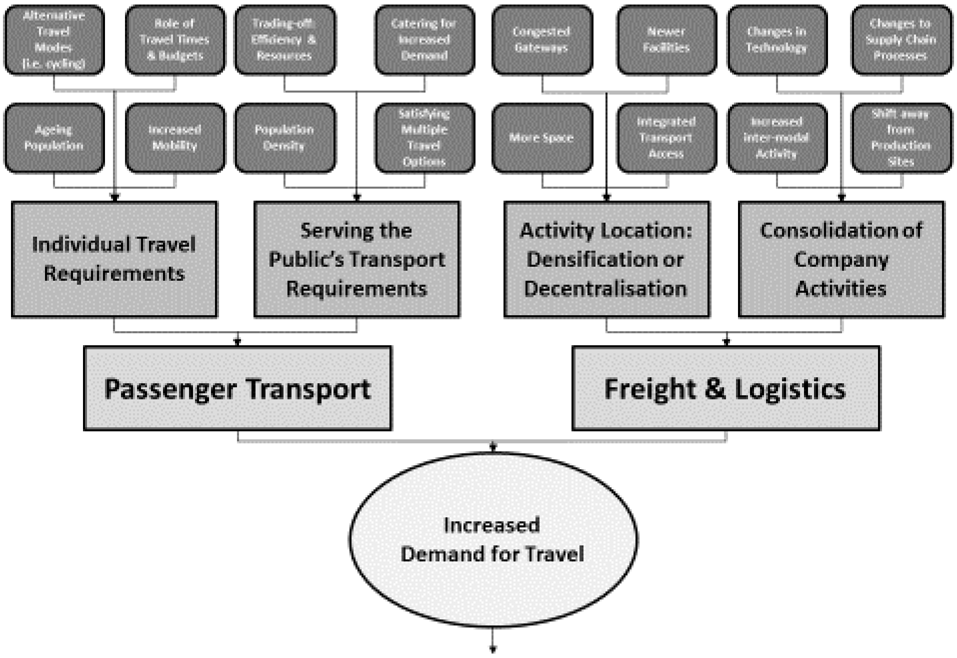
The technology space has many examples of potential pathways for moving forward in terms of providing for Australia’s current and future transport needs. As we have noted, Australia will increasingly become an importer of technology, particularly in the transport sector, and so it is important that policy makes and planners remain aware of global technology trends, picking the ‘right’ solutions and avoiding those that are irrelevant to our circumstances.

The parallel studies in health and social impacts of mobility have identified many areas where transport technology interacts strongly, often negatively affecting health and social outcomes. There are many opportunities to achieve improved health, social and mobility solutions if an integrated approach is taken to the selection and implementation of transport technology solutions.

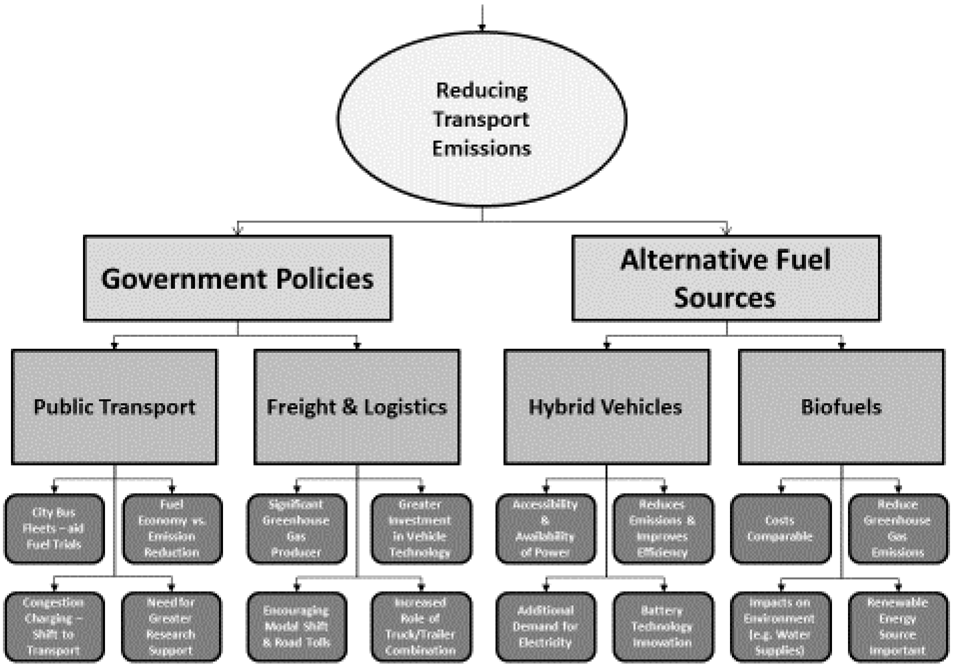
1.2 Transport Technology – Broad Trends in Transport Activity

Transport is a derived demand: in order to understand how technology can serve the future demand for mobility it is important to understand what drives that demand for mobility.

Transport Demand: Who, What, When , Where, & Why?



At the same time as travel demand is increasing, countries and governments are under pressure to reduce the carbon emissions from travel.



1.2.1 Global Community Trends

An ageing population remains one of the most significant challenges facing the Western society in the 21st century (Currie and Delbosc 2009). Evidence is mixed in respect to the trends in public transport utilisation in ageing communities. Several researchers have suggested that as the more car dependent 'Baby Boomer' generation age, public transport utilisations rates will decline (Rosenbloom 2001a, Rosenbloom 2001b, Alsnih and Hensher 2006).

1.2.2 Trends in the Role of Passenger Travel

Travel by global passenger transport has increased rapidly during the 20th century. In work done by Schafer and Victor (2000), in which they projected global vehicular travel usage to the year 2050, these authors consider future travel to be constrained by only two factors: individual time expenditure and household budgetary outlays.

1.2.3 The Role of Alternative Travel Modes

Schafer and Victor (2000) state that travel time (including non-motorised modes) is approximately constant at 1.1 hours per person per day globally; they predict that by the year 2050 total travel will increase to 103 trillion passenger kms of which 80 percent approximately will comprise high-speed travel modes and the car.

Oil depletion scenarios suggest that public transport powered largely by electricity, in conjunction with cycling and walking, will be key components of future urban mobility. Urban mobility will continue to rely on some form of external power and this is where electric vehicles will have a significant role to play.

There is some work [by Pucher et al. (2011)] on cycling in the USA which found that:

- Cycling is concentrated in central cities, especially near universities and in gentrified neighbourhoods near the city centre; and
- The majority of the growth in cycling in the USA is attributed to men in the age bracket of 25 to 64 years old, whilst cycling rates have remained steady among women and dropped dramatically for children.

1.2.4 Addressing Increased Demand for Public Transport

Increasing demand for public transport use in Australian cities has led to capacity 'crises' that in fact only represent modest changes in public transport mode share. Current public transport for work trips is confined mainly to employment in central city areas, with mode share for suburban work travel and non-work journeys remaining low. The challenge for transport planners and ultimately politicians in moving forward is to accommodate an increasing demand for public transport, particularly for work journeys and to provide a reasonable alternative for travel between low-density suburbs (Stone and Mees 2010).

Notably, the best-performing European public transport systems carry much higher patronage loads than their equivalents in the Australian environment; often with less extensive infrastructure (Stone and Mees 2010). For example, Line A of the Paris Regional Express Network (RER) regularly carries in excess of a million passengers per day on its two-track central section (RATP 2008). This is more passengers than the entire Sydney rail network, which operates eight tracks entering and exiting its central business district. Even light rail lines in other key international cities regularly carry much higher patronage than heavy rail corridors in Australian cities.

1.2.5 Public Transport – A Victim of Its Own Success

The main challenge for public transport is that it is increasingly called upon to serve diverse travel markets ranging from mobility provision to the disadvantaged through to alleviating traffic congestion; and this is all whilst trying to make efficient use of limited financial resources. A key characteristic of public transport is to carry people with differing trip origins and destinations in the same vehicle. Clearly this is a strength of public transport, but it additionally represents a weakness given commuters do not all have the same trip origins and destinations.

1.2.6 The Link between Population Density and the Attractiveness of Public Transport

There has been a belief held by many planners and other commentators on urban issues, to the effect that to maximise public transport utilisation there need to be significant changes in suburban densities (Stone and Mees 2010). As noted by Mees (2010), if urban traffic is a function of land use, then it is logical that land-use planning is the key to sustainable transport. Significant increases in density are not required to improve the viability of alternatives to the car; the relative appeals of competing urban transport modes seem to influence mode choice significantly more than variations in density. Services must be flexible enough to meet the range of travel needs. Whilst this can be difficult to achieve at times, transport policy can be altered with greater ease and less cost and disruption than alterations to the density of key cities (Mees 2010).

1.2.7 The Evolution of the Freight and Logistics Sectors

The freight and logistics sectors have exhibited a trend away from central locations, where the densities of local industries are relatively higher, to more spacious areas on the suburban fringe (Cidell 2010). The need for more space and easier transportation access to all freight transport modes (i.e. road, rail and air) has resulted in a trend towards intermodal logistics centres which require large parcels of land on the metropolitan fringe.

As freight traffic has both increased in volume and become more international in scope, it has become more concentrated on fewer ports and gateways. Inevitably, as these gateways have become congested, freight and logistic activities have begun to move towards inland ports and distribution centres to make more dockside space available for maritime activities (Cidell 2010).

1.3 Technology Trends – Developments in the Next 25 Years

1.3.1 Reducing Passenger Transportation Emissions

The transport sector's trends of more people, owning larger and more powerful cars and driving more has seemed unavoidable. With the exception of the 1970's oil price shock and the recent fuel price hike, most industrialised nations seemed to be on a continuous path towards increased utilisation of the private motor vehicle. Furthermore, it seemed inevitable that developing countries would follow these trends (Dargay, Gately et al. 2007). To date, efforts to reduce the carbon intensity of fuels have unfortunately been largely unsuccessful; even if plug-in hybrids and second-generation biofuels demonstrate long-term promise. Past improvements in vehicle efficiency have often been negated by increases in power and weight; resulting in fuel economy remaining constant. Recent events, however, have suggested that attempts to achieve passenger transport emission reductions may be slightly more successful than they would have appeared several years ago. Increases in fuel prices from 2003, as the price of oil reached approximately $150 per barrel resulted in a noticeable reduction in vehicle travel and energy use. This reduction in private vehicle use was in addition to marked increases in the use of alternative transport modes. In the USA, public transport systems achieved patronage gains of approximately 2.1 percent from 2007 to 2008. Furthermore, consumer residential preferences appeared to shift modestly to urban, walkable environments associated with less vehicle travel (Leinberger 2007).

1.3.2 A Global Perspective of Trends in Passenger Transport

Millard-Ball and Schipper (2011) conducted a cross-national analysis of trends in passenger transport in eight industrialised countries, comprising: Australia, Canada, France, Germany, Japan, Sweden, United Kingdom and the USA. Several conclusions resulted from this international comparison of travel trends, including:

- Activity in respect to total passenger kilometres in motorised modes has slowed its growth relative to Gross Domestic Product (GDP) and even declined in some countries. Most of the growth that has occurred has resulted from increased car use and increases in domestic air travel.
- Mode shift towards travel in cars has not been an important explanation of rising energy use, except in Japan [until the turn of the century].
- The energy intensity of car travel, the dominant factor in travel-related energy use and CO_2 emissions, has reduced in all countries [except Japan] since 1990. It started to decrease in Japan from 2000 onwards.

One consistent trend emerging from all eight countries that comprised this analysis is that travel activity has reached a plateau. Whilst Millard-Ball and Schipper did not make any predictions regarding the sustainability of this plateau, they did suggest that the plateau could be caused by one or more effects. These include:

- That the plateau is a temporary hiatus, with growth in activity likely to result from domestic air travel, high-speed rail or if investment in road infrastructure returns to previous levels;
- The second possibility is that the plateau will continue, if travel speeds remain constant and travel time budgets continue to have a negative impact; and
- The final possibility is that there will be a decline in travel activity in future years, reflecting the fact that 'peak travel' has been reached.

With each of these three scenarios, there is a unique set of policy implications for energy supply, transport infrastructure provision and the costs of achieving a given target for greenhouse gas emission reduction. Irrespective of the scenario, the most fundamental conclusion to result from this analysis is that continued steady growth in travel demand is unlikely.

1.4 Transport: A Key Energy Consumer

The transport sector is a major oil consumer and greenhouse gas emitter; globally it accounted for 26 percent of the world's energy use and 23 percent of energy-related greenhouse gas emissions in 2004 (IPCC 2007). The industrialised countries of the world reached an agreement to reduce greenhouse gas emissions in Kyoto, Japan in 1997. Transportation, which depends on fossil fuels as the main energy source, was one of the key sectors highlighted in that agreement (Li, Lu et al. 2013). Generally, as a dominant mode of freight movement, road transportation accounts for the largest share of the freight-related emissions (McKinnon and Piecyk 2009). As a result of the substantial increase in passenger and freight transportation demand, transportation has been the most rapidly growing sector in terms of energy and particularly oil demand and greenhouse gas emission in China (Yan and Crookes 2009). In 2005, it accounted for 37 percent of China's total oil consumption (IEA 2008). The IEA has forecast that by the year 2030, without aggressive policies and measures to reduce oil demand in the next two decades, Chinese oil demand will reach 808 Metric tonnes. Road transport will account for approximately 43 percent of this value (2008). Given that China is one of the two largest emitters of CO_2 in the world today, it continues to be subject to pressure to reduce greenhouse gas emissions (He, Liu et al. 2007). As a result, research into energy-saving technologies and alternative vehicle fuel applications is continually growing in China (Yan and Crookes 2009) and is worthy of further investigation.

1.4.1 Using Buses to Trial Alternative Fuel Sources

City bus fleets provide a unique opportunity for the commercial demonstrations of alternative fuel vehicles, because of the large vehicle size, which facilitates the inclusion of larger engines and fuel tanks, along with their fixed routes and refuelling points. In a review of the current use of alternative-fuel buses in China, Ou et al. (2010) concluded the following:

- Current alternative fuel/vehicle technologies differ substantially in their life-cycle fossil energy use and greenhouse gas emissions; however, only half of the six alternative fuel bus pathways studied currently realise energy savings and greenhouse gas emission reductions compared to conventional technologies.
- All technologies, excluding fuel cell buses, are currently feasible in China today due to the benefits of oil/natural gas substitution, although most lack obvious energy savings and reductions in greenhouse gas emissions.
- Current energy use and greenhouse gas emissions could be improved by a series of measures including:
  - Improving fuel economy for non-internal combustion engine vehicles, such as fuel cell buses and electric vehicles, whilst employing hybrid electric vehicle technology for internal combustion engine vehicles;
  - Improving fuel production efficiency for coal-based fuels and natural gas-based hydrogen;
  - Developing alternative vehicle fuel and/or alternative fuel vehicles based on local resource abundance;
  - Employing low-carbon methods, such as renewable energy for both electricity generated and coal-based fuel production.
- Integrated policies should be implemented to encourage the promotion of alternative fuels/vehicles and they should seek to:
  - Apply hybrid electric technology to diesel buses;
  - Encourage natural gas and liquefied petroleum gas buses in 'gas-abundant' cities;
  - Promote commercialised electric buses or 'plug-in' capable vehicles through battery technology innovation;
  - Support fuel cell buses and hydrogen technology research and development for future potential applications; and
  - Conduct further research on boosting vehicle fuel efficiency, applying low-carbon transportation technologies and addressing all resultant implications of coal-based transportation solutions to human health and natural resources.

1.4.2 Developing Policies to Allow the Freight Sector to Reduce its Carbon Footprint

China, as a country on the path to industrialisation, represents an economy that is growing rapidly. In addition to this economic growth and the subsequent impact on specialised industries, transportation demand, particularly in the freight and logistics sector, is also growing rapidly. During the five-year period (2006-2010), the Ministry of Transport of the People's Republic of China (MOTPRC) adopted certain policies to mitigate the increase of CO_2 emissions. Based on the analysis conducted by Li et al. (2013), the following points impacting future policy development in the freight and logistics sector were raised:

- Economic development inevitably leads to the increase of freight transportation CO_2 emissions; industry development is likely to decrease freight transportation CO_2 emissions;
- Policies on businesses, vehicle licensing and vehicle efficiency which were enacted and carried out by the MOTPRC were helpful to decrease road freight transportation CO_2 emissions:
    - In 2009, in China there were a number of businesses in the freight market: a number of single businesses owned no more than ten trucks (MOTPRC 2009). Few businesses operated intensively and had convenient operation networks. Policies were introduced to limit the minimum stock of working vehicles owned by newly registered businesses in order that the market concentration could improve.

    - An investment in vehicle technology was another option enacted to constrain or reduce truck energy use:
        - In China, to comply with the regulation, freight businesses are required to purchase vehicles satisfying fuel-efficiency requirements that are approved by the MOTPRC.
    - The MOTPRC are strongly supporting tractor and semi-trailer transportation given it is promoted to be more energy-efficient than single-unit trucks (Xue, Ma et al. 2011).
        - Tractors and semi-trailers were not allowed to separate and combine freely prior to 2008.
- To decrease road freight transportation CO_2 emissions, policies on modal shift and highway tolls which are negotiated by the MOTPRC and other ministries required careful consideration:
    - Highway tolls can increase operational costs for truck operators, which can result in them reducing the frequency of using trucks on the highway (Liao, Lu et al. 2011).
    - Higher tolls may change the modal selection for freight transportation, such as improvements to the technical efficiency and energy intensity of modes, other than road freight transportation (McKinnon 2006).

1.4.3 Alternative Fuel Options – Hybrid Vehicles versus Biofuels

Globally, in excess of 90 percent of the transport sector is powered by fuels derived from oil. However, the consumption of diesel and petrol is considered problematic due to the costs of oil, doubts about the security of oil supplies (de Alemida and Silva 2009), greenhouse gas emissions and the emissions of air pollutants and other volatile compounds (Dunn 2002). To reduce the dependence on oil in the transport sector, alternative fuel supplies such as biofuels and efficient hybrid cars are being used in increasing volume and numbers (EurObserv'ER 2009). The cost and potential emission benefits of biofuels and hybrid vehicles have been highlighted in numerous studies (Johansson and Ahman 2002). For example, costs of sugar cane ethanol are already competitive with traditional fuels, whilst using biofuels reduces emissions of greenhouse gases when produced sustainably. Furthermore the use of biofuels also reduces emissions of other air pollutants. Fuel consumption and emissions from efficient hybrid electric cars are lower than those from traditional cars (van Vliet, Brouwer et al. 2011).

1.4.4 The Use of Electric Vehicles

The use of electric vehicles is also considered a promising alternative and one that has been advocated for decades. It does not cause tailpipe emissions, but may cause emissions of greenhouse gases and other air pollutants depending on the mix of electricity sources used (Cowan and Hulten 1996). Research work by van Vliet et al. (2011), examined the efficiency and costs of both current and future electric vehicles, in addition to the impacts of charging electric vehicles on electricity demand and infrastructure for generation and distribution and consequently on greenhouse gas emissions. It can be concluded that if off-peak charging is successfully introduced and this is largely dependent upon battery technology; electric driving need not require additional generation capacity, even in the case of a complete transition to the use of electric vehicles (van Vliet, Brouwer et al. 2011). In respect to the impacts on greenhouse gas emissions, emissions from charging electric vehicles are lower than emissions from regular or parallel hybrid cars. This assumes that electricity is generated from modern coal-fired plants; given that the greenhouse gas emissions from electric driving ultimately depends most of the fuel type used in the generation of electricity for charging (van Vliet, Brouwer et al. 2011).

1.4.5 Biofuels as an Alternative Fuel Source for Transport

The need to find more efficient, cleaner and sustainable fuels drives transitions in the energy sector. The use of bioenergy, such as biofuels for transport, is seen as an appropriate alternative possessing many of these characteristics. With the largest share of all renewables (IEA 2006), bioenergy has a prominent role in any energy scenario. Bioenergy includes the first generation biofuels, which are based on the starch, sugar or oil fraction in the crop and second generation bioenergy, which is based on the cellulosic fraction of crops or other biomass, i.e. waste (Gerbens-Leens, van Lienden et al. 2012). Significant attention has been paid in the last two decades to the energy supply risks associated with reliance on fossil and nuclear fuels (IPCC 2008), giving an impulse to the development of renewables such as energy from wind, water, sunlight and biomass. Limited research, however, exists on the impact of adoption of bioenergy on water systems (Gerbens-Leens, van Lienden et al. 2012).

Gerbens-Leens et al. (2012) assessed global water use changes related to increasing biofuel use for road transport in 2030 and evaluated the potential contribution to water scarcity. Energy scenarios project an increase in biofuel consumption in the future and the transition to biofuels would require the production of more crops, involving large fresh water demands, using precipitation stored in the soil and from irrigation. Depending on the location and the growing conditions, the crop water requirements and yields vary significantly, resulting in differing biofuel 'water footprints' per country. Overall, the transition to biofuels will lead to a larger 'water footprint' for the global transport sector. Consequently, countries should consider the water factor thoroughly when investigating the extent to which biofuels can satisfy the future energy demand in the transport sector. Energy transitions will only improve the standard of living and productivity if all impacts are taken into account (Gerbens-Leens, van Lienden et al. 2012).

To supply a country with sufficient energy and to decrease carbon dioxide emissions to comply with international requirements, countries will need to decide on the selection of energy carriers. For example, China aims to produce the majority of renewable electricity in 2030 from hydropower (US Department of Energy 2010). The European Union aims to replace 10 percent of transport fuel by renewables in 2020, i.e. biofuels, electricity from biomass, wind, solar energy and/or hydrogen (European Environment Agency 2010). This will also require a choice on which renewable energy source to apply. A choice for bioenergy does not require large system changes, because it can easily be stored, co-fired in electricity plants or applied in the form of biofuels in the transport sector. The

European transport sector is dominated by road transport (European Environment Agency 2010), that can easily shift to biofuels without large system changes. A shift to electricity or hydrogen, however, would result in a significant change to the system requiring major efforts. Consequently, to support policy to make the correct decisions, a thorough analysis of the energy scenarios will be required to estimate if the projections for biomass supply are possible from a water perspective (Gerbens-Leens, van Lienden et al. 2012).

1.5 Energy Consumption and Production in Australia

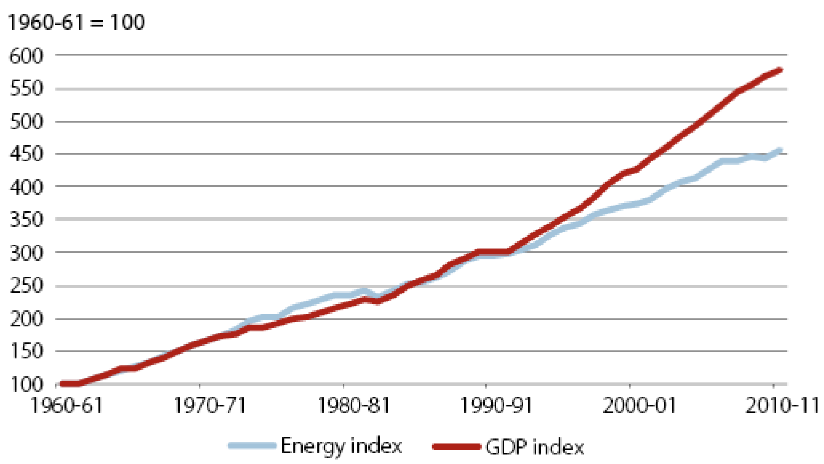
1.5.1 Energy consumption in Australia

Australia is the world's seventeenth largest consumer of non-renewable energy resources and ranks eighteenth on a per person basis [Bureau of Resources and Energy Economics, "Energy in Australia", 2013]. Australia's energy consumption is primarily composed of non-renewable energy resources (coal, oil, gas and related products), which represent 96 per cent of total energy consumption. Renewables, the majority of which is bioenergy (wood and wood waste, biomass and biogas), account for the remaining 4 per cent of consumption. Renewable energy consumption, whilst low, has been growing strongly in recent years.

While continuously increasing, growth in Australia's total energy consumption has been slowing over the past five decades. Following annual growth of approximately five per cent during the 1960s, growth in energy consumption fell during the 1970s to an average of approximately four per cent a year. This was primarily the result of the two oil price shocks of that decade. During the 1980s, an economic recession in 1982–83 and the resultant rising energy prices resulted in annual energy consumption growth falling again; this time to an average of approximately 2.3 per cent. In the 1990s, economic recession early in the decade contributed to slower energy consumption growth. However, falling energy prices (in real terms) and a turnaround in economic growth resulted in the annual growth in energy consumption remaining constant at approximately 2.3 per cent for the decade as a whole.

Over the past five years, growth in energy consumption has averaged 0.8 per cent, primarily as a result of the on-going decline in the energy intensity of the Australian economy (Figure 1).

Figure 1: Annual growth in Australia's energy consumption, 1960 – 2011



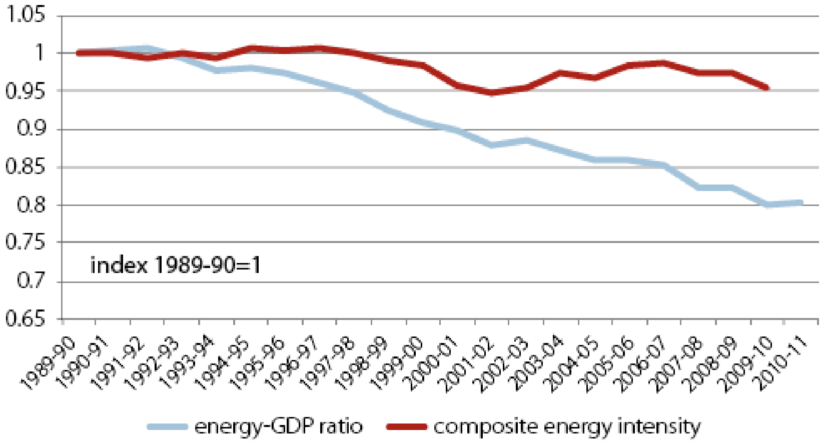
Sources: BREE 2012, Australian Energy Statistics; ABS 2012, Australian National Accounts: State Accounts, cat. no. 5206.

1.5.2 End-use energy intensity

The Australian economy has experienced a long-term decline in energy intensity (energy consumption per unit of gross domestic product). Energy efficiency improvements have been achieved through technological change, fuel switching, and structural changes. Government policies at both the national and state/territory level have contributed to the implementation of new technologies that improve energy efficiency and increase the incentives for more efficient fuel use. Growth in less energy-intensive sectors, such as the commercial and services sector, relative to higher energy-intensity sectors, such as manufacturing, has also resulted in structural shifts in the economy towards lower energy intensity.

The energy–GDP ratio provides information on how many units of energy are required for a unit of gross value of production. Thus, a declining trend of energy-GDP ratio implies that an equivalent amount of energy demand is able to generate greater value added. The aggregate energy-GDP ratio for Australia as a whole declined at an average annual rate of 1.2 per cent over the period 1989–90 to 2010–11 (Figure 2).

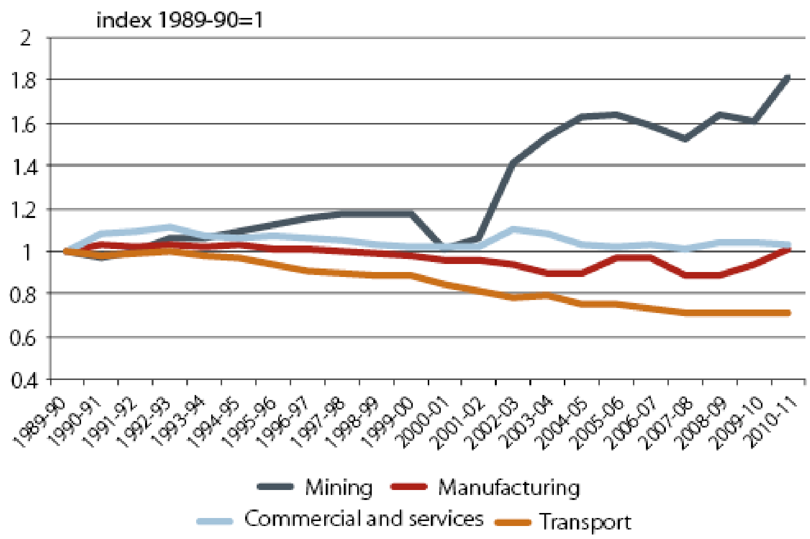
Figure 2: Trends in energy-GDP ratio and the composite energy intensity indicator in Australia



Sources: BREE 2012, End-use energy intensity in Australia; BREE Estimates.

The composite energy intensity indicator computes economy-wide energy intensity by aggregating energy intensities derived for individual sectors or subsectors. Composite energy intensity in the Australian economy declined at an average rate of 0.2 per cent a year from 1989-1990 to 2010-11 (Figure 2). The transport and manufacturing sectors are the main sources of Australia's declining energy intensity (Figure 3).

Figure 3: Trends in energy-Gross Value Added ratio of selected Australian industries



Sources: BREE 2012, End-use energy intensity in Australia; BREE Estimates

The transport sector accounts for the largest share of final energy consumption in Australia, followed by the manufacturing, mining, residential, services, and agriculture sectors. Energy intensity in the transport sector decreased between 1989-90 and 2010-11. Alternatively, the mining sector, has demonstrated an upward trend in energy intensity over the same time period. Energy intensity in the manufacturing and commercial and services sectors remained largely unchanged during this period.

The decline in energy intensity in the transport sector is considerable; falling at an average rate of 1.9 per cent per year over the twenty years to 2010-11. This can be attributed to rising fuel prices combined with technical advances in fuel efficiency, aerodynamics and lightweight materials. Furthermore, Government policies to improve vehicle fuel efficiency, such as mandatory efficiency standards, and a greater use of public transport have also contributed.

In the manufacturing and the commercial and services sectors the structural effect of shifts in activity from higher to lower energy intensity subsectors and improved efficiency (due to technological improvements and rising energy prices) reduced energy demand growth. Increased activity in both sectors, however, more than offset these effects and resulted in net energy consumption growing from 1989-90 to 2010-11.

During the period from 1989-90 to 2010-11, energy consumption in the mining sector increased by an average growth rate of 6.3 per cent a year due to a strong increase of mining activity and depletion effects. By contrast, the energy-Gross Value Added ratio increased by 2.9 per cent over this period.

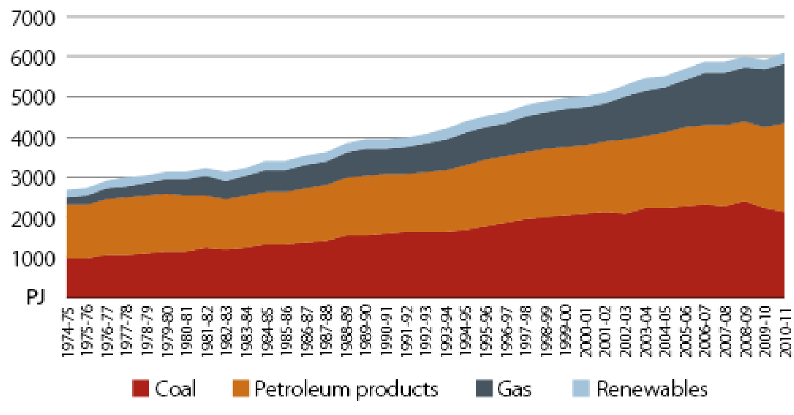
1.5.3 Energy consumption, by energy type

Total primary energy supply (TPES) can be used as a proxy for the total amount of energy consumed in the Australian economy; including energy consumed in the conversion sector, such as electricity. Australian total primary energy supply is dominated by coal, petroleum and gas.

The share of black and brown coal in the energy mix has been declining over the past two years, primarily as a result of substitution towards gas and cleaner energy sources; particularly in the electricity generation sector (Figure 4). In 2010–11, coal represented approximately 35 per cent of the energy mix, slightly less than petroleum products (36 per cent). The share of gas in Australian energy consumption has increased over the past 30 years and currently represents approximately 25 per cent. The share of renewables in Australia's total energy mix has remained largely constant at approximately four per cent over the last decade (Table 1).

Currently, approximately 53 per cent of Australia's renewable energy is comprised of biomass (wood and bagasse). Hydro power for electricity generation makes up 23 per cent of renewables consumption, with the remaining 24 per cent comprising biofuels, wind and solar energy consumption. In recent years, a decline in the use of biomass has been partially offset by increasing use of all other renewable energy sources.

Figure 4: Australia's total energy consumption, by energy type



Source: BREE 2012, Australian Energy Statistics.

Table 1: Australia's total energy consumption, by energy type

	2006-07	2007-08	2008-09	2009-10	2010-11
	PJ	PJ	PJ	PJ	PJ
Consumption of fuels	8381	8414	8475	8356	8559
Black coal	1602	1580	1598	1475	1402
Brown coal/lignite	722	725	805	742	728
Coke	73	75	63	73	87
Coal by-products	69	71	52	62	67
Liquid biofuels	3	4	7	10	14
Wood, wood waste	97	106	95	95	95
Bagasse	111	111	53	50	43
Refinery input	1506	1465	1481	1439	1524
Petroleum products	2032	2089	2043	2077	2164
Natural gas	1279	1302	1371	1414	1515
Town gas	7	4	3	0	1
Solar energy [a]	6	7	8	10	11
Total electricity	875	876	898	908	909
of which hydro electricity	52	43	43	49	61
wind energy	9	11	14	18	21
solar electricity	0	0	1	1	3
Derived fuel production	2518	2548	2507	2447	2472
Coke	90	90	69	76	87
Coal by-products	68	69	49	61	68
Petroleum products [b]	1542	1565	1544	1471	1492
Town gas	5	4	3	0	0
Thermal electricity	813	821	841	840	825
Total energy consumption [c]	5871	5876	5982	5923	6100

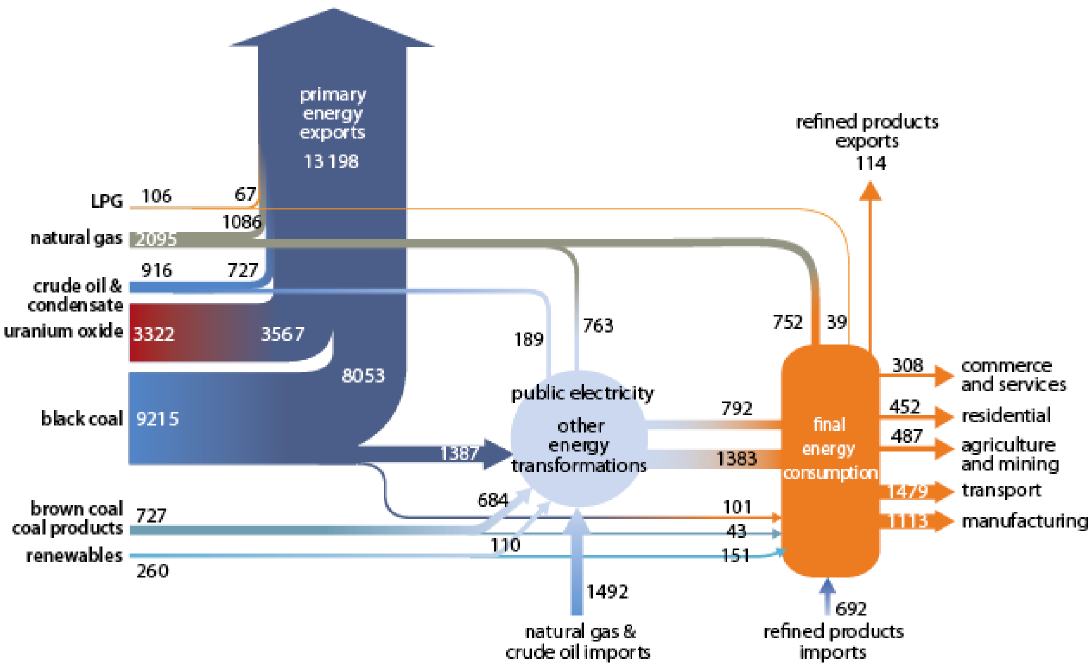
a Solar energy is from solar hot water systems. b Production may exceed refinery input as some petroleum products are produced from other petroleum products. c Total energy consumption is the total quantity (in energy units) of primary and derived fuels consumed less the quantity of derived fuels produced. Totals may not add due to rounding.
Source: BREE 2012, Australian Energy Statistics.

1.5.4 Energy consumption, by sector

Australia's total primary energy supply is estimated to have risen by three per cent relative to 2009-10 to 6100 petajoules in 2010–11. Figure 5 illustrates Australia's energy flows from the supply point to final distribution to industries and households. Domestically produced or imported primary energy may be used directly by industries and households, but is generally first consumed by transformation sectors such as refineries and power plants for use as petroleum products and electricity. In addition, many final energy products are not manufactured in Australia, but are directly imported for use by Australian industries and households. Australia is a net exporter of primary energy, with a far greater amount of primary energy production exported than consumed domestically. Australia's energy resources generated $77 billion worth of energy exports in 2011–12 while also providing Australian households and businesses with a secure, reliable and affordable domestic energy supply.

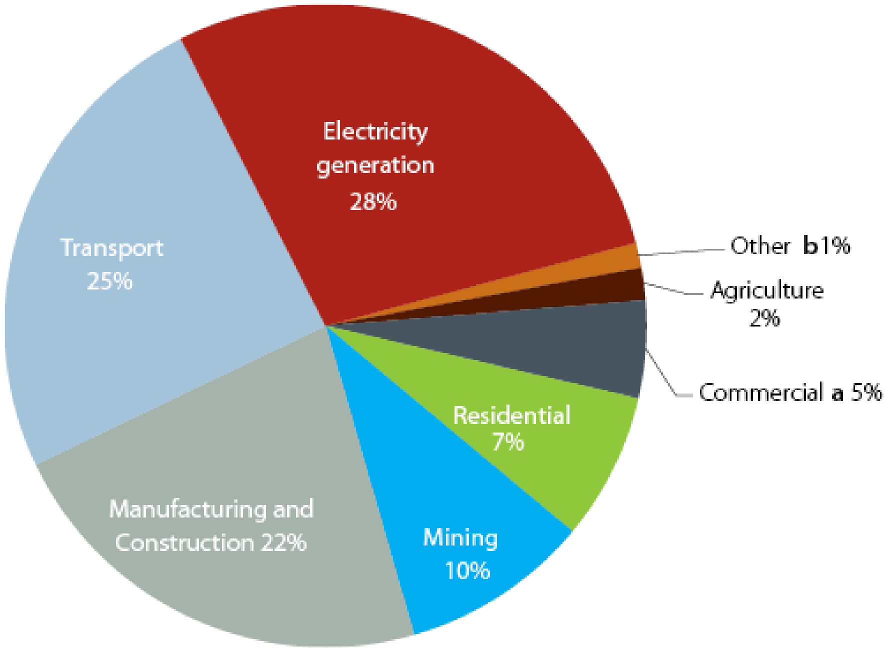
The major energy using sectors of electricity generation, transport and manufacturing together account for approximately 75 per cent of Australia's energy consumption (Figure 6). The transport sector accounts for the largest share of Australia's end use consumption. During the period from 2000–01 to 2011–12, energy consumption of transport increased by an average of 2.4 per cent per year (BREE estimate). The next largest energy-consuming sectors are the mining (which has seen a particularly large increase over the last decade, Table 2) and the residential and the commercial and services sectors.

Figure 5: Australia's energy flows, 2010–11, petajoules



Note: Some totals do not add due to statistical discrepancies and rounding.
Source: BREE 2012, Australian Energy Statistics.

Figure 6: Australia's total energy consumption, by sector, 2010–11



a Includes ANZSIC Divisions F, G, H, J, K, L, M, N, O, P, Q and the water, sewerage and drainage industries. b Includes consumption of lubricants and greases, bitumen and solvents, as well as energy consumption in the gas production and distribution industries and statistical discrepancies. Totals may not add due to rounding.
Source: BREE 2012, Australian Energy Statistics.

Table 2: Australia's total energy consumption, by sector

	1975-76	1980-81	1990-91	2000-01	2010-11
	PJ	PJ	PJ	PJ	PJ
Agriculture	40	49	56	86	99
Mining	67	71	165	254	580
Manufacturing	926	946	1074	1188	1338
Electricity generation	560	778	1065	1508	1724
Construction	29	38	37	28	25
Transport	715	835	1003	1249	1505
Commercial [a]	90	107	157	223	299
Residential	246	263	328	398	452
Other [b]	58	60	64	78	78
Total	2731	3146	3950	5012	6100

a Includes ANZSIC Divisions F, G, H, J, K, L, M, N, O, P, Q and water, sewerage and drainage industries. b Includes lubricants and greases, bitumen and solvents and energy consumption in gas production and distribution industries. Totals may not add due to rounding.
Source: BREE 2012, Australian Energy Statistics.

Table 3: Australia's energy supply and consumption, 2010–11

	Coal and coal by-products	Natural gas, CSM	Crude oil and ORF	Propane, butane, LPG	Refined products	Liquid/gas biofuels
	PJ	PJ	PJ	PJ	PJ	PJ
Supply						
Primary indigenous	9 941.4	2 094.8	915.6	105.5		27.2
plus all imports		261.0	1 229.3	24.0	667.9	
less all exports [a]	8 052.5	1 085.7	726.6	66.7	113.6	
less stock changes and discrepancies	- 238.0	- 245.2	- 105.6	8.6	- 62.9	
Total primary energy supply [b]	2 128.5	1 515.4	1 523.9	54.2	617.2	27.2
less conversions						
Coke ovens	29.4				0.6	
Petroleum refining		15.8	1 519.9	- 28.1	- 1 451.9	
Gas manufacturing		0.2		0.1		
Electricity generation [a]	1 874.8	505.6	1.0	0.0	33.1	12.6
Other conversion [c]	78.6	209.3	0.8	- 12.0	24.9	
Fuel use in conversion		32.2		0.2	106.7	
Consumption						
Total final energy consumption [d]	139.9	752.4	2.2	93.9	1 903.8	14.6
Agriculture		0.1		1.8	88.9	
Mining	5.9	151.0	1.5	1.7	145.1	1.0
Food, beverages, textiles	11.9	37.5	0.7	1.7	2.1	0.6
Wood, paper and printing	2.9	22.6		0.1	0.3	1.0
Chemical	7.2	114.8		12.8	73.1	0.2
Iron and steel	33.5	23.5		0.0	0.4	
Non-ferrous metals	46.0	124.0		0.7	72.9	0.2
Other industry	26.8	74.8		6.0	7.3	1.2
Construction		3.0		0.2	21.8	
Road transport		2.5		53.6	1 040.3	10.2
Rail transport		0.0		0.0	38.8	
Air transport					262.7	
Water transport	5.3				57.0	
Commercial and services	0.4	50.6		3.4	25.9	0.3
Residential		148.1		11.7	1.1	
Lubes, bitumen, solvents					66.0	

Table 3: Australia's energy supply and consumption, 2010–11 (Continued)

	Biomass	Wind electricity	Solar	Hydro-electricity	Total electricity	U3O8 Uranium	Total
	PJ	PJ	PJ	PJ	PJ	PJ	PJ
Supply							
Primary indigenous	137.6	20.9	14.0	60.5		3 322.4	16
plus all imports							2 183.9
less all exports [a]						3 266.7	13
less stock and discrepancies						55.8	- 587.9
Total primary energy supply [b]	137.6	20.9	14.0	60.5			6 100.1
less conversions							
Coke ovens					0.1		30.1
Petroleum refining					7.6		63.3

Gas manufacturing							0.3
Electricity generation [a]	12.6	20.9	3.1	60.5	-	909.4	1 615.9
Other conversion [c]							301.6
Fuel use in Consumption						108.7	248.2
Total final energy consumption [d]	125.0		11.0			792.4	3 839.2
Agriculture						7.9	98.8
Mining	0.0					82.3	388.6
Food, beverages,	33.6					22.6	113.2
Wood, paper and	29.2					17.9	73.9
Chemical	2.2					16.7	227.5
Iron and steel						15.7	73.1
Non-ferrous metals	1.4					146.3	391.6
Other industry	0.8					25.7	142.5
Construction						0.3	25.3
Road transport							1 106.5
Rail transport						8.2	47.0
Air transport							262.7
Water transport							62.4
Commercial and services	0.3		0.4			225.9	307.9
Residential	57.5		10.6			223.1	452.1
Lubes, bitumen,							66.0

a Includes air and water transport bunker fuels. b Total primary energy supply is a measure of the total energy supplied within the economy. It is equal to indigenous production plus imports minus exports, plus stock changes and statistical discrepancies. c Includes return streams to refineries from the petrochemical industry, consumption of coke in blast furnaces, blast furnace gas manufacture, briquette manufacturing and lignite tar in char manufacture. d Total final energy consumption is the total energy consumed in the final or 'end-use' sectors. It is equal to total primary energy supply less energy consumed or lost in conversion, transmission and distribution. Totals may not add due to rounding.

Source: BREE 2012, Australian Energy Statistics.

1.5.5 Energy consumption in the Australian transport sector

The transport sector is the largest end user of energy in Australia. More than 38 per cent of Australia's final energy use is employed in moving people and goods across the country. As a large continent characterised by major population centres located along its coastline, Australia requires goods to be transported long distances. The transportation sector is by far the largest consumer of liquid fuels (including LPG and refined products); accounting for approximately 73 per cent of final use.

Within the transport sector, road transport is the largest user of final energy, accounting for 74 per cent of the sector's liquid fuel consumption. Largely reflecting improvements in fuel efficiency, average growth in road transport fuel consumption has moderated over the past 30 years, reducing from approximately three per cent a year in the 1980s to an average of one per cent a year in the 2000s (Table 4).

Table 4: Energy consumption in the transport sector [a]

	1979-80	1989-90	1999-00	2009-10	2010-11	2011-12
	PJ	PJ	PJ	PJ	PJ	PJ
Road transport	594.1	792	942	1080.4	1118.2	1163.2
Railway transport	30.9	30.7	29.7	48.4	45.7	45.3
Water transport	97.6	55.7	55.7	67.3	62.2	66.7
Air transport	58.9	103	180.2	243.7	255.6	243.1
Other	3.5	6.2	12.7	25.6	26.6	25.5
Total	785	987.6	1220.3	1465.4	1508.3	1543.8

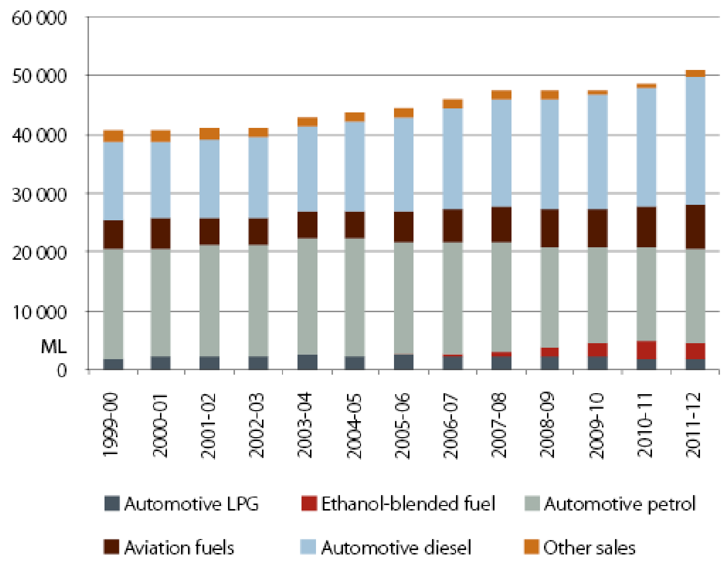
a Net energy consumption (defined as total fuel input less energy produced).
Sources: BREE 2012, Australian Energy Statistics; BREE estimation.

Air transportation has been the fastest growing consumer of transport fuels in Australia. After growing by more than five per cent a year in the 1990s, energy consumption growth in the sector has slowed to approximately two per cent a year between the years 1999–2000 and 2011–12. This slow down largely reflects lower passenger traffic between 2001 and 2003 following the collapse of Ansett, the terrorist attacks in the United States and the outbreak of SARS. Despite this, the long-term increase in international air transportation, this has been at the expense of international sea transportation. As such, energy use in the water transport sector declined steadily throughout the 1980s and 1990s; although it has increased in the past few years.

Australian demand for transport fuels has been rising steadily over the past 12 years; increasing by almost 20 per cent from 40,765 mega litres in the year 1999–2000 to 50,734 mega litres in the year 2011–12. The majority of Australia's sales of transport fuels are diesel, followed by petrol and aviation fuels (Figure 7). Automotive gasoline is the main fuel used in the transportation industry, accounting for approximately 41 per cent of total energy use in the sector. This reflects the large share of road transportation in transport sector consumption.

The phasing out of leaded automotive gasoline (commencing in 1986), was completed in 2001. Consumption of automotive LPG (which was excise free) increased at an average rate of 10 per cent per annum over the same period. In 2004 demand for LPG declined slightly following the announcement of the phase-in of taxes on excise exempt fuels. It should be noted that it has been steady since that date.

Figure 7: Australia's sales of transport fuels



Source: BREE 2013, January Australian Petroleum Statistics.

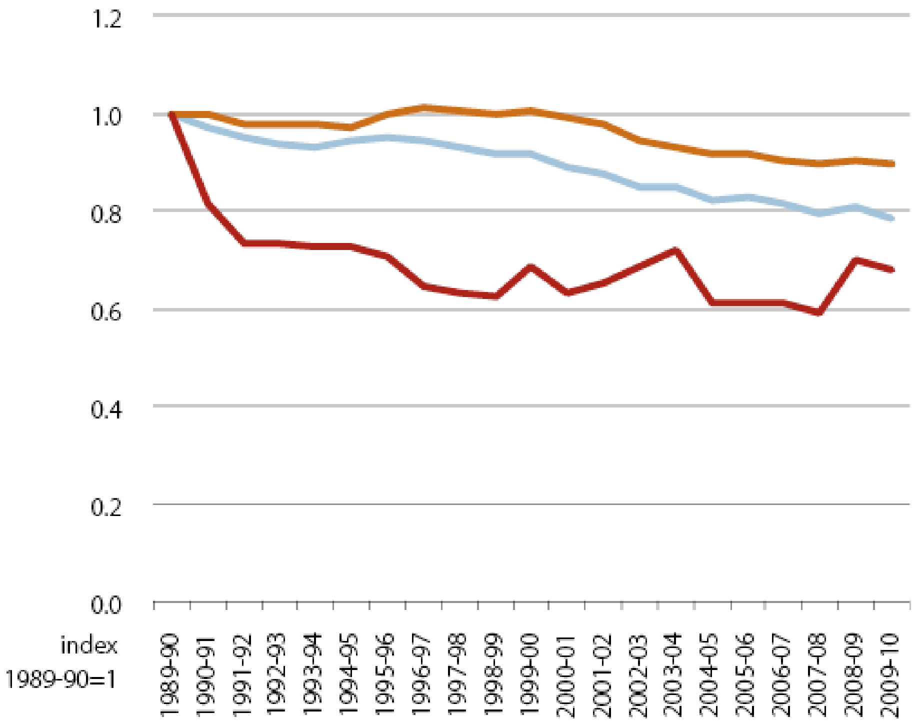
1.5.6 Fuel efficiency

In 2010–11, the transport sector accounted for approximately six per cent of economic output in terms of real gross value added and approximately 36 per cent of final energy use in Australia. About 63 per cent of energy consumed in the transport sector is associated with the movement of passengers; whilst the remainder can be attributed to the movement of freight.

Transport energy consumption of road, rail and air transport grew at an average annual rate of 1.7, 2.0 and 3.5 per cent, respectively, during the period from 1989–90 and 2010–11. Over this period energy consumption in passenger and freight transport sub-sectors grew at an average annual rate of 1.5 per cent and 2.3 per cent, respectively.

Despite substantial variability, a declining trend in energy intensity in the transport sector has occurred over the period from 1989–90 to 2009–10 (Figure 8). Whilst energy intensity in the passenger transport sub-sector increased in the mid to late 1990s, overall energy intensity declined at an average rate of 0.6 per cent a year (as falls in the 2000s offset earlier rises). Energy intensity in the freight transport sector declined more rapidly at an average annual rate of 1.3 per cent.

Figure 8: Trends in composite energy intensity indicators in the transport sector

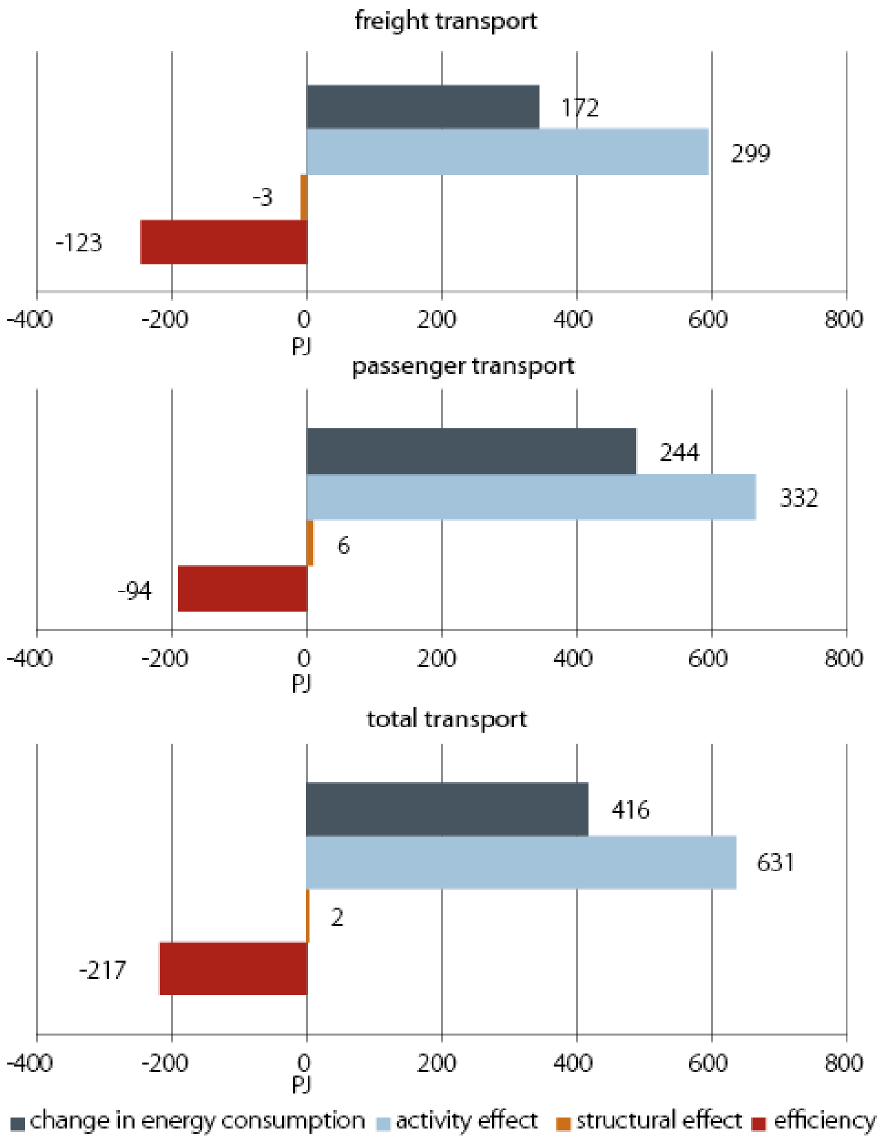


Note: These energy intensity trends do not imply any weighting of energy consumption by sector.
Source: BREE 2012, Economic analysis of Australian end-use energy intensity.

The energy intensity indicator for passenger transport, as measured by energy use per passenger-kilometre, takes into account the fuel efficiency of vehicles as well as the number of passengers in a vehicle (or occupancy). If the vehicle occupancy rate declines, energy intensity tends to increase even without changes in vehicle efficiency. Figure 9 highlights the change in energy consumption driven by changes in energy efficiency during the period from 1989-90 to 2009-10. The analysis suggests that freight transport demonstrated larger and more sustained energy efficiency savings compared with passenger transport.

Activity and efficiency effects have both had a considerable impact on the transport sector over the past two decades. Figure 9 illustrates that the activity effect resulted in transport energy consumption increasing by 631 petajoules over that period (due to increased use), comprising 332 petajoules from passenger transport and 299 petajoules for freight transport. The efficiency effect had the opposite impact in both sectors. The passenger transport and freight transport subsectors experienced 94 and 123 petajoules of reduced demand, respectively.

Figure 9: Decomposition of change in energy consumption in the transport sector, 1989-90 to 2009-10



Source: BREE 2012, Economic analysis of Australian end-use energy intensity.

1.5.7 Energy Efficiency

The Energy Efficiency Opportunities program of the Federal Government [Department of Resources, Energy and Tourism, "In depth: the Transport industry - a look at results from 2006–2008 for the Energy Efficiency Opportunities program", 2010] was set up with the aim to improve the energy efficiency of the country's largest energy users who together account for a major share of national energy use. It was underpinned by the Energy Efficiency Opportunities Act 2006, which came into effect on 1 July 2006 and was repealed in September 2014.

The Energy Efficiency Opportunities act required large energy-using businesses to conduct a detailed assessment of their energy use and to identify and evaluate opportunities to cost-effectively improve their energy efficiency. Participation in the program was mandatory for corporations using more than 0.5 petajoules of energy per year. As of October 2010, over 280 corporations have registered for the program. 199 corporations registered for the 2005-06 trigger year and first reported their results at the end of 2008.

Corporations reported to both the public and to Government on the results of their energy efficiency assessments and the opportunities that existed for projects with a financial payback of up to four years. The report detailed the following:

- Opportunities they have identified to save energy;
- Quantify the energy savings the opportunities could deliver; and
- State the corporation's business response to the opportunities.

In their first reports to Government, the 199 corporations reported data for 1099 separate entities. Of these, 119 business entities were involved in transport activity; the referenced report presents the data submitted by those transport entities.

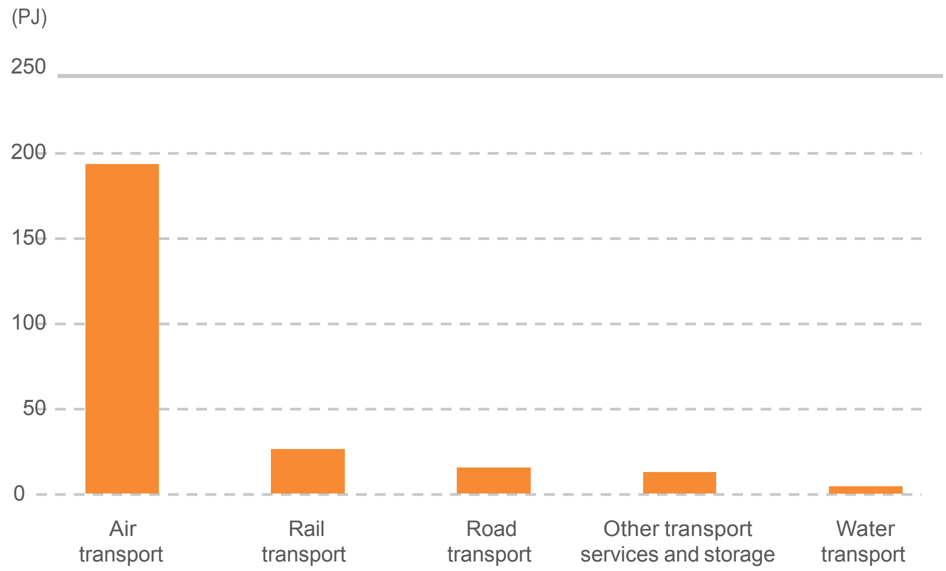
The corporations outlined their level of energy use, the proportion of assessed energy and the energy savings opportunities that they had identified through their first assessments. They also reported on the potential energy savings, financial benefits and reductions in greenhouse gas emissions that could accrue from implementing the energy savings opportunities that had a financial payback of up to four years.

Table 5: Total energy use by EEO transport industry entities 2007-08

Transport industry sub-division	Total energy use (PJ)	Share transport industry energy use (%)
Road transport	16.0	6.2
Rail transport	27.0	10.5
Water transport	5.1	2.0
Air transport	195.2	76.1
Other transport services and storage	13.4	5.2
Total transport	256.6	100.0

The dominance of air transport is seen graphically in Figure 10, with the air transport businesses using more than seven times the energy use of their rail transport counterparts. Note that road transport is a relatively small component of the reported data. This is because of the limits on business size required to report.

Figure 10: Total energy use by EEO transport industry entities 2007-08



The reporting entities identified potential energy savings as a share of total energy use and these are listed in Table 6.

Table 6: Identified energy savings by transport industry as a share of total energy use, energy savings and assessed energy

Transport industry sub-division	Energy savings identified (PJ)	Share of total energy savings (%)	Energy savings as a share of total energy use (%)	Energy savings as a share of assessed energy (%)
Air transport	8.46	82.25	4.34	4.64
Road transport	1.28	12.48	8.04	20.13
Rail transport	0.42	4.04	1.54	2.95
Other transport services and storage	0.13	1.23	0.95	2.60
Water transport	-	-	-	-
Total transport	**10.29**	**100.00**	**4.01**	**4.93**

Note: Opportunities for water transport entities were not explicitly quantified and included in the results from first assessments; no energy savings have been reported for this sub-division.

Figure 11: Identified energy savings as a percentage of assessed energy use

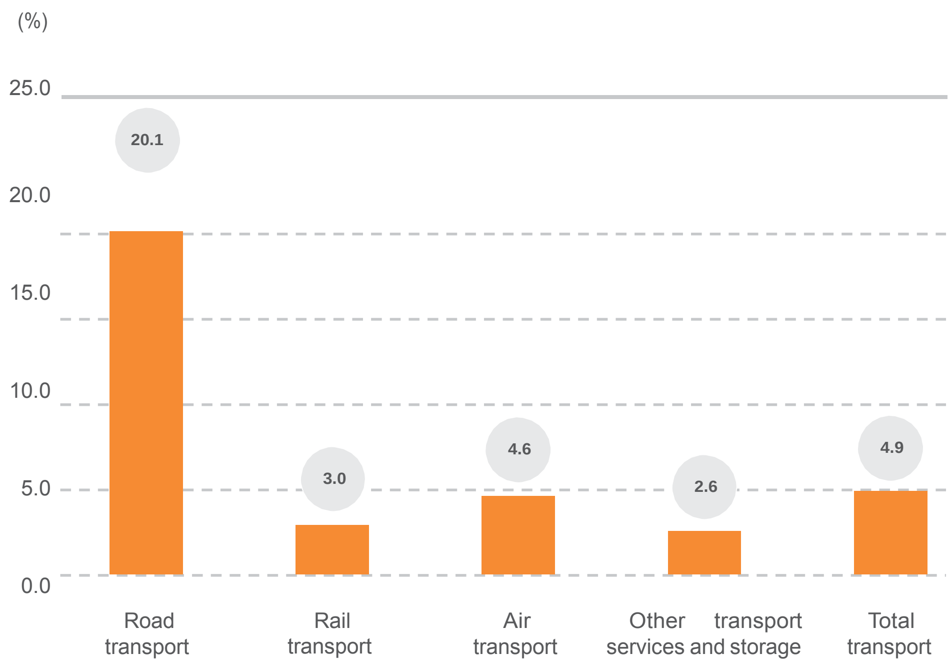
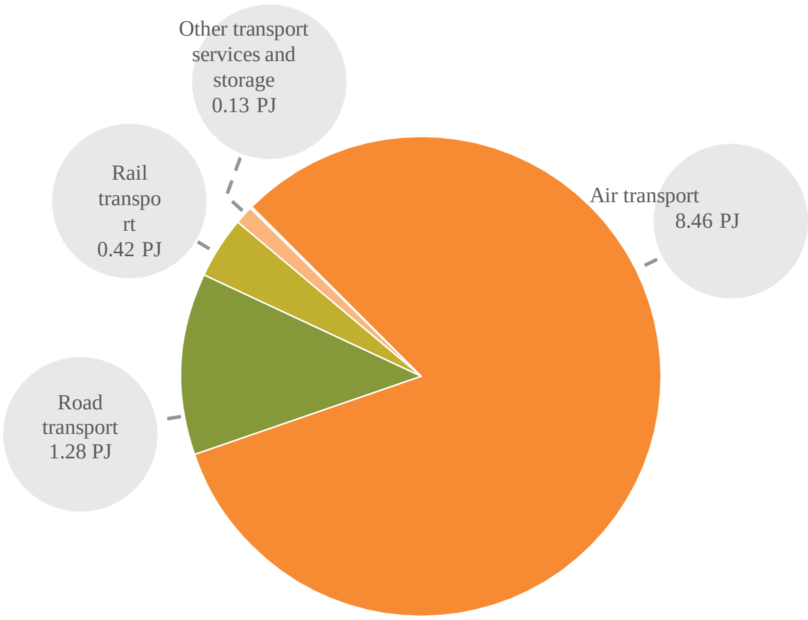


Figure 12: Identified energy savings per year by transport industry



1.5.8 Use of alternative fuels in Australia

Australia has abundant and diverse clean energy resources with significant potential for future development. Currently, renewable energy resources are used for heating and cooling, electricity generation, and as transportation fuels. Renewable resources currently utilised on a commercial scale include hydro and wind energy for electricity generation, and bioenergy and solar energy for both heating and cooling and electricity generation. Other renewable resources are mostly undeveloped at present and involve technologies still at the proof of concept stage or alternatively at the early stages of commercialisation.

The large-scale utilisation of Australia's clean energy resources faces a number of barriers. Changed regulatory and approval processes are affecting well-established technologies like wind farms in some locations. Relatively high upfront capital costs, lack of familiarity with renewable energy technologies and the nature of Australia's capital markets can make it difficult to secure project financing. For some technologies, such as geothermal, energy conversion resources can be located long distances from transmission and distribution infrastructure and markets. Consequently, in some cases the technologies to utilise these resources are immature. Despite these challenges, the deployment of clean energy technologies is gathering pace. Furthermore, it is expected to play a critical role in moving to a low emissions future whilst still meeting Australia's continued demand for energy.

1.5.9 Production of renewable energy

Renewable energy accounted for approximately four per cent of Australia's energy consumption in the year 2010–11; which is equivalent to approximately260 petajoules (Table 7). Whilst the composition is constantly changing, the overall share of renewables in Australia's energy mix has been reasonably constant over the past two decades. Hydroelectricity and various forms of bioenergy have been the dominant sources of renewable energy for a number of decades. In recent years, a number of new technologies such as wind and solar energy have emerged to gain increasing shares of the fuel mix. There is also potential for growth in other emerging technologies such as geothermal and ocean energy in coming decades.

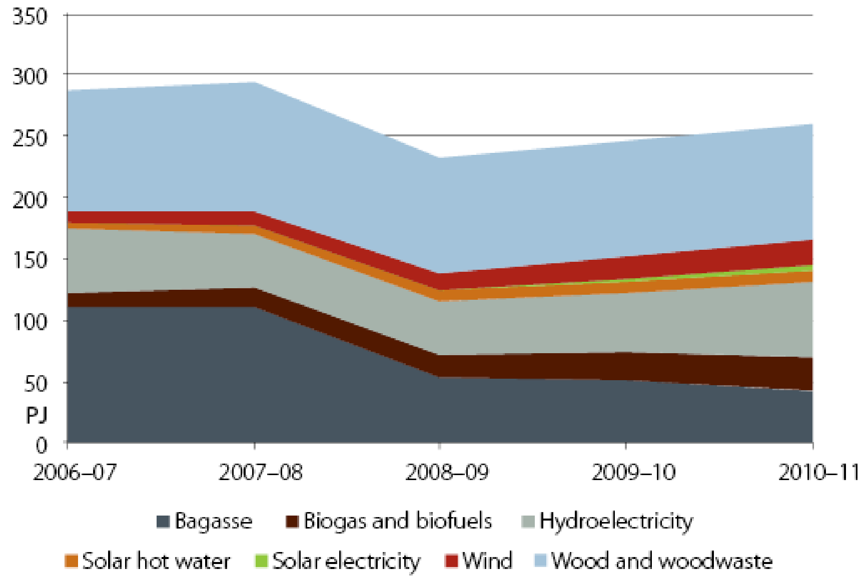
Australian production of renewable energy (including both electricity generation and direct use) was dominated by wood and wood products (36 per cent), hydroelectricity (23 per cent) and bagasse (16 per cent) in the year 2010–11. Wind (8 per cent), solar (5 per cent) and other forms of bioenergy (10 per cent) accounted for the remainder (Figure 12). Most solar energy is used for residential water heating, which accounts for approximately two per cent of final energy consumption in the residential sector.

Table 7: Australia's energy production, by renewable energy source [a]

	2006–07	2007–08	2008–09	2009–10	2010–11
	PJ	PJ	PJ	PJ	PJ
Bagasse	110.8	110.8	52.8	50.2	42.8
Biogas and biofuels	10.8	15.2	20	23.1	27.2
Hydroelectricity	52.3	43.4	42.7	48.8	60.5
Solar hot water	6	6.7	8.2	10.1	11

Solar electricity	0.4	0.4	0.6	1	3.1
Wind	9.4	11.1	13.8	18.2	20.9
Wood and wood waste	96.7	105.9	94.7	95.2	94.8
Total	**286.3**	**293.6**	**232.8**	**246.5**	**260.3**

Figure 13: Australia's energy production, by renewable energy source [a]



a Includes both electricity and heat.

Source: BREE 2012, Australian Energy Statistics.

Renewable energy production declined at an average rate of 2.4 per cent a year in the five years preceding the year 2010–11. This was primarily as a result of falling bagasse use by sugar manufacturers in Queensland and New South Wales. However, in the year 2010–11, renewable energy production increased by six per cent from the previous year. This was largely as a result of increased hydroelectricity generation (24 per cent growth). In the year 2010–11, the strongest growth in renewable energy production occurred in solar-powered electricity generation, which increased by 204 per cent; although it should be noted that this was from a small base. Wind-powered electricity generation and solar hot water also increased considerably; by 15 per cent and 8 per cent, respectively.

1.5.10 Solar energy in Australia

Australia's primary solar energy consumption accounted for 4.2 per cent of all renewable energy use and approximately 0.2 per cent of total primary energy consumption in the year 2010–11. Primary solar consumption has increased significantly since the year 2006–07 at an average growth rate of 22 per cent per year. The bulk of the growth over this period has been from installations of domestic solar hot water systems. Solar PV systems made a smaller contribution; however, installations have been growing more rapidly in recent years (Figure 21). In total, Australia's solar energy consumption in the year 2010–11 was 4.3 TWh (14 PJ). Of this, more than 90 per cent was used in the residential sector. Currently, solar energy has minimal impact in the transport sector.

1.5.11 Use of non-conventional transport fuels in Australia

The transport sector is one of the largest energy consuming sectors in the Australian economy. Conventional fuels (petrol, diesel and jet fuel) currently account for approximately 95 per cent of Australia's transport fuel consumption, whilst non-conventional transport fuels (mainly LPG and biofuels) account for the remaining five per cent. As illustrated in Figure 12, at present the proportion of energy generated from renewable sources used in the transport sector is limited.

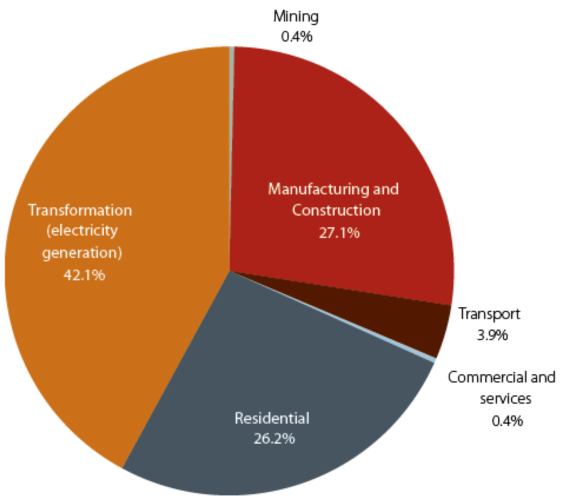
Australia's imports of petroleum products are expected to continue to rise. Increasing the use of alternative fuels and diversifying the fuel mix in the transport market can help mitigate some of the risks Australia is exposed to in the conventional fuel market. Some alternative transport fuels also assist in lowering emissions from the transport sector.

In late 2011, the Australian Government released its Strategic Framework for Alternative Transport Fuels. This document set out a long-term strategic framework to support the market-led development of alternative transport fuels in the context of maintaining liquid fuel security whilst moving toward a low emission economy.

Alternative transport fuels available for use, or expected to become available over the medium to longer term, include biofuels (such as ethanol and biodiesel), gaseous fuels (compressed natural gas, liquefied natural gas and liquefied petroleum gas) and synthetic fuels (coal to liquids, gas to liquids, biomass to liquids and shale to liquids). Australia's electricity grid could also support the uptake of electric vehicles and further electrification of the rail network.

There are a number of policies that encourage the production and use of alternative transport fuels in Australia. Under the Ethanol Production Grants program, grants are provided for the domestic production of ethanol and the Energy Grants Scheme (Cleaner Fuels) provides a grant for the domestic use of biodiesel and renewable diesel. There are also concessional excise arrangements in place for gaseous fuels (LPG, CNG and LNG). The LPG Vehicle Scheme provides grants for the purchase of a new LPG vehicle or the conversion of an existing vehicle to LPG. Fuel tax credits are also available to heavy duty vehicles in some circumstances.

Figure 14: Renewable energy consumption, by sector, 2010–11



Source: BREE 2012, Australian Energy Statistics.

1.6 Implications for Mobility

1.6.1 Impacts of Australia's Critical Dependency on Auto-mobility on Oil Requirements

Most experts agree that automobile dependence is related to an unsustainable urban environment. Interestingly enough, however, such an observation is in stark contrast with the mobility choice and preferences of the global population. In such scenarios, the automobile is the preferred option when income levels reach a certain threshold. Unfortunately, other transport alternatives such as public transport inevitably do not compare with the convenience and ease of access offered by the automobile. Consequently, private and more flexible forms of transportation, such as the automobile, are fundamental to the concept of urban mobility and despite their obvious flaws should not be ignored as options in the debate regarding sustainable transport alternatives. It is interesting to note that a bias often exists in the transport-oriented community with an emphasis on public transit and non-motorised transportation modes as the dominant, if not key strategy towards achieving sustainable transportation. This is despite the fact that almost all public transit systems are financially unsustainable. This subsequently places financial burdens on society as whole. Despite its common exclusion from such discussions, freight transportation must also be included in such debates because of the substantial growth of raw materials and goods being traded in a global economy. Interestingly, however, freight transportation commonly relies on more environmentally sound modes such as rail and maritime transport, although trucking does play a significant role in local markets (Rodrigue 2013) .

Whilst it may appear unlikely, Australia's current fuel resources are worryingly low. Although Australia is one of the world's top energy exporters, its current stocks of liquid fuels are at reduced levels. This includes the oil that the majority of the transport sector is reliant upon. Australia's worsening liquid fuel security problem was detailed in a report prepared for the National Roads and Motorists' Association (NRMA) in early-February 2014. To make matters worse, a year after the issue was first raised, there has been no action to address these growing risks from either a logistical or financial perspective (Vivoda 2014).

According to the report prepared for the NRMA, refinery closures coupled with growing demand for petroleum have increased Australia's dependency on imported refined petroleum products. As a result, oil-dependent sectors such as transport, mining and agriculture are vulnerable to supply-chain interruptions or future oil-price spikes. The situation is worsened by the fact that Australia is the only IEA member state that consistently fails to maintain the mandated stockpile of 90 days' worth of net oil imports. Australia's stockpiles were at 57 days as of November 2013. The NRMA report in question estimates Australia's in-country stockpile, which excludes all shipments en-route to Australia, is at only 23 days (Vivoda 2014).

With a growing demand for liquid fuels and a continued approach from the Federal Government that distances itself from any form of intervention, it is anticipated that by the year 2030 there is a high probability that Australia will find itself with no refining capacity, less than 20 days' worth of liquid fuel stocks, and most importantly will be entirely at the mercy of the international oil market. As a result, the author of the report prepared for the NRMA has called upon the Federal Government to address the problem. This year's National Energy Security Assessment and Energy White Paper suggests making fuel stocks a matter of a national security risk analysis (Vivoda 2014).

Not only is Australia's heavy reliance on imported oil risky, it's ultimately expensive. In 2012, Australia's net oil imports were approximately 561,000 barrels per day. At an average of US$109.08 a barrel for that year, the total bill for these net oil imports was US$22.3 billion, or approximately 1.7% of Australia's Gross Domestic Product (GDP. At the same time, there are fears of a slowdown in Australia's mineral export revenues as China's economy loses pace (Vivoda 2014). Despite the highlighted concerns, currently the Federal Government appears to be refusing to consider the potential threats to Australia's coal, Liquid Natural Gas (LNG) and other mineral exports. For example, Australian LNG costs more than that offered by its African and North American competitors. Furthermore, Australia's customers in Asia are increasingly critical of the prices they are being charged by Australia's exporters.

This apparent complacency of Australia in respect to its oil imports can be traced back to the discovery of oil in the mid-1960s in Bass Strait. Whilst not substantially large by global standards, these reserves increased Australia's oil self-sufficiency from 10% to 70% in the years preceding the 1973 global oil crisis. During this time the price of oil in global markets increased significantly. Four decades later the picture regarding oil self-sufficiency is vastly different, however, the general public do not fully comprehend it. In this respect, approximately only 1% of Australians consider the energy crisis, petrol prices and fossil-fuel supplies to be our most pressing issue. Through potentially a combination of Australia's good fortune during the 1970s and the continuous positive news headlines regarding energy exports, has inadvertently resulted in a free-market approach to the oil market. Alternatively, other nations around the world that suffered greatly as a result of OPEC's competitive pricing strategies during this period, have taken stronger steps towards oil independence and ultimately oil self-sufficiency (Vivoda 2014).

Not only did the Hawke Government's free-market attitude to oil imports continue through the years when Prime Minister, John Howard was in charge, it was documented in Australia's first ever Energy White Paper released in 2004. This Energy White Paper openly acknowledged Australia's oil deficit, but instead of raising the issue as a significant energy security threat, it instead attempted to alleviate these concerns by highlighting the then current surpluses in gas, uranium and coal supplies. The policy implication at this time was clear; that is as long as Australia remained a net energy exporter, its liquid fuel balance was not a cause for concern (Vivoda 2014).

Unfortunately this situation did not change with the Labor Party's return to power in 2007. Similarly to its predecessor, the 2012 Energy White Paper also portrayed the existing situation of Australia as an energy producer and net exporter positively. Ultimately, this implied overall energy security. Now in 2014, the Abbott Government, in preparing this year's Energy White Paper, appears to consider the international oil market so resilient that the supply of crude oil and refined petroleum to Australia is effectively guaranteed (Vivoda 2014).

Interestingly, in 2004, oil prices were rising; however, there were Government forecasts that oil prices could be expected to reduce to US$20 a barrel. However, by mid-2008, oil prices had peaked at approximately US$146 per barrel. Given the recent global financial crisis, oil prices have since receded and so far petrol prices have been restrained. It should be noted that they are expected to increase over the next decade (Laird 2014).

Although Australia remains committed to the basic principles of free-market economics, the consequences would be long-lasting if such an approach results in further reductions in oil supplies. A bipartisan unobtrusive approach and general public complacency regarding Australia's energy future may not serve the nation's best interest in the long term. Energy security issues may inevitably impact ordinary Australians directly through high consumer prices, fuel shortages and the environmental impacts associated with energy consumption. Given the importance of energy to the Australian economy, it is vital that the Government re-evaluates its approach to energy policy and engages in a systematic risk analysis regarding both Australia's growing liquid fuel import dependency and potential threats to demand for its energy exports. In terms of practical solutions to our growing liquid fuels import dependency, meeting the IEA's mandated stockpile levels would be a positive first. The Government should also consider measures aimed at reducing the demand for liquid fuels in Australia and in doing so attempt to lessen the critical impacts of Australia's dependency on the automobile. These might include higher fuel efficiency standards, improving public transport infrastructure and service provision, promoting carpooling, or introducing congestion charges in the central areas the major cities (Vivoda 2014).

1.6.2 Sustainability of Dependence on Self-directed Vehicles

Australia's transport is among the least energy efficient in the world. This can be primarily attributed to the Government's continual investment in roads over rail. A recent international scorecard revealed that Australia has scored poorly in the energy efficiency of its land transport, and is significantly behind other major economies. This unfortunately means that Australians are using more energy to travel each kilometre than people in developed nations such as the US, and other major emerging economies including Brazil, China and India. On overall energy efficiency across national efforts, buildings, industry and transport ranked Australia tenth out of 16 major OECD countries. However, the scorecard, published by the American Council for an Energy-Efficient Economy, found that Australia ranked last for transport and similarly for overall energy efficiency, Australia is clearly experiencing a backward trend. Additionally, the report notes that these deteriorating trends have only happened recently (Laird 2014).

A question that needs to be asked is "how did Australia get here?'' Ultimately this trend is exacerbated by Australia's investment in the construction of new roads to the detriment of urban transit. In the first budget prepared by the Abbott government, approximately A$4.25 billion of funds originally allocated for urban rail construction were withdrawn and instead re-allocated to the construction of new roads.

On a recent scorecard, using OECD, IEA and other independent data, Australia's transport was ranked against 15 other countries. In this process, countries could earn a possible 25 points for on-land transport energy efficiency, according to eight different criteria. On three of the eight criteria, Australia scored zero points. These three criteria included fuel economy of passenger vehicles, with respect to performance and the setting of future standards and for having no fuel efficiency standards for heavy trucks. On the four criteria allocated to public transport utilisation and the investment in rail transit as compared to roads, Australia scored just one point for each. It was only in the criterion defined "energy intensity of freight transport" that Australia did get full marks. It should be noted that this score was significantly assisted by the very high energy efficiency of the iron ore railways in the Pilbara region of Western Australia (Laird 2014).

During the 2011/12 financial year cars, buses and trucks used nearly 32 billion litres of petrol, diesel, and LPG. By comparison, rail used 1.67 billion litres of diesel (or its electricity equivalent) in a year for a smaller passenger task but a larger freight task than its on-road equivalent. This reflects the fact that rail is significantly more energy efficient than road transport in moving both people and freight.

During the late 1990s, both the Chartered Institute of Logistics and Transport, and Engineers Australia issued a number of warnings that cheap oil would not last forever, and more energy efficient transport was required if Australia was to address its then unsustainable oil requirements. These warnings, and a subsequent one delivered in 2002 by the then Australian Treasury Secretary, highlighted the very challenging problems posed to future generations resulting from predicted increases in urban traffic and interstate road freight (Laird 2014).

As noted in the preceding section, not only is the cost of oil a key reason for change, a further reason for reform is the actual amount of money spent on roads and road vehicle usage. In the early 1990s, research commissioned by the Australian Automobile Association determined that the total cost of road vehicle operations, including the resultant fuel consumption, the buying and maintaining of vehicles, road works, road crashes and all associated external costs represented approximately 11% of GDP. In 2013-14 terms, this figure equates to A$173 billion per annum. Given fuel costs and road outlays has increased at a rate that is greater than inflation over the past 20 years, and allowing for the growing high levels of road congestion, this estimate is most likely conservative (Laird 2014). There are numerous hidden costs of road vehicle use, not including road congestion, leading to a "road deficit" of approximately 1% of GDP. Road congestion costs add a further 1% (approximately) of GDP and traffic congestion and therefore these costs cannot simply be reduced by the construction of more roads. Additionally, Australia's four largest cities need major urban rail upgrades, and the states need federal funds to progress the new rail construction. Examples include a second Sydney Harbour rail crossing and the new Melbourne Rail Link (Metro) (Laird 2014).

A recent report prepared by the Bureau of Infrastructure Transport and Regional Economics acknowledged that Australia's three levels of Government in combination with the private sector are now spending in excess of A$20 billion a year on road construction and maintenance. Informed comment on our land transport policy has been provided in a recent report titled "Spend more, waste more. Australia's roads in 2014: moving beyond gambling". As noted by this report, "between 2008-09 and 2011-12, approximately A$4.5 billion more was spent on roads than was raised in almost all road-related taxes and charges." After noting the need for reform in road pricing, this report concluded that the annual outlay on roads, which is set to grow even larger, is a "road spend [that] can only be described as hideously inefficient." Ultimately, building more freeways will induce more traffic, resulting in increased road congestion with greater demands for liquid fuel use. A more sustainable approach would be for Australia's major cities to expand their urban railways, and for people to make greater use of rail, buses, cycling and/or walking; thus reducing liquid fuel use and all resultant emissions (Laird 2014).

1.6.3 Increased Likelihood of Less Flexible Transport Forms

Whilst the implementation of demand-oriented policies and mechanisms are an important component in promoting sustainable transport, it is important that these measures be coupled with transport supply improvements. Transportation infrastructure needs to be expanded to accommodate rapidly growing transport demands. As long as the global urban population continues to grow, there are pressures to expand urban transport infrastructures. In urban areas the biggest challenge is to expand and improve the transportation supply in a manner that the automobile and trucking are only part of the equation rather than the primary focus as they are currently. Consequently, in order to implement effective transport supply expansion policies, fast, efficient, reliable and accessible transport alternatives must be provided. The preferred approach is through private initiatives. For passengers, this can be achieved by expanding public transit infrastructure, improving existing public transit services, and by making cities friendly to both pedestrians and non-motorised forms vehicles (Rodrigue 2013).

The issue of sustainability is providing public transit with a new impetus given all previous emphasis was on its ability to mitigate automobile dependency and provide equity in mobility. Finally, it is acknowledged that this is an extremely difficult challenge considering the dominance that the automobile has and continues to impose globally. It must be noted that this continued prominence is the result of many positive factors favouring the automobile that include flexibility, convenience and relatively low costs. As a result, automobile dependency is therefore the end-result of market forces expressed as consumer preferences and national manufacturing policies. Consequently, all transportation alternatives that can be provided must do so only if they prove to be cost effective whilst ultimately fulfilling a particular demand (Rodrigue 2013).

Both public and private transport as less and more flexible forms of transportation respectively has important roles to fulfil. The long-term trend has been a substantial growth of private transport and this is despite all of the efforts made (particularly of recent) to promote public transportation. In the North American context, this has witnessed limited success. As a result, public transportation being the least flexible of both forms of transport needs to perform a complementary role and not just a primary role as was often believed to be the situation. The expansion and development of mass transit systems must not only satisfy a niche demand but also make effective use of urban space by conforming to a range of factors including urban form, density, and modal preferences. Furthermore, the fleets and networks used to provide these services must ensure a level of flexibility whilst guaranteeing low ridership costs which as an end-result need to reduce both per-passenger pollution levels and traffic congestion. In respect to existing public transit services, methods of improving and upgrading should include the improvement of service coverage and quality in addition to increasing frequency where and when it is most needed, i.e. during peak periods. Additionally, the designed modes of mass transit transportation which may include subway, light-rail, trams, buses, 'group' taxis or a combination need to be designed, implemented, and operated in a manner that not only facilitates complementarity and inter-changeability but needs to do so whilst remaining cost-effective (Rodrigue 2013).

The integration of individual modes of non-motorised transport modes such as walking and cycling, if properly promoted and encouraged, can provide access to local area attractors such as shopping centres, schools and work. Additionally, for cities struggling with the impacts of serious traffic congestion and air pollution, non-motorised transport should be considered as a viable alternative whilst serving a role as a crucial link in an integrated public transportation system. Although cycling can be a challenging mode to promote and integrate into the urban transport system; primarily due to issues with weather extremes, i.e. winter or excessive heat, there is a clear and currently unsatisfied need to better integrate pedestrian movements into sound urban design and architecture (Rodrigue 2013).

1.6.4 Implications of Fixed Route Transport Solutions

The vast majority of Australia's key cities have now developed strategies and have set targets for increased mode share of public transport, walking and cycling and reduced car usage; however, none of these cities have taken the essential next step to implement a funded plan. Sustainable cities and sustainable transport systems will remain a distant dream until all tiers of Government adopt a plan and an implementation strategy that is fully funded in budgets. Unfortunately, the experience to date in

Australian cities is that improved sustainable transport options have not been fully supported through funding and implementation. Ultimately, the achievement of a sustainable transport system for each city requires a commitment to the development and implementation of a long-term plan (Richardson and Newman 2008).

There is now significant evidence to demonstrate that increased use of public transport can be encouraged by improvements to service and frequency (Richardson and Burgess 2005). In both Australia and North America, there has been a resurgence of the use of public transport, particularly rail but additionally light rail and bus-way systems along dedicated rights of way. In recent years, the rate of growth of patronage has become restrained due to a lack of capacity on such systems during peak periods. This lack of capacity, particularly in train networks is clearly evident in all of Australia's major cities where suburban railway networks exist. In moving forward, the new paradigm in developing public transport systems is to ensure that they are fast, frequent, well connected and most importantly have the capacity to carry all of the commuters who wish to use them (Richardson and Newman 2008).

If Australia is to move towards a sustainable transport system in all of its major cities, the existing public transport system must be developed and improved so that it has the capability to move approximately four times the current patronage by the year 2030. A failure to expand the public transport system by at least this magnitude will expose Australian cities to enormous risk from increased petrol prices, potential petrol rationing and growth and capacity restraints on the road system resulting from increased traffic congestion. Furthermore, if Australian cities are to be sustainable cities, they must be developed as transit cities. Such cities are more than simply cities with transit. Instead these cities must comprise of a network of fixed route systems operating at frequencies less than ten-minute intervals all day so that passengers can make use of the services without the need for a timetable. Furthermore, these systems need to be able to accommodate so that transfers between services can take place with minimal inconvenience and time (Richardson and Burgess 2005).

In order to overcome the car dependence that currently exists we need to have transportation and land use options which are more favourable for sustainable transport modes, i.e. they need to save time, if they are used in preference to the automobile. People cannot be expected to overcome car dependence unless a city provides them with options that mean they can maintain their travel time budget to approximately one hour a day. In summary this means (Richardson and Burgess 2005):

- Transit needs to be faster than traffic down each major corridor; and
- More people need to live and work where they can have sustainable transportation options

Sprawling development inevitably means that most journeys require a car. To reverse this trend requires transit to be faster than traffic down main corridors, or at least in peak periods. It also necessitates that Transit Oriented Developments (TODs) need to be built around the stations (Richardson and Burgess 2005). TODs consists of mixed-use, higher-density development centred on a major public transport access point. They includes residential, retail and employment activities as well as high quality open spaces (Arup 2014). Key transformative urban change is often the end-result from the development of rail systems as they provide a faster option than the car on a sustainable basis (Richardson and Burgess 2005).

1.7 Implications for Transport Infrastructure

1.7.1 Implications for all Forms of Transport Infrastructure

In the 2014 Federal budget prepared by the Abbott Government, an additional A$11.6 billion was committed to what is described as an "infrastructure growth package" that is primarily focussed upon roads, but according to the Government aimed at fast-tracking what it believes to be critical infrastructure. In part, this package will be funded by what is described as an asset recycling initiative which will cost the Government a further A$5 billion over five years in order to encourage the states to sell assets and redirect the funds into infrastructure. In summary asset recycling will work as follows (Bliemer, Standen et al. 2014):

- State sells asset:
  - For example, the State sells an asset for A$1 billion and reinvests A$800 million in new infrastructure.
- Federal Government provides 15% of the sale price multiplied by the proportion invested by the State:
  - For the example in question this would equate to 15% of A$800 million or A$120 million.
- Payments to the State are then made in the following two stages:
  - 50% when asset sale process starts and infrastructure planning commences; and
  - Remainder will be paid on the sale of the asset and commencement of the infrastructure project.

Funds for the asset recycling initiative will be generated from the sale of Medibank Private and the potential sale of the Royal Australian Mint, Defence Housing Australia, Australian Hearing, and the registry services business of ASIC (Bliemer, Standen et al. 2014) .

Additionally, a further A$3.7 billion will be directed towards road projects, including A$2.9 billion for Sydney's WestConnex, Melbourne's East-West Link, Adelaide's North-South Corridor, Northern Territory road upgrades, the Toowoomba Second Range Crossing, and the Perth Freight Link. This funding will also extend to national highway upgrades, black spots, and the Roads to Recovery program. Furthermore, an additional A$2.9 billion will go to support the Badgerys Creek airport in Western Sydney, which is part of a larger ten-year A$3.5 billion Western Sydney Infrastructure Plan being delivered in conjunction with the New South Wales State Government. Combined, the total Federal Budget investment is expected to result in an additional infrastructure investment of A$125 billion, and add approximately 1 percentage point to GDP. To generate the finance required for this additional spending, the Federal Government reintroduced the bi-annual indexation of the fuel excise, which commenced in August 2014 (Bliemer, Standen et al. 2014).

In an attempt to improve project selection and delivery, the Government plans to introduce new governance arrangements for Infrastructure Australia (IA), in order to provide it with greater independence and transparency. IA will now be required to undertake audits of Australia's infrastructure asset base every five years and develop a 15-year infrastructure plan. Furthermore, IA will now also be responsible for evaluating proposals of 'natural significance' in respect to economic infrastructure, as well as proposals in the health and education sectors. Lastly, it will now be requested to evaluate projects seeking in excess of $100 million of Government funding (Bliemer, Standen et al. 2014).

1.7.2 Barriers to Achieving Necessary Urban and Regional Planning Requirements

In terms of planning, Transit Oriented Developments [TODs] can improve connectivity between various activities and amenities and provide opportunities for social interaction and access to jobs. The most successful TODs are people-focused developments which prioritise liveability, mobility and choice. They are walkable, vibrant and safe neighbourhoods connected to frequent and reliable transit services. Good TODs can provide all the benefits associated with liveable communities: a mix of uses that makes it possible to get around without a car, a greater mix of housing types and transportation choices, an increased sense of community among residents, a heightened sense of place (United States Environmental Protection Agency). These developments produce lower greenhouse gas emissions (as much as 43% lower than conventional suburban development) and promote more active lifestyles. They also create value for property owners, businesses, local governments, transit agencies and residents (Arup 2014).

Due to the concentration of development and business activities, TODs generate value that can be subsequently reinvested in communities. Some of the value capture strategies include the following (Arup 2014):

- Property and sales taxes;
- Real estate lease and sales revenues;
- Parking fees;
- Joint development;
- Special assessment districts; and
- Public-private partnerships.

There are generally four main aspects to create successful TODs and these include (Arup 2014):

- Connect dense employment centres. Understanding the relationship between employment centres and residential TODs is an important part of the TODs equation.
- Regional collaboration within the greater metro area and between metro areas.
- Proactive planning and public policies to encourage TODs as government support for TODs is the strongest predictor of success.
- Public-private partnerships for joint development to leverage private sector investment along the transit line.

Community Development Corporations (CDCs) can make use of TODs to stimulate comprehensive and lasting revitalisation in neighbourhoods and increase affordability because families that make use of transit ultimately spend less money on transportation. CDCs can play a significant role in neighbourhoods that have been bypassed by the market and are not a high priority for local Governments or transit agencies by initiating projects that will benefit the community (United States Environmental Protection Agency).

Most cities in the USA regulate development through conventional zoning; the primary purpose of which is to segregate incompatible land uses and accommodate the movement and storage of vehicles. Unfortunately, these codes date back to concerns about the industrialisation of American cities at the beginning of the last century and are no longer as relevant to the realities of cities today. Shifting demographics and the changing real estate market have created an unprecedented window of opportunity to channel growth into liveable communities situated adjacent key transit corridors. This opportunity represents one that should be taken advantage of since it is increasingly clear that one of the most sustainable, low-cost, long-term solutions to addressing a number of global problems ranging from climate change to the dependence on foreign oil – is public-private investment in neighbourhoods where people no longer need to drive (United States Environmental Protection Agency).

A public-private partnership is a contractual agreement between a public agency (Federal, State or Local) and a private sector entity that makes use of the skills and assets of both with the key aim being to deliver a service or development for public benefit. Public-private partnerships are especially useful for generating private investment in TODs for the following reasons (United States Environmental Protection Agency):

- They are more flexible than joint development arrangements, and
- They do not require publicly owned land, however, as with any joint development, each partner does bring with it elements to assist the arrangement.

Local Governments, for example, can assist in assembling land, rezoning it, and ultimately funding environmental remediation with Federal Government grants. Private investment can also be provided if a local Government provides an 'in-kind' match, 'in-lieu-of' fees, or gap financing. The combination of public and private entities is a progressive, pragmatic solution to the practical difficulty associated with completing certain tasks. Local Governments in particular, can be particularly effective in providing incentives to the kind of projects they want by working with developers to mitigate the following four risks associated with in the development process (United States Environmental Protection Agency):

- Entitlement risk - bringing communities to consensus on a station area plan that creates predictability for both the community and the developer, and by expediting the review process.
- Construction risk - prioritising inspection services for TODs, and by vetting contractors.
- Financial risk - working with local banks to provide lower-cost mezzanine loans; a type of debt used for commercial and multi=family construction that is typically very expensive.
- Marketing of the finished development, i.e. advertising its proximity to local transit.

Generally speaking, transit agencies or cities cannot create TODs that generate high ridership and achieve other public goals on their own. They are not likely to own enough land at stations to create projects of monumental change, and their real estate departments may lack the necessary staff, resources and/or sophistication assuming they exist. However, many transit agencies and cities do enter into joint arrangements with private development partners on publicly-owned land to ensure that it is built with the functionality required that will support increased transit ridership, or development that supports other public goals including affordability and neighbourhood revitalisation. Private developers bring with them their own resources, including additional property, and expertise to joint development projects, which ultimately seeks to increases the success of the proposed development (United States Environmental Protection Agency).

1.8 Technology implications of Health and Social Effects on Transport

Brief reference is made here to the outcomes of the parallel studies of Health Effects and

Social Impacts in terms of their implications for transport.

1.8.1 Key factors influencing transport choice and individual health

- Higher residential densities, good street connectivity based on grid networks, mixed land use and high-quality active transport infrastructure are associated with higher levels of walking and cycling
- Shorter distances to public transport stops are associated with higher levels of walking, especially among people on lower incomes who are more reliant on public transport
- Having accessible and attractive public open space and recreation facilities is associated with higher levels of recreational physical activity, particularly walking
- There is widespread recognition that land use and transportation planning decisions contribute to individual transportation choices
- Whilst these relationships are not straightforward, decisions about the way we build cities impact the ability and willingness of individuals to use alternative modes of transport
- Re-designing cities to support active modes of transport would therefore have co-benefits across multiple portfolios including health, environment and transport
- Purpose of travel: results from household travel surveys show that the three main reasons for travel are to fulfil daily requirements including: social and recreation purposes, shopping and commuting

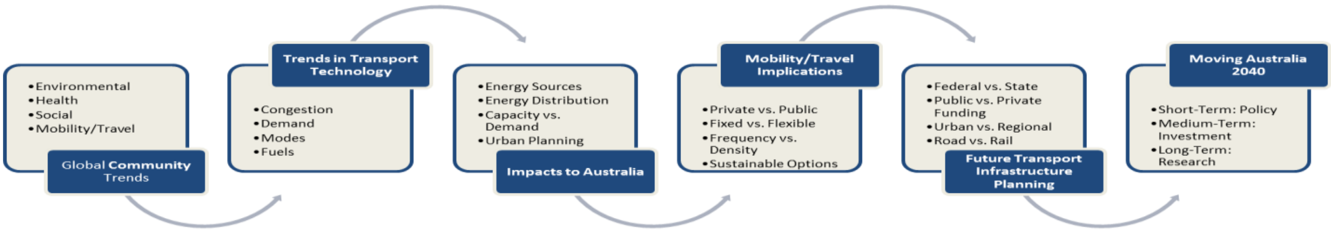
- Transport mode: the vast majority of trips in Australian cities are made by motor vehicle, with car transport (either as a driver or passenger) accounting for around 70-80% of trips
- Distance travelled: motor vehicle transport dominates Australian cities, despite the fact that a large proportion of trips are short
- Transport poverty: an increasing number of people are living further away from central business districts and activity centres. This increases distances between where people live and where they need to travel for work, shopping, socialising and recreation
- Low density housing continues to be built on the urban fringe of Australian cities. Fringe developments are typically characterised by: low housing and employment density, limited (if any) mixed use development, poor access to public transport and poorly connected street networks
- Walkability: there are a variety of reasons why people choose walking as a means of transport including: the ability of residents to walk locally, which depends on neighbourhood design and a walkable neighbourhood, having higher levels of population density, with connected street networks and local destinations
- Access to cycling infrastructure: a key factor influencing community well-being is access to a principal bicycle network with 400 meters of residents' homes
- Access to public transport: residents of outer suburban developments are vulnerable to mortgage and oil stress should fuel prices rise, given they have very poor access to public transport

1.8.2 Key behavioural factors as barriers and pathways in Australian transport decisions

- External barriers to transport choice: utility and cost, local availability, social disadvantage and neighbourhood design.
- Subjective influences on travel choices:
  - personal attitudes, social norms, beliefs, habits and fears
  - personal and cultural appeal of the car, including its promise of power and freedom and the comfort and privacy afforded
  - fear and perception of risk are important barriers to transport decisions, including fear of traffic and fear of violent crime, which are the two main reasons given for increasingly driving children to school rather than allowing them to walk, cycle or take public transport
  - fear of crime also influences women's use of public space and public transport
- Pathways to sustainable transport futures include:
  - 'peak car' literature indicates that car use is tapering off in younger people
  - tapering-off car use in many developed countries is also linked to disillusionment with the inefficiencies of cars in some urban areas: congestion is one factor and 'peak car' usage suggests that many cities are transitioning to a new transport era where of car domination is being eroded, in part as the result of traffic congestion and the self-limiting factors of high car use
  - one of the factors shown to prompt mode shift by people with a preference to driving is a lack of free parking
  - car parking requirements and by association, availability, strongly influences car ownership and housing market outcomes
  - there are strong but often under-acknowledged links between parking and housing supply
  - there is some evidence that in locations with high land prices and high transport accessibility, parking demand is elastic – households will purchase more or less parking depending on their preferences and ability to pay
  - the possibility exists that rather than influencing travel choices directly, local transport infrastructure influences where people would choose to live
  - emerging transport modes can be broadly categorised as: car sharing schemes, bike sharing, private buses, private taxi sharing and driverless cars
  - four main strategies exist for addressing urban traffic congestion: planning, prohibition, pricing and marketing. The potential of marketing of sustainable transport is often underestimated; there is potential to prompt different travel preferences without hard infrastructure.

1.9 Key transformative steps for Australia to take

The schematic below illustrates the linkages between current and future trends in transport and provides a framework within which to think about transformative steps that may be appropriate for Australia.



1.9.1 Stimulus

Australian governments need to stimulate infill development of our existing urban areas in order to prevent urban sprawl that exacerbates the transport challenge for residents and businesses and reduces the sustainability of our country. Government policies that stimulate fringe development and hinder infill development, whilst pandering to the development community, ought to be withdrawn and redirected. Such stimuli could include the use of TODs to expand the options available to urban dwellers.

1.9.2 Initiatives

There are a range of initiatives that should be taken to improve the energy efficiency of our existing transport modes and to encourage the adoption of more efficient transport modes. The now-abandoned Energy Efficiency Opportunities Scheme [Section 1.5.7] identified several opportunities for achievement of energy efficiency and these initiatives could be continued, perhaps without need for legislation. Other examples of such initiatives have been provided in Section 1.6.

1.9.3 Research

Australia will increasingly be the importer of research outcomes, not the initiator. But opportunities to initiate research appropriate to this country's needs remain and Australia should seek out global research partners facing similar challenges.

There is evidence that *millennials* are driving less than their parents – research that aimed to understand the drivers for this and sought to embed those behaviours in current and future generations would be most beneficial.

Development of socially, politically acceptable and equitable forms of travel pricing [not just roads] will be an urgent research priority.

It will be fundamentally important that future transport solutions embed and improve the resilience of our communities, transport links, freight corridors, ports etc. Given our high degree of urbanisation - in locations adjacent to the coast - our transport links are particularly vulnerable to rises in sea level.

1.9.4 Innovation

There exists significant scope for innovation in the development of transport systems and the adoption of international technologies to suit a different future. Solution flexibility will be a key requirement, as the behaviours and living patterns of citizens will change in the future.

1.9.5 Investment

Transport infrastructure provision has always posed a significant investment need and the challenges for prioritisation, efficient and effective planning, design, construction and operation have never been greater. Given the relative shortage of funds for transport investment and the changing nature of demand scenarios project selection should be biased toward many, less expensive projects than one or two projects that are high cost and, potentially, risk.

1.9.6 Regulation

Many of the proposals above will require some changes to regulations and, in some cases, the introduction of regulation. Given recent Government initiatives the introduction of regulation is likely to prove problematic and will require careful positioning and argument. Technocrats will need to become adept at marshalling the necessary policy arguments.

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ACOLA Project 08

Securing Australia's Future: Sustainable Urban Mobility

Technology Study Addendum

Singleton and Pender
December 2014

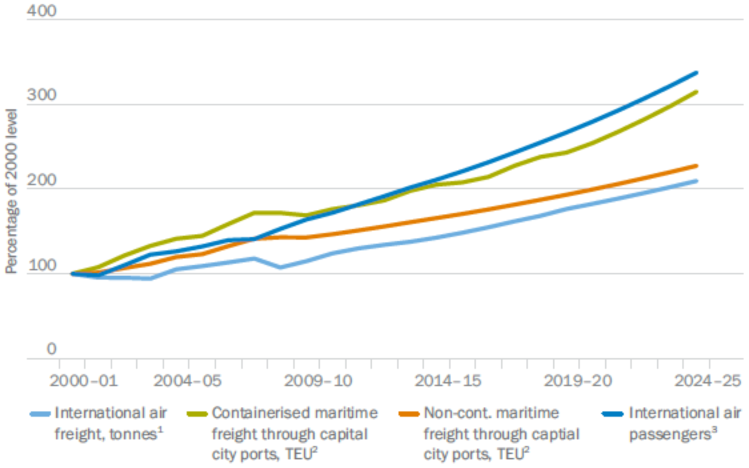
1 Transport Technology: Addendum

1.1 Introduction

This addendum to the main Technology Study report addresses the aviation and freight sectors; in a number of cases base data is noted by reference to the main report (Singleton and Pender, November 2014). Similarly figure and table references are from that document, unless otherwise noted. The maritime sector is addressed as a component of the freight sector.

In the period to 2061 and on 'medium' growth projections, the combined population in Australia's capital cities will grow by nearly 16 million and the proportion of Australians living in a capital city will significantly increase, from 66.0% in 2011 to 73.4% in 2061. Similarly, with rapidly changing social and economic circumstances, the demands on our transport systems will grow significantly. 'Business as usual' will not be sufficient to achieve sustainable mobility outcomes as our transport systems lack sustainability at present. Predicted growth in freight and passenger demand in Australia to 2025 is illustrated in Figure A1.

Figure A1: Growth in Australian freight and passenger tasks



Sources: 1 Hamal, K 2011, International air freight movements through Australian airports to 2030, 2011 Australasian Transport Research Forum
2 BITRE 2010, Australian Maritime Acitivity to 2029–30
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The aviation and freight technology sectors comprise many potential pathways, in terms of providing for Australia's current and future transport needs in those sectors. Australia will increasingly be an importer of technology, particularly in the transport sector, and so it is important that policy makers and planners remain aware of global technology trends, picking the 'right' solutions and avoiding those that are not relevant to domestic circumstances.

1.2 Aviation

1.2.1 Aviation Trends – Developments in the Next 25 Years

Approximately sixty years ago, civil aviation as an industry was in its infancy, as it was only responsible for a tiny proportion of the global transport sector. Today it is an integral part of the world economy, accounting for approximately nine per cent of global GDP and carrying in excess of two billion passengers and 41 million tonnes of freight and mail each year (International Civil Aviation Organisation (ICAO) 2007). Total world revenue traffic (international and domestic, passenger and cargo) on scheduled airlines in 2006 exceeded 510 billion Revenue Total Kilometres (RTK), including almost four trillion Revenue Passenger Kilometres (RPK)[1]. Cargo traffic is anticipated to grow at approximately six per cent over the same period. If these forecasts are realised, passenger (RPK) and cargo (RTK) traffic will increase by 180 and 220 per cent respectively in the twenty-year period from 2006 to 2026 (Macintosh and Wallace 2009). This success of the aviation industry is poised to continue with industry forecasts predicting worldwide Revenue Total Kilometres to continue growing at an average rate of approximately five per cent per annum over the next 20 years (Airbus 2007, Boeing 2007).

A major part of the European airline industry was in severe difficulty well before the traumatic events of the 11th of September 2001, with a number of factors starting to impact adversely on the industry's financial fortunes from the year 2000. It is important to understand this recent history given its implications for future trends. A 'slowing down' in key national economies such as those of Germany and Japan, in addition to several more in Europe, had reduced sustained airline traffic growth. The collapse of the 'dot.com' boom undermined business confidence which in turn impacted the demand for business travel. Simultaneously, in many long-haul markets, overcapacity was becoming a serious problem. This overcapacity in conjunction with a rapid growth of low-cost operators such as Ryanair, especially in intra-European markets, was resulting in a strong downward pressure on average fares and yields, despite an increase in costs. From October 1998 to October 2000, fuel prices doubled, whilst labour rates continued to rise as a result of new wage agreements negotiated in the aftermath of the profitable period from 1995 to 1999. Inevitably the events of 11 September 2001 turned a growing crisis into disaster as traffic levels in many key markets collapsed; especially on the North Atlantic. Furthermore, a number of key European airlines filed for bankruptcy and most of Europe's scheduled airlines posted large losses or severely diminished profits for the same year. Only the large low-cost carriers such as Ryanair and EasyJet reversed this trend by demonstrating increased profits (Mason and Alamdari 2007).

With this in mind, however, the post-2008 global recession has had a significant impact on airlines' finances, both for passenger and air cargo activities. Although a reduced demand had been expected as part of a cyclical downturn, the crisis came significantly sooner and with a greater impact than most experts had anticipated. Firstly, in 2008 an increase in fuel prices reduced airline profits and this was shortly followed by a weakened finance sector which inevitably reduced demand for air travel. Given that most airlines had learnt from the onset of the recession that followed the events of the September 11th 2001 terrorist (9/11) attack in the USA, they reacted very quickly to this downturn by grounding considerable capacity in the short-term (Franke and John 2011).

[1] Total world revenue traffic (international and domestic, passenger and cargo) on scheduled airlines in 2006 exceeded 510 billion revenue tonne kilometres (RTK), which included almost four trillion revenue passenger kilometres (RPK).

Mason and Alamdari (2007) report on a study conducted to identify future trends in the European air transport sector in the forthcoming 10-15 years. The study is based on the views of industry experts, who have highlighted the following:

- Business travellers will increasingly seek better value for money leading to the end of business class services in short-haul markets;
- Leisure travellers will take advantage of low fares to vacation more frequently within Europe and further abroad;
- The airline market is likely to consolidate into a small number of very large network carriers and a similarly small number of very large low-cost carriers;
- The surviving low-cost carriers will prosper and will eventually carry approximately half of all intra-Europe air traffic;
- Feeder services into main hub airports will increasingly be operated by lower cost-based franchised partner airlines;
- There will continue to be an independent role for the small and medium sized European carriers by focussing on point-to-point markets and feeding traffic to large network airlines;
- High-speed rail could also feed into main hubs where the infrastructure allows, but elsewhere is likely to compete with short-haul air services;
- Competition for network carriers will continue to intensify on major long-haul markets; and
- Services to the Gulf and beyond will become increasingly vulnerable to competition from airlines based in this region given their large expansion in capacity.

On a related note, airport infrastructure has had to cope with this range of changing demands; the main one being the growth in air traffic over recent years. To a certain extent this growth is now being restrained by the fuel price increases and the resultant impacts to demand for air travel. Furthermore, there have been changes in the patterns of the demands placed upon airport infrastructure, resulting from the changes in airline business models such as the growth in low-cost carriers and the introduction of new aircraft types. Recently launched aircraft types such as the Airbus A380 and Boeing 787 are now in service and, in the case of the Airbus A380, the need to have two aerobridge's to aid boarding and disembarking passengers and the increased wingspan of these planes has meant airports have had to reconfigure certain aspects of their terminal design and apron parking to accommodate these planes (Forsyth 2007).

Increasing demand and changing patterns of demand pose an adjustment problem for airports. Increased demand places pressure on airport facilities, which often cannot be addressed in the short-term. It is possible for most airports to cope in the short-term without significant capacity additions but increased delays will result. Unfortunately, terminals will become more congested, especially if it is difficult to provide adequate facilities for security screening. Although airports will cope, there may still be an underlying problem concerning the efficiency with which their limited capacity is allocated to multiple users. In the long-term, the expansion of airport capacity may not ultimately result in the most efficient form. Airports are subject to strong environmental and political constraints on expansion and the ownership and regulatory frameworks which many operate in mean that investments in capacity expansion will often not be directed to the most cost-effective solutions (Forsyth 2007).

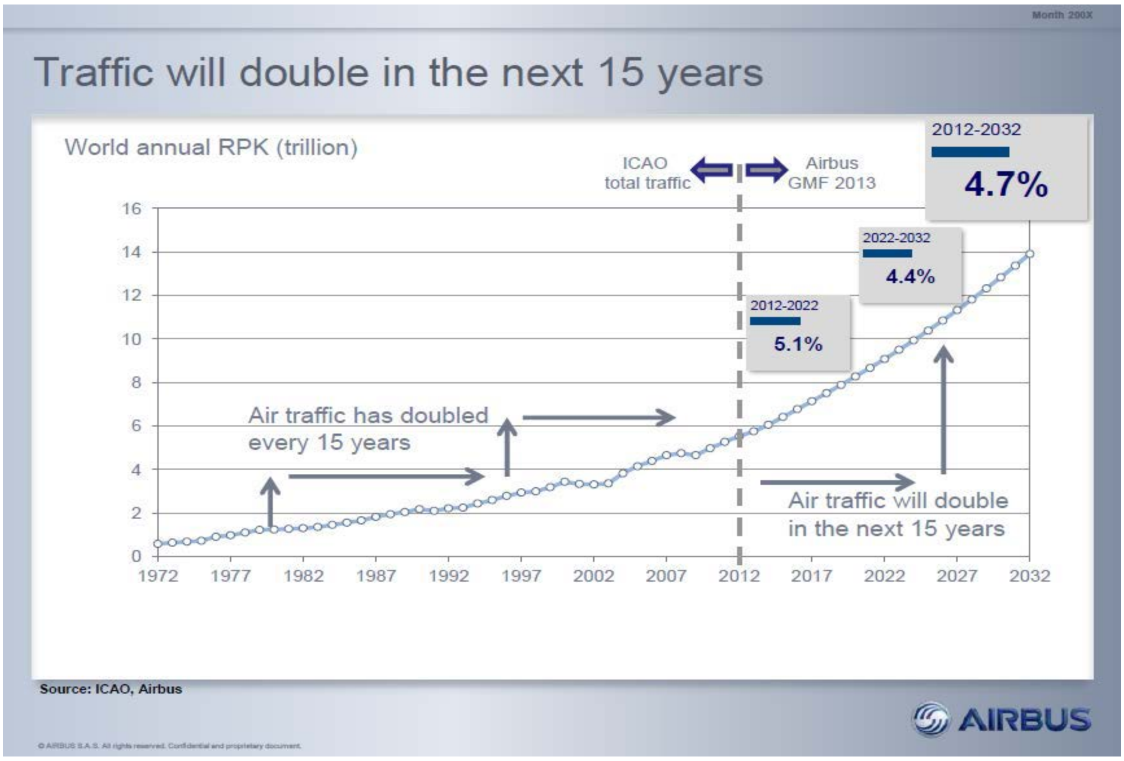

Figure A2: Growth in global aviation traffic

Airports are also facing changes in the patterns of the demand, from both new airline business models (such as low-cost carriers) and from new aircraft types. The latter are not likely to have a significant impact on the use of airports. The new business models, however, are making a difference. The increasing use of secondary airports or major airports with spare capacity is lessening the pressure arising from demand growth. However, with the proliferation of local airport subsidies and cross-subsidies within major airports and in airport systems, it is likely that a less than ideal allocation of air traffic to airports will result (Forsyth 2007).

1.2.2 Aviation Technology Trends – Implications

Continuing rapid growth in aviation will provide economic benefits and allow greater mobility amongst the world's population. However, these benefits will come at a cost, most notably a significant increase in aviation greenhouse gas emissions. Whilst aviation is not currently one of the main drivers of global emissions, the current rate of growth in this sector suggests it could become a contributing factor in the coming decades. A report prepared by the Intergovernmental Panel on Climate Change (IPCC) in 1999 (on request of the ICAO) determined that civil aviation carbon dioxide (CO_2) emissions could rise by between approximately 60 per cent and 1000 per cent between 1992 and 2050 (Intergovernmental Panel on Climate Change (IPCC) 1999). Furthermore, more recent research highlights that as strong global economic growth continues, aviation CO_2 emissions are likely to experience in excess of a three-fold increase between the years 2000 and 2050 (Berghof, Schmitt et al. 2005, Horton 2006). Concerns about rapid growth in the industry and the associated threat to the climate system have prompted debate about the future of aviation (Macintosh & Wallace 2009).

Concerns about emissions growth have led to calls for additional market measures to be introduced to restrict demand and prompt innovation in international aviation. These proposals have met with resistance, given that many Governments have been concerned about the potential for such measures to adversely affect the aviation sector and associated industries such as tourism. As a whole the international aviation industry is facing increasing pressure to reduce the growth in greenhouse gas emissions. To date the industry as a whole has been able to deflect calls for the imposition of effective abatement measures because it has been able to successfully argue that it is only a minor cause of global warming and that it has achieved advances in emission intensity since the early 1990's (Macintosh & Wallace 2009).

Frustrated at the lack of action in this respect, the European Union (EU) has proposed extending its emissions trading scheme to international aviation in 2012 (Council of the European Union (CEU) 2007). This proposal has been met with effectively universal opposition from non-EU countries. At this point, it is unclear whether the EU will proceed with this scheme and defy the international community. However, its willingness to propose the scheme is a sign of the intensity of the pressure for more action to be taken to contain the growth in emissions. Projections based on ICAO's (2007) traffic forecast suggest international aviation CO_2 emissions will increase by between 111 and 144 per cent between 2005 and 2025 (Macintosh & Wallace 2009).

Stabilising international aviation emissions at levels consistent with risk adverse climate targets without restricting demand will be extremely difficult. To prevent emissions from increasing by more than 100 per cent between 2005 and 2025, the emission intensity of international aviation would have to be reduced by 32 per cent, which would require an average annual decrease of approximately 1.9 per cent. To stabilise emissions at 2005 levels, the emission intensity would have to be improved by 65 per cent. This would necessitate an average annual decrease of 5.2 per cent. With current technology, emission intensity improvements of this magnitude appear unlikely. Under current policy settings, emissions are likely to increase significantly unless there is a major global economic downturn or other shock to the aviation market (Macintosh & Wallace 2009).

1.2.3 Demand for Aviation in Australia

Aviation contributes over $32 billion to Australia's GDP. It directly employs 149,000 people and over 160,000 people indirectly (Oxford Economics, 2011).

Whilst carrying only 0.1 per cent of Australia's international freight by weight, aviation freight makes up nearly 21 per cent of freight by value — over 750,000 tonnes of high-value and time sensitive freight, worth over $110 billion during 2011–12. Over the last twenty years the volume of freight flown into and out of Australia has more than doubled and is expected to increase by a further 120 per cent by 2030 (Figure A 1 and BITRE, various).

Continued passenger growth at major airports is already testing the capacity of airport infrastructure, particularly during peak periods. International air travel will grow strongly to 2030, with both domestic and international passenger movements through capital cities almost doubling. Substantial investments by airport operators will be required to meet this demand.

Increasing demands from the resources sector has also put significant pressure on some regional airports and their infrastructure. Conversely, some regional airport usage is declining as population changes take place. Table 4 (Singleton & Pender, November 2014) identifies energy consumption in Australia's aviation sector.

1.2.4 Aviation: Conclusions

The aviation sector does not make a significant contribution to Australian urban mobility, although access to airports is becoming an increasingly significant component of metropolitan travel demand. In terms of passenger travel, it is only the domestic aviation market that may be strongly influenced by technology trends, if Fast Train becomes an alternative to east coast city to city air travel. The likelihood of this substitution occurring will increase as land access to our airports become more challenging with increasing congestion of ground transport networks.

Aviation freight is a specific market for high value, low volume goods and is expected to continue its current growth trend.

Concerns about aircraft emissions are likely to continue to grow – in line with global concerns – but this is not expected to affect the supply of domestic aviation services or to hasten any mode shift to alternative modes e.g. rail.

1.3 Freight

1.3.1 Freight: The Evolution of the Freight and Logistics Sectors

The freight and logistics sectors are evolving - as are other transport sectors – however, spatially there is a trend away from central locations, where densities of local industries are relatively higher, to more spacious areas on the suburban fringe (Cidell 2010). Whilst in some respects, such a shift can be attributed to factors common to all suburban growth, major changes in the global logistics industry have also played a role. The need for more space and easier transportation access to all freight transport modes (i.e. road, rail and air) has resulted in a trend towards intermodal logistics centres which require large parcels of land on the metropolitan fringe. Coupled with lower taxes and newer infrastructure this has become a reality in many major cities globally. Additionally, at the national and regional levels, there has been a change in the spatial organisation of the freight distribution sector; from the concentration of maritime traffic in fewer but larger ports to a shift towards inland 'ports' as the sites of growth in order to alleviate congestion at terminals. Simultaneously, many metropolitan areas are experiencing dramatic growth along their suburban fringes in terms of freight distribution and inter-modal activity; signifying an outward shift from the traditional central city (Cidell 2010).

Historically, the location and volume of warehousing and freight distribution have been dependent almost entirely on the population of a metropolitan area. Consequently, population and freight growth have effectively occurred in unison (McKinnon 1983). Traditionally, most factors impacting the location of warehousing activity are similar to any other industry, i.e. proximity to clients, real estate costs, access to transports modes such as major highways, staff availability and more broadly, the associated costs of doing business (Glasmeier and Kibler 1996). Within North America, historically this meant close proximity to the central city area and key industrial centres and to traditional transport modes associated with the maritime and rail transport sectors (Eaton 1982). As cities expanded outward, warehousing facilities were thought to have done the same. As many cities shifted from production to consumption sites, warehousing and distribution facilities were no longer about storing components or exporting final products, but facilitating the incoming flow of goods. Furthermore, recent changes in technology, including containerisation and supply chain management, have resulted in firms consolidating all of their activities in the one place. This has generally resulted in a significantly larger geographical presence at correspondingly greater distance from the central city area (Glasmeier and Kibler 1996).

As freight traffic has both increased in volume and become more international in scope, it has become more concentrated on fewer ports and gateways. Inevitably, as these gateways have become congested, freight and logistic activities have begun to move towards inland ports and distribution centres to make available more dockside space for maritime activities (Cidell 2010). In work by the same author, in which the locations of freight establishments per capita of fifty of the largest US cities were mapped, it was confirmed that there was a definite increased concentration of freight activity in the Ohio and Missouri River valleys (two of North America's longest and largest rivers) (Cidell 2010). Additionally, as containerisation and high levels of throughput have led to the increased need for single-story distribution centres, spread over significantly larger surface areas, freight distribution activity has shifted from the traditional central city areas to suburban sites. Of the fifty cities analysed in the research by Cidell (2010), only four did not experience a decentralisation of freight activity over the last twenty years. Whilst it is important to consider the impacts of increased freight activity on the suburban fringes of key cities, consideration must also be given to central city locations. For example as inner city rail yards are modified to become inter-modal yards, established neighbourhoods will have to deal with increasing volumes of train and truck traffic (Cidell 2010).

Following the economic crisis and the collapse of world trade in 2009, most regions of the world embarked on the path of recovery in 2010. Global freight volume transported by sea and air rebounded strongly and reached a new high. In rail and road freight, recovery has been slower with volumes still below pre-crisis levels, reflecting domestic economic performance more than trade performance.

Maritime transport remains the backbone of international trade, with over 80% of world cargo by volume transported by sea and therefore a key component of the freight sector. Following the 2009 recession, world seaborne trade experienced robust growth in 2010, in line with the global economic recovery. UNCTAD preliminary data show that seaborne trade, measured in tons loaded, grew 7% to 8.4 billion tons in 2010, or 2% above the pre-crisis peak in 2008, reaching a new record high. Maritime activity grew strongly in the decade to 2011–12. Bulk port throughput grew by more than 75 per cent and container trade by two thirds. Concurrent with and facilitating this growth has been the trend to much larger bulk and container vessels.

By 2030, the bulk freight task will increase by half and national container throughput is projected to double. Australia's containerised international exports will almost double by 2030 due to strong demand from China and South East Asia. At the same time Australia's strong demand for consumer goods imports will grow broadly in line with the economy, increasing freight imports.

Total coastal freight has slightly declined in the same period to 2011–12 — from 53 million tonnes in 2002–03 compared to 49.5 million tonnes in 2011–12 (an approximate decline of 0.7 per cent per annum) (BITRE).

The number of cruise vessels operating in Australia continues to increase. In the four years to 2012, Australian cruise passenger numbers more than doubled, with New South Wales and Queensland accounting for two thirds of Australian cruise passengers (CLIA, 2012).

But growth was uneven across regions. It could be best described as reflecting a two-speed recovery in the world economy, with developing economies faring better than developed economies. This was clearly reflected in the movement of seaborne freight. The total amount of goods unloaded (in tonnes) in developing economies grew to 11% above pre-crisis peak while in developed economies volumes were still 11% below their 2008 peak. Cargo loaded in developed countries expanded to 4% above pre -crisis levels whilst in developing countries volumes remained slightly below the peak (UNCTAD 2011).

Whether this will be a long term structural shift, where developing economies, especially Asia, start importing more from developed economies, remains to be seen in the coming years.

1.3.2 Energy Consumption Trends

The transport sector is a major oil consumer and greenhouse gas emitter; globally it accounted for 26 per cent of the world's energy use and 23 per cent of energy-related greenhouse gas emissions in 2004 (IPCC 2007). The industrialised countries of the world reached an agreement to reduce greenhouse gas emissions in Kyoto, Japan in 1997. Transportation, which depends on fossil fuels as the main energy source, was one of the key sectors highlighted in that agreement (Li, Lu et al. 2013). Generally, as a dominant mode of freight movement, road transportation accounts for the largest share of the freight-related emissions (McKinnon and Piecyk 2009).

1.3.3 Developing Policies to Allow the Freight Sector to Reduce its Carbon Footprint

China, as a country on the path to industrialisation, represents an economy that is growing rapidly. In addition to this growth and the subsequent impact on specialised industries, transportation demand, particularly in the freight and logistics sector is growing rapidly. Low-cost and dependable transportation helps businesses remain competitive; for door-to-door transportation, the most widely used mode is road transportation. The main benefit of this mode is its flexibility, whilst its disadvantages are the expenses associated with consumption of fossil fuels (Li, Lu et al. 2013). In research work by Li et al. (2013), these authors explored the impacts of factors on the carbon dioxide emissions from road freight transportation in China from 1985 to 2007. During the five-year period (2006-2010), the Ministry of Transport of the People's Republic of China (MOTPRC) adopted certain policies to mitigate the increase of CO_2 emissions. Other countries have also introduced various measures to improve road freight efficiency and to reduce CO_2 emissions, demonstrating that the evolution of CO_2 emissions does have an impact on the considerations and the decisions of policy-makers (Li, Lu et al. 2013). Based on the analysis conducted by Li et al. (2013), the following points were raised given their impacts to future policy development in the freight and logistics sector:

- Economic development inevitably leads to the increase of freight transportation CO_2 emissions; industry development is likely to decrease freight transportation CO_2 emissions;
- Policies on businesses, vehicle licensing and vehicle efficiency which were enacted and carried out by the MOTPRC were helpful to decrease road freight transportation CO_2 emissions:
    - In 2009, in China there were a number of single businesses in the freight market that owned no more than ten trucks (MOTPRC 2009). Few businesses operated intensively and had convenient operation networks. Policies were introduced to limit the minimum stock of working vehicles owned by newly registered businesses in order that the market concentration could improve.
    - An investment in vehicle technology was another option enacted to constrain or reduce truck energy use:
        - In China, to comply with the regulation, freight businesses are required to purchase vehicles satisfying fuel-efficiency requirements that are approved by the MOTPRC.
    - The MOTPRC are strongly supporting tractor and semi-trailer transportation given it is promoted to be more energy-efficient than single-unit trucks (Xue, Ma et al. 2011).
        - Tractors and semi-trailers were not allowed to separate and combine freely prior to 2008.
- To decrease road freight transportation CO2 emissions, policies on modal shift and highway tolls which are negotiated by the MOTPRC and other ministries required careful consideration:
    - Highway tolls can increase operational costs for truck operators, which can result in them reducing the frequency of using trucks on the highway (Liao, Lu et al. 2011).
    - Higher tolls may change the modal selection for freight transportation, such as improvements to the technical efficiency and energy intensity of modes, other than road freight transportation (McKinnon 2006).

1.3.4 Energy Consumption in Australia's Freight Sector

As a large continent characterised by major population centres located along its coastline, goods in Australia must be transported long distances; more than 38 per cent of Australia's **final** energy use is employed in transporting people and goods across the country. As a consequence, the transport sector is the largest end user of energy in Australia **and** is by far the largest consumer of liquid fuels (including LPG and refined products), accounting for approximately 73 per cent of final use.

Within the transport sector, road transport is the largest user of **final** energy, accounting for 74 per cent of the sector's liquid fuel consumption. Largely reflecting improvements in fuel efficiency, average growth in road transport fuel consumption has moderated over the past 30 years, reducing from approximately three per cent a year in the 1980s to an average of one per cent a year in the 2000s. Table 4 (Singleton & Pender, November 2014) identifies energy consumption in Australia's freight sector and Figure 5 (Singleton & Pender, November 2014) illustrates Australia's energy flows from the supply point to final consumption.

1.3.5 Freight: Conclusions

Attention to technology trends in Australia's freight sector should be focussed on the following:

- Energy consumption and therefore emissions of road-based freight vehicles, including the energy intensity of those movements
- On-going availability of fuel supplies for road-based freight vehicles
- Evolution in the logistics sector and the implications for location and size of freight terminals etc.
- Potential for transfer of long-haul inter-city freight to rail, including possible pricing and regulatory controls
- Road pricing options, as part of a broader approach to metropolitan network management
- In the maritime sector, competition between Australia's major capital city ports may be inefficient, as most international carriers will need to call at all three east coast ports
- Furthermore, increasing port access capacity [vessel draught] may no longer be a driver

Overall, the freight sector is complex and warrants careful monitoring on many fronts.

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