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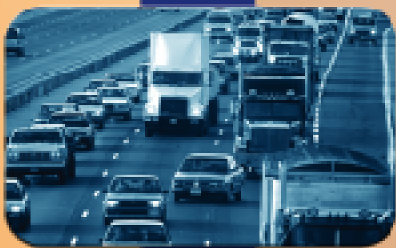

Report 107

Greenhouse Gas Emissions From Transport

Australian Trends to 2020

DEPARTMENT OF TRANSPORT AND REGIONAL SERVICES

bureau of transport and regional economics

GREENHOUSE GAS EMISSIONS FROM TRANSPORT

AUSTRALIAN TRENDS TO 2020

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FOREWORD

This report presents the results of a Bureau of Transport and Regional Economics (BTRE) study to update base case (or 'business-as-usual') projections of greenhouse gas emissions from the transport sector. The work was undertaken on behalf of the Australian Greenhouse Office (AGO).

The work updates previous Bureau projections of transport sector greenhouse gas emissions published in Bureau of Transport and Communications Economics (BTCE) Report 88 (*Greenhouse Gas Emissions from Australian Transport: Long-term projections*) and BTCE Report 94 (*Transport and Greenhouse: Costs and options for reducing emissions*).

The BTRE acknowledges the contributions of Australian Greenhouse Office staff—in particular, Jo Evans, Simon Wear and Anthony Tabor.

The study was undertaken by Dr David Cosgrove, Dr David Gargett (project leader), David Mitchell, Mark Cregan and Dion Epstein, under the guidance of Deputy Executive Director Phil Potterton.

Tony Slatyer
Executive Director
November 2002

AT A GLANCE

- This report, compiled on behalf of the Australian Greenhouse Office (AGO), presents the results of a detailed Bureau of Transport and Regional Economics (BTRE) study into the modelling and forecasting of greenhouse gas emissions from the Australian transport sector.
- Overall, emissions from the domestic transport sector in 2010 are projected, under *base case* (or 'business-as-usual') assumptions, to be close to 47 per cent above the level for 1990. By 2020, the BTRE projects such business-as-usual emissions to be 68 per cent above 1990 levels.
- Policy measures currently in place aimed at greenhouse gas abatement from transport—comprising the Compressed Natural Gas Infrastructure Program (CNGIP), the Alternative Fuels Conversion Program (AFCP), the Environmental Strategy for the Motor Vehicle Industry (ESMVI) and the Diesel and Alternative Fuels Grants Scheme (DAFGS)—are estimated as capable of reducing this 47 per cent growth by 2010 to about a 43 per cent growth.
- The scale of these forecast increases (which are similar in magnitude to previously released Bureau projections of transport emissions) points to the fact that Australian transport demand is highly dependent on underlying economic and population growth.
- Within the aggregate forecast growth in domestic transport emissions over the next two decades (at about 1.7 per cent per annum), aviation is projected to have the strongest rate of growth (averaging about 4.4 per cent per annum), followed by commercial road vehicles (2.2 per cent per annum). The passenger car fleet will remain the single largest contributor to total sector emissions, but is expected to exhibit a slower rate of growth (of around 1 per cent per annum between 2000 and 2020).
- The sum of emissions from all other transport activities (accounting for around 9 per cent of total transport emissions) is forecast to grow at close to 1 per cent per annum (2000–2020).

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UNITS

kilo (k) $=10^3$ (thousand)

mega (M) $=10^6$ (million)

giga (G) $=10^9$ (billion)

peta (P) $=10^{15}$

Note:

1 gigagram = 1 kilotonne

1 kilowatt-hour (kWh) = 3.6 megajoules

EXECUTIVE SUMMARY

The Bureau of Transport and Regional Economics (BTRE) has recently modelled future greenhouse gas emissions from the transport sector using two different methods (both of which gave similar results for the overall projected trend):

- modelling transport sub-sectors, and then aggregating to sector totals (here termed a ‘bottom-up’ approach)
- modelling the sector as a part of the total economy (a ‘macro modelling’ or ‘top-down’ approach).

This report, compiled on behalf of the Australian Greenhouse Office (AGO), describes the results of using the former approach—bottom-up modelling (i.e. detailed modelling of transport sub-sectors, typically using vehicle fleet models). The project formulation essentially followed AGO specifications.

As table ES.1 shows, the present study estimates direct greenhouse gas emissions from transport in 1998 (the latest year for which detailed modal energy data are available) to be 17 per cent above 1990 base year levels—at 69 612 gigagrams (i.e. 69.612 million tonnes) of carbon dioxide (CO_2) equivalent. By 2010 (the middle year of the first ‘budget period’ of the Kyoto greenhouse targets, i.e. 2008 to 2012), transport sector emissions are projected under ‘base case’, or ‘business-as-usual’ (BAU), assumptions to be close to 47 per cent above the level for 1990 (the Kyoto target base year).

By 2020, BAU emissions from Australian transport are projected to be around 68 per cent higher than 1990 levels. The BTRE base case emission projections to 2020 are given in detail in Chapter 1 of the report.

The BTRE business-as-usual scenario incorporates a continuation of present trends in fuel efficiency improvements for transport vehicles. Due to continuing technical innovation, average fuel intensity across the transport sector is projected (in the base case) to fall by the order of 1.5 per cent per annum.

In Chapter 4, the projection analyses are adjusted to factor in the possible future effects of Australian government policy measures (aimed at abating greenhouse emissions from the transport sector) that have already been put in place. These measures consist of the Compressed Natural Gas Infrastructure Program (CNGIP), the Alternative Fuels Conversion Program (AFCP), the Environmental Strategy for the Motor Vehicle Industry (ESMVI) and the Diesel and Alternative Fuels Grants Scheme (DAFGS). This ‘base case with measures’ scenario produces emission projections that are somewhat lower than the base case estimates. For example, total transport sector emissions for 2010 are estimated to grow to about 43 per cent above 1990 for the *base case with measures,* as opposed to about 47 per cent for business-as-usual (see table ES.1 and figure ES.1).

Such strong projected increases over the coming decade, for both the *base case* and *base case with measures* scenarios (at about 2 per cent and 1.8 per cent per annum respectively), point to the fact that Australian transport demand is highly dependent on underlying economic and population growth. The rate of emissions growth is expected to be below the forecast rate of GDP growth (averaging about 3 per cent per annum) and above that of population growth (averaging about 0.7 per cent per annum). Similar orders of magnitude increases were found for most Australian States and Territories (see Chapter 3).

The projections are, of course, subject to considerable uncertainty, principally concerning the likelihood of the various assumptions that had to be made in the modelling process. Sensitivity analyses were performed (see Chapter 2), where the values assumed for the major explanatory variables (such as economic growth, population growth and vehicle fuel intensity) were varied, and the effects on the emission projections examined.

Using the most optimistic assumptions (i.e. choosing future values for each of the major explanatory factors so as to give the lowest likely emission projections for a base case trend), carbon dioxide equivalent emissions from Australian transport in 2010 would still reach 78.3 million tonnes (an increase of 31 per cent over the 1990 base level). Alternatively, using pessimistic assumptions for the major underlying factors, total greenhouse emissions from transport in 2010 would reach 94.2 million tonnes (an increase of 58 per cent over 1990 levels).

Previous Bureau work on projecting greenhouse gas emissions from transport derived similar order of magnitude estimates for the overall trends as presented in this report. Though the different analyses have seen relatively large changes in the modal contributions to aggregate transport emissions, the growth forecasts for the aggregate have been quite comparable. Total domestic transport emissions had a forecast growth in BTCE Report 88 (1995a) of around 1.5 per cent per annum over the period of 1990 to 2015. This was revised upwards to about 1.85 per cent per annum (1990–2015) in BTCE Report 94 (1996b). The current BTRE base case has an aggregate growth in the sector's emission level of about 1.83 per cent per annum over the period of 1990 to 2015—very close to that of Report 94. The 'base case with measures' scenario has slightly lower estimated aggregate growth than the base case—at about 1.7 per cent per annum (over 1990–2015).

The BTRE base case results presented in this report differ somewhat from projections published recently by the AGO (2002). The projections issued by the AGO were derived by averaging the results of the BTRE *bottom-up* modelling and the results from two *top-down* models - the Centre of Policy Studies' (Monash University) MMRF-Green model and ABARE's GTEM. Top-down models typically generate higher transport projections than the Bureau's bottom-up fleet models (primarily due to top-down models lacking any constraint parameters to allow for the trend towards saturation in future Australian car ownership per person - see Chapter 2). These 'averaged' projections in the AGO's *National Communication 2002* have BAU growth for the transport sector as 54 per cent between 1990 and 2010 (with a likely range of 46 to 62 per cent, as opposed to the BTRE base case result of 47 per cent). 'With measures' growth (1990-2010) is projected in the AGO report to be 48 per cent (versus BTRE result of 43 per cent).

The BTRE also investigated several hypothetical policy scenarios for reducing emissions from the transport sector. Of the policies examined, optimal road pricing was judged to offer the largest potential for reducing greenhouse gas emissions from transport by 2010 (see Chapter 5).

TABLE ES.1 EMISSION PROJECTIONS FOR ENERGY END-USE BY AUSTRALIAN DOMESTIC CIVIL TRANSPORT

(Gigagrams of direct CO2 equivalent)

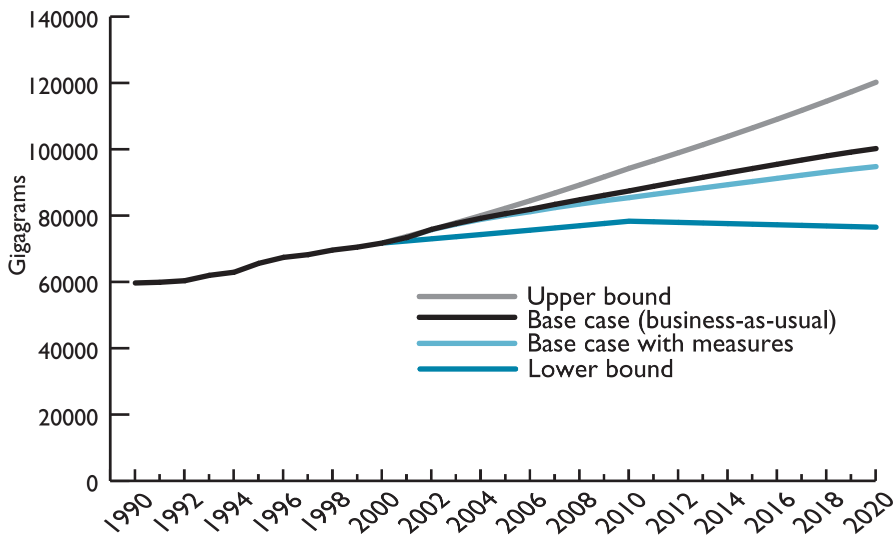
Year	*Cars*	*Road freight*	*Air*	*Rail*	*Coastal shipping*	*Other*	*Total*	*% change in total from 1990*
1990	34220	17321	2565	1741	1939	1890	59676	..
1998	39170	20268	4846	1743	1614	1972	69612	+17%
2010 base case								
	47792	26153	7792	2186	1363	2151	87437	+47%
2010 base case with measures								
	45801	26149	7792	2186	1363	2117	85408	+43%
2010 optimistic sensitivity								
	41260	24435	7172	2099	1309	2033	78308	+31%
2010 pessimistic sensitivity								
	50778	28840	8659	2304	1436	2231	94248	+58%

.. not applicable

Notes: Energy supply emissions are not included (i.e. rail does not include emissions from electricity generation).
Only the direct greenhouse gases—carbon dioxide, nitrous oxide and methane—are included (i.e. effects of indirect greenhouse gases, such as carbon monoxide and nitrogen dioxide, are not included here).
'Air' is total domestic aviation (i.e. including general aviation).
'Other' includes buses, motorcycles, small marine pleasure craft, ferries and recreational off-road motor vehicles.

Source: BTRE estimates.

FIGURE ES.1 PROJECTIONS OF CO_2 EQUIVALENT EMISSIONS FROM AUSTRALIAN DOMESTIC TRANSPORT



Notes: 'Base case with measures' projections adjust the business-as-usual projections to allow for the possible effects of Australian government policy measures (aimed at abating greenhouse emissions from the transport sector) that have already been put in place. 'Upper bound' projections consist of the highest level of emissions likely without major structural change to the Australian transport sector (pessimistic sensitivity scenario). 'Lower bound' projections consist of the lowest level of emissions likely without major structural change to the Australian transport sector (optimistic sensitivity scenario).

Source: BTRE estimates.

chapter 1

BASE CASE PROJECTIONS OF AUSTRALIAN TRANSPORT EMISSIONS TO 2020

The Bureau of Transport and Regional Economics (BTRE), for this report, has compiled revised *base case*, or 'business-as-usual' (BAU), projections of fuel use and greenhouse gas emissions from the Australian transport sector. This study has used a *bottom-up* modelling approach across each of the main transport activities. The term 'bottom-up' is used here in the sense that the estimates are composed using a summation across major transport sub-sectors (typically calculated using vehicle fleet models or activity-specific econometric equations). This is as opposed to a common use of the term 'top-down' to refer to a total sectoral (or 'macro') estimate, typically derived from an economy-wide General Equilibrium model.

The revised modelling and projections were done on behalf of the Australian Greenhouse Office (AGO). The Bureau estimates presented here are essentially based on methodologies developed for Bureau of Transport and Communications Economics (BTCE) Report 88—*Greenhouse Gas Emissions from Australian Transport: Long-term projections* (BTCE 1995a), and BTCE Report 94—*Transport and Greenhouse: Costs and options for reducing emissions* (BTCE 1996b).

SUMMARY OF RESULTS

Table 1.1 summarises the results for the base case projections. Emissions (in terms of direct CO_2 equivalent) from energy end-use by civil domestic transport as a whole in 2010 are expected to increase by close to 47 per cent from 1990 levels. By 2020, the Bureau projects such business-as-usual emissions to be 68 per cent above 1990 levels. Table 1.1 shows that total end-use emissions (in the base case) are likely to rise from about 69 600 gigagrams (Gg)—i.e. 69.6 million tonnes—of CO_2 equivalent in 1998 to about 100 200 gigagrams (100.2 million tonnes) in 2020. Emissions growth is highest for commercial road vehicles and for airlines. The results show that transport has an inherently high rate of growth in emissions, in line with its fairly direct link to economic and population growth.

The BTRE has also been conducting transport emission projections using a top-down approach (the results of which will be reported in a forthcoming BTRE Working Paper), partly to check consistency between the two modelling approaches. The recent Bureau research using a multi-sectoral model of the Australian economy (an enhanced version of the MMRF–Green model) has obtained comparable results to the bottom-up forecasting approach presented here. The current BTRE top-down results forecast BAU transport emission growth between 1990 and 2010 of about 45.4 per cent—similar to this report's bottom-up base case result (of a likely increase of 46.5 per cent over that period).

In accordance with AGO specifications, all emission values in this report that are given as 'CO_2 equivalent' refer to *direct* CO_2 equivalent emissions—i.e. they include solely the effects of the directly radiative gases emitted from transport fuel use: carbon dioxide, methane (CH_4) and nitrous oxide (N_2O). The specified Global Warming Potentials (GWPs) for calculating the CO_2 equivalent mass estimates for emissions of methane and nitrous oxide (21 times for CH_4 and 310 times for N_2O, using a reference period for warming effects of 100 years) were taken from Intergovernmental Panel on Climate Change (IPCC) guidelines on national greenhouse gas inventories (IPCC 1996; 1997).

Due to the difficulty in accurately quantifying global averages for warming due to 'indirect' greenhouse effects (i.e. the effects of gases such as carbon monoxide, which are not radiatively active themselves, but which can influence the concentrations of the direct gases), the IPCC reports referenced (1996; 1997) did not give GWP values for indirect greenhouse gases[1]. The emission level estimates would be significantly higher (and the scope for future abatement of those levels somewhat better) if the *indirect* effects of other gases emitted from transport—particularly the ozone precursors such as carbon monoxide (CO), nitrogen oxides (NO_x) and non-methane volatile organic compounds (NMVOCs)—were also taken into account. Previous Bureau studies (e.g. BTCE Reports 88 and 94, BTCE Working Papers 22 and 24) included rough (order of magnitude) estimates of the indirect effects in their CO_2 equivalent emission values.

Note that this methodological difference means that values for 'CO_2 equivalent emissions' given in the earlier Bureau projection reports (BTCE 1995a; 1996b) are not directly comparable to those presented in this report. CO_2 equivalent totals calculated using six gas species (CO_2, CH_4, N_2O, CO, NO_x and NMVOCs—as in the earlier reports) will tend to be 10 to 20 per cent higher than those calculated using just the three direct gases (CO_2, CH_4, N_2O—as for this report). Other variations between the reports' methodologies include:

1 Note that an earlier IPCC report (1990) attempted to roughly quantify the indirect effects using a GWP approach, and recent IPCC research (see Section C of <www.ipcc.ch/pub/tar/wg1/010.htm>) has also focussed on ways to incorporate the indirect gases into a basic GWP reporting formulism.

- differing treatment of minor emission sources (such as fuel use by military vehicles, utility engines, pipelines and recreational vehicles)
- differing projection periods
- revised and updated data for historical time-series.

If these effects are allowed for (and CO_2 equivalent totals are roughly recalculated from BTCE Report 88 and BTCE Report 94 data on a basis consistent with the current work), then the previous Bureau projections can be shown to contain similar order of magnitude estimates for overall emission trends as those presented in this report. Estimates of the modal contributions to the transport sector's aggregate emission level exhibit substantial differences between the various sets of projections. However, the different analyses have all derived quite comparable growth forecasts for aggregate transport emissions. Total direct greenhouse gas emissions from domestic transport had a forecast growth in BTCE Report 88 (1995a) of around 1.5 per cent per annum over the period of 1990 to 2015. This was revised upwards to about 1.85 per cent per annum (1990–2015) in BTCE Report 94 (1996b). The current BTRE base case has estimated growth in the sector's aggregate emission level of about 1.83 per cent per annum over the period of 1990 to 2015—very close to that of BTCE Report 94. The 'base case with measures' scenario (see Chapter 4) has slightly lower estimated aggregate growth than the base case—at about 1.7 per cent per annum (1990–2015).

TABLE 1.1 PROJECTED INCREASES IN GREENHOUSE GAS EMISSIONS FROM AUSTRALIAN CIVIL DOMESTIC TRANSPORT—END USE

(Gigagrams of direct CO_2 equivalent)

					Percentage Change	
Sub-sector	*1990 (Gg)*	*1998 (Gg)*	*2010 (Gg)*	*2020 (Gg)*	*1990–2010*	*1990–2010*
Cars	34 220	39 170	47 792	50 110	40%	46%
Trucks	9 924	11 779	14 606	17 443	47%	76%
LCVs	7 397	8 489	11 547	14 431	56%	95%
Aviation	2 565	4 846	7 792	11 922	204%	365%
Other	5 569	5 329	5 700	6 303	2%	13%
Total	59 676	69 612	87 437	100 208	47%	68%

Notes: Figures relate to energy end-use (i.e. do not include emissions from power generation for electric railways).

LCV—light commercial vehicle.

'Other' includes rail transport (non-electric), water transport (coastal shipping, ferries and small pleasure craft), buses, motorcycles and unregistered off-road motor vehicles.

For aviation, emissions during 1990 were not fully representative of the sector's trend growth pattern. 1990 was an anomalous year for Australian air transport since air travel was severely affected by an extended strike by airline pilots.

Values relate solely to 'direct' CO_2 equivalent emissions (i.e. the radiative effects of emissions of CO_2, CH_4 and N_2O). CO_2 emissions account for over 95 per cent of such CO_2 equivalent estimates for transport. CO_2 equivalent estimates would be significantly higher (possibly of the order of 10 to 20 per cent) if the 'indirect' effects of other gases emitted (such as CO, nitrogen oxides and volatile organic compounds) were quantified and also taken into account. The global average effects of the indirect gases are difficult to quantify since such gases typically only have short atmospheric lifetimes, with their decay involving complex chemical processes.

Due to methodological and data differences, BTRE emission estimates will differ slightly from those appearing in the AGO National Greenhouse Gas Inventory (NGGI). For example, the NGGI total for the transport sector is 3 per cent higher than the table value for 1990, and 4 per cent higher than the 1998 BTRE value.

Year values for all emission estimates and projections refer to 'year ending 30 June'

Source: BTRE estimates.

Note also that BTRE bottom-up emission values will tend to differ to some extent from the emission estimates contained to date in the AGO National Greenhouse Gas Inventory (NGGI) — see <http://www.greenhouse.gov.au/inventory/>. The BTRE estimation methodologies are substantially more detailed than the default methods of the NGGI Workbook for Transport (National Greenhouse Gas Inventory Committee 1998a)—and transport data inconsistencies have been given particular consideration throughout these analyses. The creation of time-series estimates for transport emissions required a considerable amount of standardisation of the underlying data for transport tasks, efficiency and energy use. For example, most studies dealing with trends in road transport have had to rely on data from the Australian Bureau of Statistics (ABS) Survey of Motor Vehicle Use (SMVU), now conducted annually. However, due to changes over time in the survey's scope, vehicle classifications and collection methods, coherent time-series comparisons are not always possible using the raw survey data. In general, the SMVU results published by the ABS need to be standardised, across the various survey years, before trend growth rates (for road transport tasks) can be derived from them.

The most significant variation between BTRE and current NGGI estimates is due to differences in the N_2O emission factors assigned to passenger motor vehicles fitted with three-way catalytic converters. The N_2O emission factors for such vehicles reported in the NGGI transport workbook are higher than BTRE values (based on data presented in BTCE 1995a and US Environmental Protection Agency 2001b) by as much as twofold. Note that there is considerable uncertainty surrounding the actual level of N_2O emissions from motor vehicles. (Forthcoming reviews of the NGGI transport estimates may resolve this issue and, in the future, provide more robust estimates for N_2O emissions from transport.)

As an example of the average BTRE divergence from the NGGI, consider emission estimates for 1998 (the most recent year for which a detailed modal breakdown is currently available for transport energy use). The NGGI transport estimate for 1998 totals 72.8 million tonnes of CO_2 equivalent, compared to the BTRE's estimate of 69.6 million tonnes (see table 1.1), a difference of about 4 per cent.

As mentioned above, the most significant component of this difference is due to the estimated emissions of N_2O from the car fleet. If the BTRE projections had been done using the N_2O emission rates from the NGGI, the results would have been on average about 5 per cent higher.

For 1998, the other differences between the NGGI and current BTRE estimates relate to:

- the NGGI adopting lower estimates of domestic aviation emissions (due to not allowing for data accounting problems with aviation fuel sales)
- the NGGI emission values for trucks being towards the high end of the probable range for 'actual' values while the BTRE estimates for commercial road vehicles are toward the lower end (due to data uncertainties associated with the SMVU, the actual on-road fuel intensity for trucks is not accurately known)
- the NGGI adopting lower estimates of rail and maritime emissions (with fuel consumption data often being revised).

The NGGI is derived from energy use data provided by the Australian Bureau of Agricultural and Resource Economics' (ABARE) Fuel and Electricity Survey. BTRE estimates are partly based on ABARE data—supplemented with data from the Apelbaum Consulting Group's work for the Australian Transport Energy Data and Analysis Centre (ATEDAC). They were also based on a detailed examination of activity levels in each major transport sub-sector (e.g. using sources such as the SMVU). The differences caused by these data discrepancies are generally relatively small, and may be resolved in future either by the NGGI transport sector reviews or by ATEDAC's ongoing work on transport data standardisation.

The energy end-use projections are presented in more detail in tables 1.2 and 1.3. Table 1.4 repeats the results from table 1.3, but with the addition of emissions due to power generation for electric railways. Rough estimates of full fuel cycle (FFC) emissions for the transport sector are then given in table 1.5, where the table 1.4 results have been increased to allow for transport fuel supply and processing. Based on CSIRO results (Beer et al. 2001), the BTRE estimates that the current fossil fuels used by transport incur a FFC emissions 'overhead' of the order of 20 per cent, relative to their energy end-use (i.e. end-use emissions for liquid fossil fuels are scaled up by 20 per cent to obtain FFC estimates).

By 2020, greenhouse gas emissions from Australian domestic civil transport are projected (in the BTRE base case scenario) to grow to almost 122 500 gigagrams (i.e. 122.5 million tonnes) of FFC direct CO_2 equivalent.

TABLE 1.2 BASE CASE EMISSION PROJECTIONS BY MAJOR SECTOR, FOR ENERGY END-USE BY AUSTRALIAN DOMESTIC CIVIL TRANSPORT, 1990–2020

(Gigagrams of direct CO_2 equivalent)

Year	Road	Air	Other	Total
1990	52961	2565	4149	59676
1991	52743	3142	4012	59897
1992	53068	3393	3896	60357
1993	54616	3553	3811	61980
1994	55290	3707	3924	62921
1995	57255	4274	4071	65600
1996	58813	4636	3944	67393
1997	59259	4840	4124	68223
1998	60898	4846	3869	69612
1999	62016	4781	3705	70502
2000	62920	4996	3804	71720
2001	64296	5280	3804	73380
2002	66474	5541	3831	75846
2003	67957	5789	3860	77606
2004	69254	6050	3890	79194
2005	70356	6313	3923	80592
2006	71351	6584	3957	81892
2007	72520	6868	3993	83381
2008	73573	7164	4031	84767
2009	74586	7471	4070	86127
2010	75534	7792	4111	87437
2011	76556	8130	4153	88840
2012	77529	8485	4197	90211
2013	78455	8856	4243	91554
2014	79358	9245	4290	92893
2015	80201	9650	4339	94190
2016	81016	10073	4390	95479
2017	81801	10513	4442	96756
2018	82533	10968	4496	97997
2019	83163	11437	4552	99153
2020	83677	11922	4610	100208

Note: 'Other' includes rail transport (non-electric), water transport (coastal shipping, ferries and small pleasure craft), and unregistered off-road motor vehicles.

Sources: BTRE estimates, Apelbaum Consulting Group (2001), ABARE (1999), ABS (2000a; 2000c; 2001a).

TABLE 1.3 BASE CASE EMISSION PROJECTIONS BY TYPE OF TRANSPORT, FOR ENERGY END-USE BY AUSTRALIAN DOMESTIC CIVIL TRANSPORT 1990–2020

(Gigagrams of direct CO_2 equivalent)

Year	Cars	Road freight vehicles	Air	Rail (non-electric)	Coastal shipping	Other (minor)	Total
1990	34220	17321	2565	1741	1939	1890	59676
1991	34351	16982	3142	1727	1811	1885	59897
1992	34847	16810	3393	1673	1742	1890	60357
1993	35600	17607	3553	1641	1684	1896	61980
1994	36148	17722	3707	1769	1664	1911	62921
1995	37496	18329	4274	1708	1866	1926	65600
1996	38355	19018	4636	1672	1770	1942	67393
1997	38607	19203	4840	1806	1811	1957	68223
1998	39170	20268	4846	1743	1614	1972	69612
1999	40009	20537	4781	1717	1475	1982	70502
2000	40696	20762	4996	1782	1505	1980	71720
2001	41491	21329	5280	1840	1442	1998	73380
2002	43187	21798	5541	1875	1429	2015	75846
2003	44070	22386	5789	1911	1417	2033	77606
2004	44748	22992	6050	1948	1406	2050	79194
2005	45431	23399	6313	1986	1396	2068	80592
2006	45910	23902	6584	2025	1388	2085	81892
2007	46523	24445	6868	2064	1380	2101	83381
2008	46999	25010	7164	2104	1373	2118	84767
2009	47426	25583	7471	2145	1367	2135	86127
2010	47792	26153	7792	2186	1363	2151	87437
2011	48189	26768	8130	2229	1359	2166	88840
2012	48540	27379	8485	2272	1356	2180	90211
2013	48843	27990	8856	2316	1353	2195	91554
2014	49116	28609	9245	2361	1352	2209	92893
2015	49342	29216	9650	2407	1351	2224	94190
2016	49547	29817	10073	2454	1351	2238	95479
2017	49742	30396	10513	2502	1352	2251	96756
2018	49898	30962	10968	2551	1354	2265	97997
2019	50021	31459	11437	2600	1356	2279	99153
2020	50110	31874	11922	2651	1359	2292	100208

Notes: ‘Air’ is total domestic aviation (i.e. including general aviation).
‘Other (minor)’ includes buses, motorcycles, small marine pleasure craft, ferries and unregistered off-road motor vehicles.

Sources: BTRE estimates, Apelbaum Consulting Group (2001), ABARE (1999), ABS (2000a; 2000c; 2001a).

TABLE 1.4 BASE CASE EMISSION PROJECTIONS BY TYPE OF TRANSPORT, AUSTRALIAN DOMESTIC CIVIL TRANSPORT (INCLUDING ELECTRIC RAIL), 1990–2020

(Gigagrams of direct CO_2 equivalent)

Year	*Cars*	*Road freight vehicles*	*Air*	*Rail*	*Coastal shipping*	*Other (minor)*	*Total*
1990	34220	17321	2565	3218	1939	1890	61152
1991	34351	16982	3141	3213	1811	1885	61383
1992	34847	16810	3393	3205	1742	1890	61888
1993	35600	17607	3553	3163	1684	1896	63502
1994	36148	17722	3707	3297	1664	1911	64448
1995	37496	18329	4274	3312	1866	1926	67204
1996	38355	19018	4640	3229	1770	1942	68950
1997	38607	19203	4838	3465	1811	1957	69882
1998	39170	20268	4846	3375	1614	1972	71244
1999	40009	20537	4782	3398	1475	1982	72183
2000	40696	20762	4996	3518	1505	1980	73456
2001	41491	21329	5280	3558	1442	1998	75098
2002	43187	21798	5541	3614	1429	2015	77585
2003	44070	22386	5789	3673	1417	2033	79368
2004	44748	22992	6050	3733	1406	2050	80979
2005	45431	23399	6313	3794	1396	2068	82400
2006	45910	23902	6584	3855	1388	2085	83723
2007	46523	24445	6868	3918	1380	2101	85236
2008	46999	25010	7164	3983	1373	2118	86646
2009	47426	25583	7471	4048	1367	2135	88031
2010	47792	26153	7792	4114	1363	2151	89365
2011	48189	26768	8130	4182	1359	2166	90793
2012	48540	27379	8485	4251	1356	2180	92190
2013	48843	27991	8857	4321	1353	2195	93559
2014	49116	28610	9245	4392	1352	2209	94924
2015	49342	29216	9650	4465	1351	2224	96248
2016	49547	29817	10073	4539	1351	2238	97564
2017	49742	30396	10513	4614	1352	2251	98868
2018	49898	30962	10968	4691	1354	2265	100137
2019	50021	31459	11437	4769	1356	2279	101321
2020	50110	31874	11922	4848	1359	2292	102406

Notes: Rail transport here includes emissions from power generation for electric railways. Emissions for all other sectors relate solely to energy-end-use.
'Air' is total domestic civil aviation (i.e. including general aviation).
'Other (minor)' includes buses, motorcycles, small marine pleasure craft, ferries and unregistered off-road motor vehicles.

Sources: BTRE estimates, Apelbaum Consulting Group (2001), ABARE (1999), ABS (2000a; 2000c; 2001a).

TABLE 1.5 ORDER OF MAGNITUDE ESTIMATES FOR FULL FUEL CYCLE EMISSIONS BY AUSTRALIAN DOMESTIC CIVIL TRANSPORT, 1990–2020

(Gigagrams of direct CO_2 equivalent)

Year	Cars	Road freight vehicles	Air	Rail	Coastal shipping	Other (minor)	Total
1990	41064	20785	3078	3566	2327	2268	73088
1991	41221	20378	3769	3558	2173	2262	73362
1992	41816	20172	4072	3540	2090	2268	73958
1993	42720	21128	4264	3492	2021	2275	75900
1994	43378	21266	4448	3650	1997	2293	77033
1995	44995	21995	5129	3654	2239	2311	80323
1996	46026	22822	5568	3564	2124	2330	82434
1997	46328	23044	5806	3826	2173	2348	83526
1998	47004	24322	5815	3724	1937	2366	85168
1999	48011	24644	5738	3742	1770	2378	86284
2000	48835	24914	5995	3874	1806	2376	87801
2001	49789	25595	6336	3926	1730	2398	89774
2002	51824	26158	6649	3990	1715	2418	92754
2003	52884	26863	6947	4055	1700	2440	94889
2004	53698	27590	7260	4123	1687	2460	96818
2005	54517	28079	7576	4191	1675	2482	98519
2006	55092	28682	7901	4260	1666	2502	100103
2007	55828	29334	8242	4331	1656	2521	101912
2008	56399	30012	8597	4403	1648	2542	103600
2009	56911	30700	8965	4477	1640	2562	105255
2010	57350	31384	9350	4551	1636	2581	106853
2011	57827	32122	9756	4628	1631	2599	108562
2012	58248	32855	10182	4705	1627	2616	110233
2013	58612	33589	10628	4784	1624	2634	111871
2014	58939	34332	11094	4864	1622	2651	113503
2015	59210	35059	11580	4946	1621	2669	115086
2016	59456	35780	12088	5030	1621	2686	116661
2017	59690	36475	12616	5115	1622	2701	118219
2018	59878	37154	13162	5201	1625	2718	119737
2019	60025	37751	13724	5289	1627	2735	121151
2020	60132	38249	14306	5379	1631	2750	122447

Notes: Emissions include greenhouse gas contributions from fuel supply and processing for transport vehicle use. Rail transport includes emissions from power generation for electric railways.
'Air' is total domestic civil aviation (i.e. including general aviation).
'Other (minor)' includes buses, motorcycles, small marine pleasure craft, ferries and unregistered off-road motor vehicles.

Sources: BTRE estimates, Apelbaum Consulting Group (2001), ABARE (1999), ABS (2000a; 2000c; 2001a), CSIRO (2001).

OVERVIEW OF THE PROJECTION METHODS

Throughout the rest of this introductory chapter, we make use of what are termed 'simplifying frameworks' for understanding the factors determining transport fuel use (and consequently emission levels). These are simple mathematical formulae—in reality, just straightforward calculating instructions, given various inputs. Such formulae are based on the more rigorous modelling presented in the appendices to the report.

What the simplifying frameworks achieve is conceptual simplifications that allow reasonably robust, but very approximate, estimates to be made of the major trends in fuel consumption by Australian transport. Yet before any experts take offence at this level of simplification, let us add that such an approach can be useful—especially as it allows a ready demonstration of the major sources, and their interactions, leading to transport fuel use.

The complete models used in this report, for making projections of future transport fuel use, are generally quite complex—and can include myriad details for factors such as the differences in vehicle technologies, the age structures of fleets or fuel type disaggregations. Yet, the essential drivers of such projections (and typically, the order of magnitude of the detailed model results) can be readily understood by using the simple identities presented below.

CURRENT TRANSPORT FUEL USE

Australian domestic transport currently consumes in the order of 30 gigalitres (GL)—i.e. 30 billion litres—of petroleum fuels per annum (ignoring, for the moment, the differences in properties between fuel types). For example, allowing for the different energy contents and densities of the various fuels, Australian transport in 1998 accounted for oil and gas consumption equivalent to about 29.74 gigalitres of automotive gasoline.

The dominant transport fuel is automotive gasoline. In 1998 the consumption level was close to 18 GL (about 70 per cent of which was unleaded petrol and 30 per cent leaded petrol). Automotive gasoline (or 'petrol') use is currently followed by three other major transport fuels:

- automotive diesel oil (ADO), with 1998 consumption equivalent to around 7.5 GL of automotive gasoline
- liquefied petroleum gas (LPG), with 1998 consumption in the order of 2 GL of automotive gasoline equivalent
- aviation turbine fuel (Avtur), with 1998 consumption at around 2 GL of automotive gasoline equivalent.

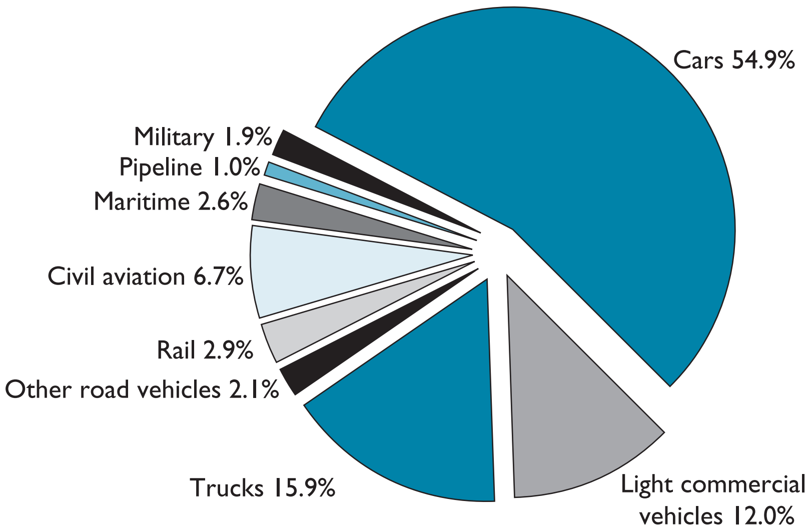
Smaller amounts of a variety of other energy sources are used by the Australian transport sector including fuel oil, natural gas (NG), coal, aviation gasoline, ethanol and electricity. However, even though most of Australia's urban railways are now electrified, these other fuel sources currently account for less than 5 per cent of total primary energy consumption by Australian transport.

Of annual transport fuel consumption, equivalent to approximately 30 gigalitres of automotive gasoline, passenger cars account for the major proportion (with close to 55 per cent of the total, as shown in figure 1.1).

Referring to figure 1.1:

- light commercial vehicles (LCVs) account for around 12 per cent of total transport fuel use and trucks for around 16 per cent
- domestic civil aviation accounts for close to another 7 per cent
- all other transport-related activities (such as coastal shipping, trains, pipelines, military transport, buses and motorcycles) account for under 11 per cent.

FIGURE 1.1 SHARES OF AUSTRALIAN DOMESTIC TRANSPORT FUEL USE, BY TRANSPORT MODE FOR 1997–98



Notes: Values refer purely to fuel end-use; therefore, 'Rail' here does not include primary energy consumption due to electricity generation and transmission for electric traction use. (If electricity generation and transmission losses were included, the rail sector's share would increase to about 4 per cent.)
'Maritime' includes small craft use as well as coastal shipping.
Estimates of fuel consumption shares for the movement of oil and gas by major pipelines and for military transport are shown here (and in figure 1.6) for comparison purposes, but these sectors are not included in the transport analyses (or any emission results derived) in this report.
Total (energy end-use by domestic transport) = 1054 petajoules (PJ) for 1997–98, with an average energy density for liquid fuels of about 35 megajoules per litre.

Sources: BTRE estimates, ABARE (1999), ABS (2001a).

As the three major road vehicle categories account for close to 83 per cent of current transport fuel use, this summary will concentrate on the outlook for car, truck and LCV fuel consumption. Aviation (a particularly fast-growing sector) will also be examined in detail. Models of these and the other sub-sectors (such as rail and sea transport) are presented in Appendices I–V. Aggregate energy consumption data from the various models are presented in Appendix VI (tables VI.4–VI.5). In the National Greenhouse Gas Inventory, military vehicles and pipelines are not included in the transport sector and, consequently, have not been included in the emission estimates and emission projections of this report.

FORECASTS OF CAR FUEL USE TO 2020

So, beginning with car fuel use, the simplifying framework looks like this:

Car fuel use = vehicles per person x population x travel x average fuel intensity (1.1)

Which, for 1997–98, gives roughly:

16.9 gigalitres = 0.5 vehicles per person x 18.8 million persons x 15 500 kilometres per vehicle x 0.116 litres per km

That is, a rough identity for current aggregate Australian car fuel use (of around 17 billion litres per annum) is composed of the car ownership level (of about 0.5 cars per person), times the national population (around 18.8 million people for 1998), times the average annual vehicle utilisation—or vehicle kilometres travelled (VKT)—of 15 500 kilometres per vehicle, times the average car fleet fuel intensity of 0.116 litres per kilometre (more commonly quoted as 11.6 L/100 km)[2]. For the car fleet, approximately 90 per cent of total fuel used is automotive gasoline. BTRE estimates of fleet fuel intensity are based on data from the ABS *Survey of Motor Vehicle Use* (SMVU).

The advantage of the simplifying framework comes when one starts to consider the likely future for car fuel use. By modelling (or using assumptions about) the likely growth of the components of the simplifying framework, it allows the ready generation of systematic forecasts of fuel use by the Australian car fleet.

Vehicles per person

The trend in per capita car travel (kilometres per person) in Australia has in general been following a logistic (saturating) curve against real per capita income—measured here by real Gross Domestic Product (GDP) per person (see figure 1.2A). The assumed base case rates of GDP growth imply that per capita car travel should level out at around 9000 kilometres per person by 2020. Together with base case assumptions about the trend in annual VKT per car, car ownership per capita is forecast to also stop growing appreciably

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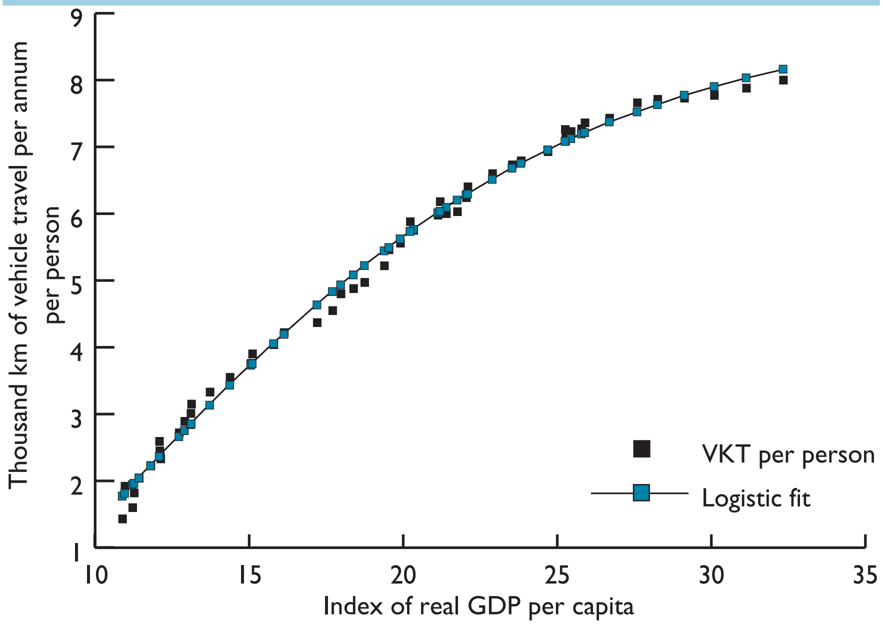
2 Note that due to rounding, some of the identities presented here will have slightly differing numerical values on their left-hand and right-hand sides.

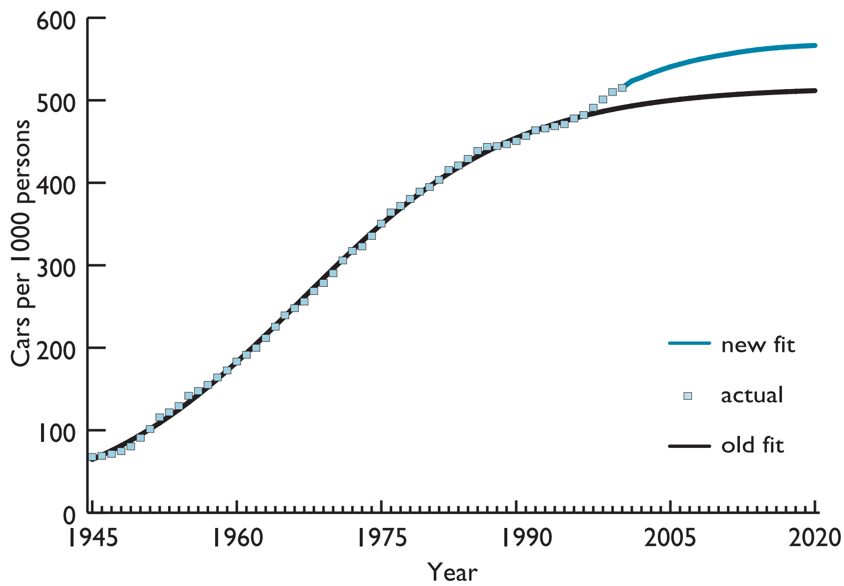
around 2020, having effectively approached a 'saturation' level of about 0.57 cars per person (see figure 1.2B). These logistic curves have been remarkably insensitive to the price of petrol and only somewhat responsive to the price of new vehicles. A large volume of new vehicle sales in recent years, associated with a period of rapid growth in incomes and lower car prices, has inflated the actual car stock to moderately above the original trend curve (see tail-end values of figure 1.2B). However, the relationship between vehicle travel and income level has remained close (tail-end values of figure 1.2A). It is still likely that car travel and ownership will continue to follow this fundamental pattern over the next 20 years. As can be seen from figure 1.2B, the actual trend in cars per person had been following a basic logistic (s-shaped) curve for over 50 years.

FIGURE 1.2a PER CAPITA HISTORICAL TREND IN ANNUAL PASSENGER TRAVEL VERSUS REAL AUSTRALIAN INCOME LEVELS



Sources: BTRE estimates, ABS (2001a).

FIGURE 1.2B PROJECTED CAR OWNERSHIP IN AUSTRALIA



Notes: 'Old fit' refers to projected values used in BTCE Report 94 (BTCE 1996b). 'New fit' refers to revised estimates allowing for price and income effects (including the recent surge in vehicle sales).

Sources: BTRE estimates, ABS (2000b).

All industrialised countries around the world have exhibited similar vehicle ownership curves, some with higher and some with lower saturation levels (e.g. Japan has a much lower saturation level due to the relative lack of road space).

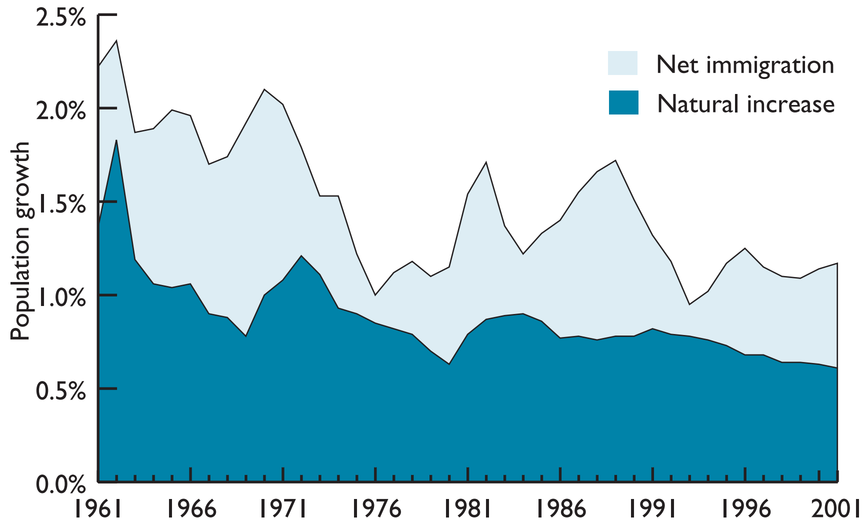
It is, of course, possible that in the longer term, the car ownership trend will depart from this simple curve. Major structural changes to the transport sector (e.g. Intelligent Transport Systems influencing travel patterns and behaviour) could conceivably allow significantly higher vehicle ownership levels than currently. Alternatively, the spread of new technologies that substitute for transport (such as telecommuting and video-conferencing), could serve to reduce the level of car ownership in the future. Likewise, the fuel price increases that are probable when future world oil consumption outstrips oil production could also deter future car use.

Population

The two main sources of population growth are natural increase and immigration. The contribution each has made to population growth over the last 40 years is shown in figure 1.3 (where the two components have been stacked—thus summing to total growth). The average growth rate of both components has tended to decline over time.

The Australian Bureau of Statistics has previously produced three scenarios for population growth—see <www.abs.gov.au> for details—projecting national population to be between about 22 million and 24 million people by 2020. The following analysis uses population projections based on the time trend to 2020 of the ABS Series III projections (ABS 2001b), assuming a net immigration level of about 70 000 persons per year and a further declining rate of natural increase (due to a fairly rapid ageing of the population, coupled with a fairly low fertility rate). The population of Australia is forecast to reach about 22.2 million in 2020 under this scenario.

FIGURE 1.3 COMPONENTS OF AUSTRALIAN POPULATION INCREASE



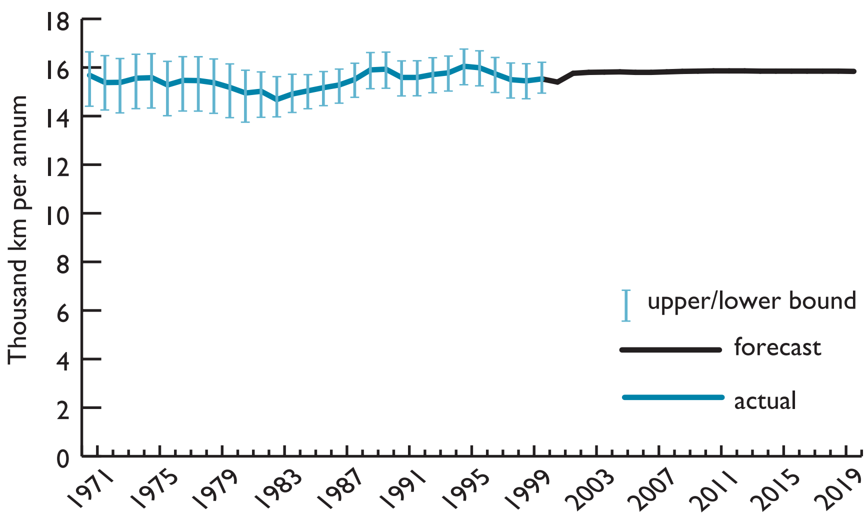
Source: ABS (2001b).

Average travel (kilometres per vehicle)

There is some controversy over what exactly is the average utilisation of the Australian car fleet. What little data are available, on the average kilometres travelled by cars in Australia, tend to be inconsistent and difficult to reconcile. Given that data on aggregate gasoline sales are known quite accurately, it is possible to estimate average fleet utilisation by using estimates for the number of vehicles on the road and the average rate of fuel consumption (L/100 km). Using this method, we are fairly confident that the current figure lies in the vicinity of 15 500 kilometres per vehicle per annum—but, with some uncertainty in the average fleet fuel consumption rate, it could be as much as 10 per cent higher or lower.

Despite not knowing car travel as accurately as one would like, there is enough evidence available to suggest that average VKT per vehicle has not varied greatly over the last 30 years (see figure 1.4). The BTRE considers the figure for current usage to be close to 15 500 kilometres per year per car, and that this is likely to increase only slowly in the future. There are a variety of factors that would tend to increase average VKT over time (such as increasing income levels). There are also a number of factors that would tend to decrease average VKT per car (such as the ageing population, increasing traffic congestion and more multi-car households). For the purposes of this projection framework, assume that these factors continue a rough balance in the future, and that average fleet VKT will increase only slightly over the next 22 years to around 15 800 kilometres per vehicle (figure 1.4).

FIGURE 1.4 ESTIMATED AVERAGE ANNUAL KILOMETRES TRAVELLED PER VEHICLE FOR THE AUSTRALIAN PASSENGER CAR FLEET



Source: BTRE estimates, ABS (2001a).

Average fuel intensity of cars

The average on-road fuel intensity of cars is another factor that is not known to great accuracy. The average on-road fuel performance on the Australian car fleet is probably between 11 to 12 litres per 100 kilometres, and most likely currently lies toward the middle of this range.

Trends in average fuel intensity are primarily influenced by two factors:

- technological progress allowing decreases in the fuel intensity of engines of given size and power

- a tendency for consumers to choose vehicles with larger, more powerful engines and more performance features.

With these two factors roughly counter-balancing, the average fuel efficiency of the Australian car fleet—allowing for the inclusion of four-wheel drive (4WD) passenger vehicles—has not changed greatly over the past 30 years (probably improving by only about 10 per cent over this period, based on ABS SMVU trend data).

For projecting fuel use out to 2020, assume a median (or base case) scenario in which the new car fleet improves its sales-weighted average fuel intensity (on-road) from about 10.3 L/100 km currently to about 9 L/100 km by 2020. Note that these fuel intensity estimates allow for the effects over time of increasing levels of urban congestion and increasing sales of 4WD passenger vehicles—often commonly termed 'All Terrain Wagons' (ATWs). This median scenario (which is based on car manufacturers' product plans for the future and on a continuation of historical trends in fleet composition) has average fleet fuel intensity declining from about 11.6 L/100 km currently to about 10.8 L/100 km by 2020.

Car fuel use by 2020

Putting together the components of the simplifying framework gives a base case forecast for car fuel use in 2020 of about 21.5 billion litres. That is:

21.5 gigalitres= 0.57 vehicles per person x 22.2 million persons x
15 800 kilometres per vehicle x 0.108 litres per kilometre

This is an increase of around 27–28 per cent on current car fuel use. Car fuel use is currently growing at about 1.5 per cent per year. By 2020, with a near-saturation of cars per person, that growth rate could have slowed to practically zero (with the first and third right-hand elements above nearly constant and reductions in fuel intensity roughly balancing population growth by 2020).

The projected greenhouse gas emissions from cars under the base case also rise about 28 per cent between 1998 and 2020.

FORECAST OF TRUCK FUEL USE TO 2020

A similar simplifying framework for trucks can be set out in the form:

Truck fuel use= freight task x average fuel intensity / average load (1.2)

This gives a current estimate of:

4.5 gigalitres = 120 billion tonne–kilometres x
0.375 litres per kilometre / 10 tonnes per vehicle

where a freight task of 'x times y' tonne–kilometres (tkm) is equivalent to 'x' tonnes of freight being moved 'y' kilometres.

Note that the 'average load' figure in the above identity is calculated across the total truck fleet—i.e. includes both rigid and articulated vehicles. The average load for rigid trucks (at 3.5 tonnes per vehicle) is substantially lower than that for articulated trucks (18.2 tonnes per vehicle). Rigid trucks accounted for approximately 55 per cent of total kilometres performed by heavy road freight vehicles and articulated trucks 45 per cent in 1999–2000.

The above 4.5 gigalitres of fuel will be primarily consumed as automotive diesel oil (ADO).

What can this framework (equation 1.2) tell us of the likely future fuel use by trucks?

Taking the last two components first, the trends in truck fuel use per kilometre are downward, in line with technical progress in engine and vehicle design. However, for the base case, the Bureau assumes that the average fuel intensity of the truck fleet will rise slightly to around 0.385 litres per kilometre by 2020. This assumed rise comes about primarily due to load per truck being assumed to increase, especially as more multiple-trailer vehicles enter the fleet. The base case scenario has average load per truck estimated as likely to reach about 17.3 tonnes by 2020. Thus, the BTRE assessment of the future fleet structure implies a significant fall in the amount of fuel required per unit freight task (i.e. in terms of litres of fuel consumed per tonne–kilometre of freight movement) over the next 20 years.

However, that does not mean that total truck fuel consumption will necessarily fall over the period. You have to look at the likely trend in the first component of the framework—the freight task—to complete the picture.

The freight task is currently growing exponentially—at least as fast as economic growth. While this cannot continue indefinitely, there are no signs yet of saturation in Australian truck freight use per person (as there are in car ownership per person). Similarly, there are no signs of saturation in current levels of United States' truck freight per person: American levels of road freight per person are already much higher than those in Australia (see figure 1.5).

Assuming an average 3 per cent (per annum) for GDP growth rate over the next 20 years (roughly, the assumed GDP growth under the base case), and that freight growth continues to be stronger than GDP growth, the result will be a more-than-doubling of the road freight task.

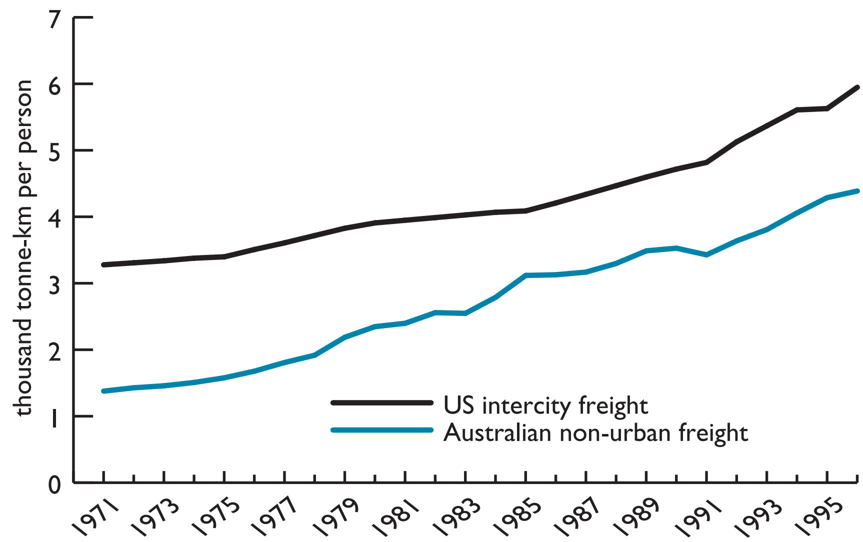
Putting these assumptions into the simplifying framework results in the following forecast of truck fuel use in 2020:

6.5 gigalitres (ADO) = 290 billion tonne–kilometres x
0.385 litres per kilometre / 17.3 tonnes per vehicle

This is nearly a 50 per cent increase on current annual fuel use by trucks (even after assuming a significant decrease in truck fuel intensity per tonne–kilometre).

Greenhouse emissions from heavy trucks are thus likely to grow by about 50 per cent between 1998 and 2020.

FIGURE 1.5 COMPARISION OF AUSTRALIAN NON-URBAN PER CAPITA ROAD FREIGHT AND US INTERCITY PER CAPITA ROAD FREIGHT



Source: BTS (1999), BTRE estimates.

Forecast of LCV Fuel Use to 2020

The light commercial vehicle (LCV) category includes utilities, panel vans and light trucks up to a weight of 3.5 tonnes (but does not include 4WD passenger vehicles and 'People Mover' passenger vans) comprising around 14 per cent of the motor vehicle fleet.

Again, a simplified framework illustrates the factors behind LCV fuel use:

LCV fuel use = number of vehicles x kilometres per vehicle
x average fuel intensity (1.3)

Giving current fuel use of about:

3.7 gigalitres = 1.7 million vehicles x 16 600 kilometres per vehicle x
0.133 litres per kilometre

For LCVs, the major fuel type is automotive gasoline (accounting for over 60 per cent of total fleet fuel use), though there is also major use of diesel and LPG.

LCV fuel use by 2020

For future LCV fuel use, the first component above (the number of vehicles) is likely to be linked to the growth of the service economy. As such, it is unlikely to show any tendency towards saturation in the near future. The numbers of LCVs increased greatly during past decades, but the average growth rate has now slowed to about 2.8 per cent per year.

Similarly to the car fleet, assume here, for simplicity, that kilometres travelled per vehicle will remain roughly constant in the future.

As with cars, the BTRE expects average fuel intensity of the LCV fleet to decline slowly. Some increases in average payloads will be more than offset by increases in engine efficiency.

Therefore, by assuming that vehicle numbers continue to grow at about 2.8 per cent per year, the base case forecast of LCV fuel use in 2020 becomes:

6.3 gigalitres = 3 million vehicles x 16 600 kilometres per vehicle x 0.125 litres per kilometre

This is an increase of around 70 per cent from current consumption levels. Again, greenhouse gas emissions are likely to increase by a similar magnitude.

FORECASTS OF DOMESTIC AVIATION FUEL USE TO 2020

Domestic commercial aviation also has a simplifying framework—with skm denoting seat–kilometres, pkm denoting passenger–kilometres:

Domestic aviation fuel use = skm x fuel per skm (1.4)
with skm = (Australian pkm + foreign pkm)/load factor

The load factor is the average proportion of the aircraft seats that are occupied.

For 1997–98:

$$1.8 \text{ GL} = \frac{0.044 \text{ litres per skm x (26 billion pkm + 3.7 billion pkm)}}{0.72}$$

The domestic aviation fuel use given above is estimated non-military usage, assuming 20 per cent of total domestic Avtur (aviation turbine fuel) sales serve military aircraft.

The first component on the right-hand side of equation 1.4 is the domestic airline task in seat–kilometres. It in turn is made up of two components:

- Australians travelling on the domestic network (about 26 million passengers per year, each travelling on average about 1000 kilometres, with an average aircraft load factor of 0.72) contributing about 36 billion seat–kilometres
- foreign tourists travelling on the domestic network (about 3.2 million per year travelling a slightly longer distance at a similar load factor to domestic passengers, 0.72) accounting for about 5.1 billion seat–kilometres.

Both of these components are growing rapidly. Continuing these trends over the next 20 years, the Australian component can be expected to grow at something like 4 per cent per year, and the foreign component at 9 per cent per year. With average travel distances assumed to increase to 1400 kilometres and with an average load factor of 0.75, the Australian component in 2020 will be almost 108 billion seat–kilometres (skm). Foreigners will contribute about 37 billion skm, for a total task of about 145 billon skm (i.e. more than triple the current skm task, given current growth rates)[3].

If aircraft fuel intensity were to fall from a current average of 0.044 litres per skm to about 0.031 litres per skm (a relatively large assumed decrease in fuel intensity), avtur use by domestic aviation in 2020 would still more than double, if current passenger growth rates are maintained, to about 4.5 gigalitres per year.

There are also small amounts of aviation gasoline (avgas) used by the general aviation sector. The total amount of avgas used is about 0.1 gigalitre per year, and is expected to remain essentially constant over the forecast period.

FORECAST OF OTHER TRANSPORT FUEL USE TO 2020

'Other' transport (not explicitly considered in this introductory chapter, but included in the detailed modelling of following chapters) includes coastal shipping, ferries, other small craft (primarily outboard motors), buses, railway transport (trains and trams), motorcycles, and off-road recreational vehicles. Current primary fuel end-use (oil and gas), totalled across all these activities, is of the order of 2 billion litres (in gasoline equivalent). Also, for many of these sectors, growth is relatively low.

For the simplified framework projections, assume that the growth rate of fuel use across all 'other transport' remains at about 1 per cent per year. This gives an estimate of total oil and gas consumption by other transport as increasing to about 2.5 gigalitres (gasoline equivalent) per year by 2020.

3 The aviation forecasts are the most sensitive segment of the base case scenario to the assumptions regarding future growth in transport demand. The projections presented here are done on the assumption that Australian domestic aviation will continue to grow strongly—i.e. future growth in travel demand will not be constrained in any way. Since the underlying growth rates are so high for aviation, any structural changes in non-urban travel behaviour in the future will have a large effect on the eventual task levels. As an example, suppose that air travel is constrained in the future to never exceed a 40 per cent mode share of non-urban passenger-kilometres (assuming that by this level, aviation would have totally replaced the contestable portion of long-distance travel, leaving mostly rural local traffic as the residual). Then growth in air passenger–kilometres could possibly be limited to the order of 170 per cent over the next 20 years (as opposed to over 240 per cent estimated using the current base case assumptions). For details of a projection scenario of the 'constrained' type (with future saturation of air mode share) see BTE Working Paper 38 (1998).

FORECAST OF DOMESTIC TRANSPORT FUEL USE TO 2020

Table 1.6 shows a comparison of the projections' starting point (estimates for 1998), and their end-point (estimates for 2020), given our simplified frameworks and all the assumptions about the major components driving total fuel use. Figure 1.6 presents the changes in modal fuel use for the base case scenario over the projection period.

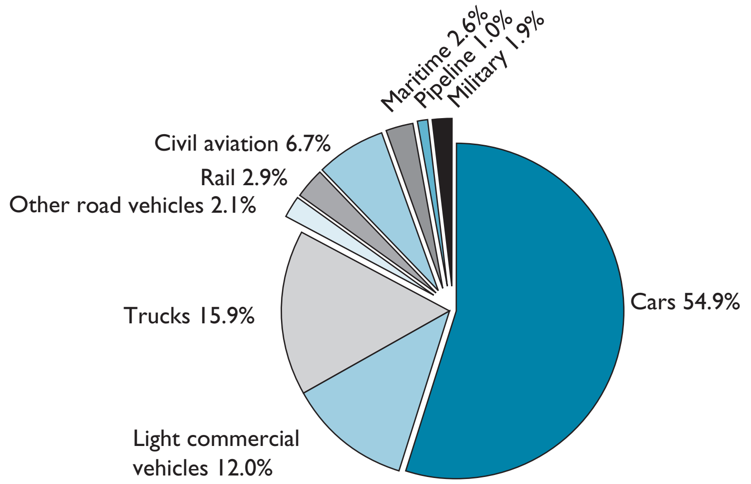
TABLE 1.6 PROJECTED INCREASES IN FUEL END-USE BY DOMESTIC AUSTRALIAN TRANSPORT— SIMPLIFIED ESTIMATES

	1998		2020		Increase
Sub-sector	*(GL)*	*(GL petrol equivalent)*	*(GL)*	*(GL petrol equivalent)*	*1998–2020 (%)*
Cars	17.0	16.9	21.6	21.5	27
Trucks	4.5	5.0	6.5	7.3	46
LCVs	3.7	3.7	6.3	6.3	70
Aviation	1.9	2.0	4.6	4.9	142
Other	1.9	2.1	2.3	2.5	23
Total		29.7		42.5	43

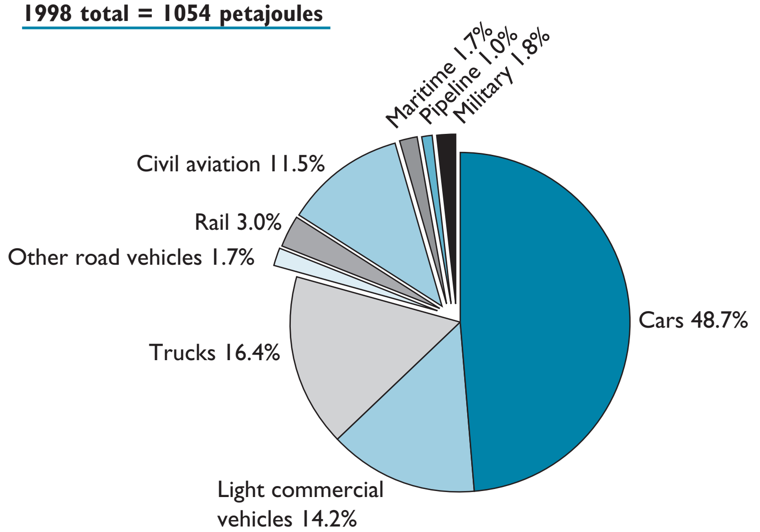
Notes: Figures refer to oil and gas end-use (i.e. do not include electricity consumption).
'GL petrol equivalent' = gigalitres of petrol (i.e automotive gasoline) equivalent consumption, on an energy content basis.
Due to rounding and the approximate nature of the simplified frameworks, values shown here will differ slightly from detailed base case results presented in later sections of this report.

Source: BTRE estimates.

FIGURE 1.6 COMPARISON OF MODAL ENERGY SHARES FOR AUSTRALIAN TRANSPORT, 1998 ACTUAL AND 2020 BASE CASE PROJECTIONS



1998 total = 1054 petajoules



2020 total = 1513 petajoules

Notes: Vaules relate to energy end-use (i.e. do not include losses due to electricity generation).
Sources: BTRE estimates, ABARE (1999), ABS (2001a)

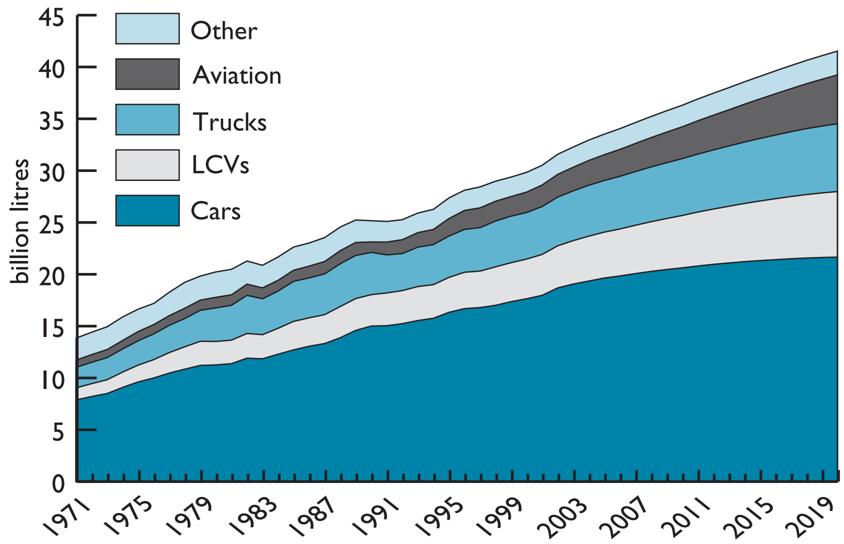
The comparisons show that:

- *total* domestic transport fuel use is forecast to grow from around 29.7 gigalitres (gasoline equivalent) in 1998 to around 42.5 gigalitres (i.e. a 43 per cent increase)

- *all major* categories are expected to show increased levels of fuel use
- *LCVs and domestic aviation* are expected to show marked increases in their share of the total usage
- *cars* are expected to show a corresponding decline in their *share* of total transport fuel use (a reflection of the tendency to saturation in per person car ownership).

Figure 1.7 shows the time trend of the components, where the dominance of cars and their slowing growth rate of fuel consumption are evident. However, trucks, LCVs and civil aviation are all increasing their total fuel consumption quite strongly—resulting in total transport fuel use growing approximately linearly. This is a phenomenon that is also apparent for the road sector in terms of numbers of vehicles (passenger car equivalents) or vehicle kilometres travelled (passenger car equivalent kilometres).

FIGURE 1.7 LONG-TERM TRENDS IN AUSTRALIAN DOMESTIC TRANSPORT FUEL CONSUMPTION AND BASE CASE FORECASTS TO 2020



Notes: Oil and gas consumption (end-use) – i.e. do not include electricity consumption. 'Other' consists of the maritime sector, non-electric rail and minor motor vehicle use (e.g. motorcycles and buses).

Sources: BTRE estimates based on BTRE Indicators (2002a), ABS (2001a) and ABARE (1999).

MODE SHARE TRENDS

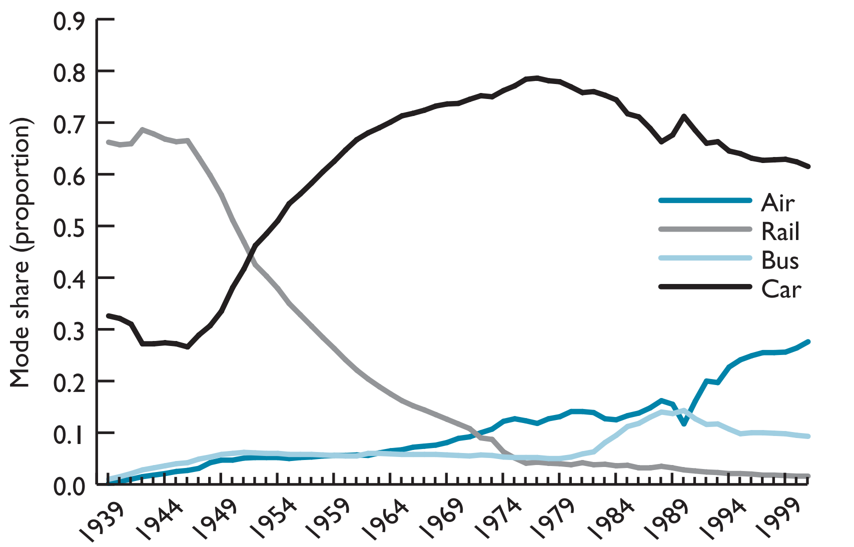
The simplified frameworks tend to hide some important changes going on at lower levels of aggregation of the transport task.

For example, notable mode shifts have been going on in passenger transport since the end of the Second World War (figure 1.8). Throughout the first half of the century, rail played a significant role in non-urban passenger movement. (There were even special trains put on to carry football supporters to neighbouring towns for ‘away’ games!) Steadily, rail lost out to car, as motor vehicles became commonplace and the road system was fully developed. Similar switches of rail to road (in mode share) also occurred for urban passenger transport.

At the same time, air travel was growing quickly, interrupted only in the early 1980s by a halving of bus fares following bus deregulation. Air had its own deregulation in the early 1990s and resumed its take-over of long distance passenger travel from the other modes.

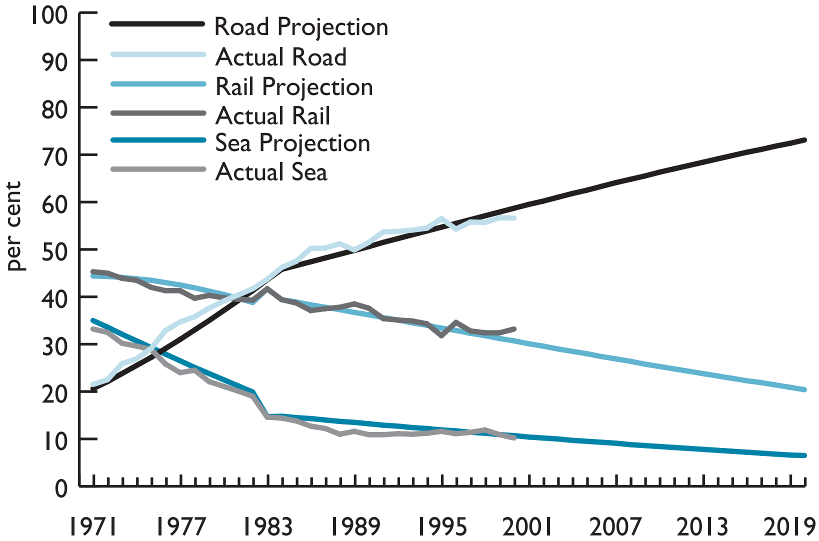
The freight task has seen similar mode-share shifts (figure 1.9). For general interstate freight, road has been the clear winner since the 1970s, taking share from rail and coastal shipping. In the absence of a major revival of rail transport (something which is possible when freight forwarders begin to run their own trains), road is likely to continue to increase its share of the freight task.

FIGURE 1.8 MODAL SHARES OF AUSTRALIAN NON-URBAN TRAVEL, MEASURED ON A PASSENGER – KILOMETRE BASIS



Source: BTRE estimates.

FIGURE 1.9 TRENDS IN MODE SHARE FOR AUSTRALIAN INTERSTATE NON-BULK FREIGHT



Note: On a tonne-kilometres basis, air freight accounts for less than 0.5 per cent of interstate movement.
Source: BTRE estimates.

EMISSION INTENSITY LEVELS

The emission intensity of a transport activity (i.e. the rate of emissions per unit transport task) will vary according to a variety of factors. These include factors such as: the mode chosen, type and condition of the transport vehicle, type of fuel consumed, average vehicle occupancy, traffic levels and environmental conditions.

National average values for modal emission intensity do not fully capture the range of such variation across a particular mode, and will not accurately represent the likely emissions from a specific transport activity. However, they will give a reasonable idea of the relative efficiencies of the various modes that will be encountered on average.

For the major passenger transport modes, the following current values for greenhouse emission intensity—in grams of direct full fuel cycle CO_2 equivalent per passenger–kilometre (g/pkm)—have been derived as part of the BTRE base case scenario:

- The Australian car fleet has an average emission intensity of around 207.3 g/pkm. This value for cars relates to nationally averaged travel, with an average occupancy level of 1.55 persons per vehicle—urban car use (with an average occupancy of about 1.5) incurs an average emission rate of around 220 g/pkm and non-urban driving (with an average occupancy of about 1.7) around 180 g/pkm.

- For rail, urban trains average around 132 g/pkm and urban trams average around 124 g/pkm (where electric rail values are inflated somewhat by the high emission rate of Victorian base load electricity generation from brown coal). Non-urban railways have a national average emission intensity of around 123 g/pkm. (For Australian rail, average operating loads are approximately 140 passengers per train and 20 passengers per tram.)
- The Australian bus and coach fleet has a national average emission intensity of around 93 g/pkm (with urban bus intensity, at an average occupancy of about eight, of around 142 g/pkm and non-urban intensity, at an average occupancy of about thirteen, of around 71 g/pkm).
- Domestic civil aviation (including general aviation) has an average emission intensity of around 196 g/pkm (where the average airline load factor is about 75 per cent).

For Australian domestic freight transport, BTRE base case values for current greenhouse emission intensity levels (in grams of direct full fuel cycle CO_2 equivalent per tonne–kilometre) are:

- The commercial road freight fleet has a combined intensity (i.e. across all vehicle types, at average operating loads) of approximately 184 g/tkm, consisting of values of the order of 2000 g/tkm for LCVs, 233 g/tkm for rigid trucks and 82 g/tkm for articulated trucks.
- Public (or 'Government') rail systems (also at average operating loads) have a bulk freight emission intensity of around 24 g/tkm (including emissions from supply of electric power) and a non-bulk freight intensity of around 33 g/tkm. Private (bulk) rail freight has an intensity of close to 8 g/tkm.
- Australian coastal shipping has an average intensity of around 17 g/tkm.

FUELS TO MEET THE FUTURE DEMAND

The simplified frameworks used above also abstract from the types of fuels used to meet the demands of transport. For Australian transport fleets:

- cars mostly use petrol (except for heavy LPG use by the taxi fleet)
- the LCV fleet is a mixture of petrol, diesel (ADO) and LPG vehicles
- heavy trucks primarily use diesel
- for railways, the primary energy sources are electricity and diesel
- aviation primarily uses aviation turbine fuel (Avtur)
- coastal shipping consumes mostly diesel and fuel oil.

We do not expect this basic picture to change all that significantly over the next decade or so. Transport fuel demand will still be primarily met by petroleum, with natural gas possibly increasing its share of total transport fuel use to something like 2–3 per cent. The increasing share of commercial road vehicles within total fuel use will mean that diesel use will account for a greater proportion of future consumption.

In the longer term, however, alternatives to petroleum use are likely to be required if transport activity levels are to be maintained.

The roll-over in the global oil market (i.e. the point where the world demand for oil outstrips the capacity to produce it) is generally forecast to occur by 2030 (USGS 2000)—after which there will be significant upward pressures on oil prices.

chapter

2

SENSITIVITY ANALYSES FOR TRANSPORT EMISSION PROJECTIONS

As a part of the BTRE's revision of the projections of transport sector emissions, the Australian Greenhouse Office (AGO) requested that the Bureau undertake sensitivity testing of the results to changes in the underlying assumptions. This chapter presents the results of various sensitivity tests conducted by the BTRE.

SENSITIVITY ANALYSES PERFORMED ON ALL SUB-SECTORS

For all sub-sectors of transport, five sensitivity analyses were performed:

1. low and high economic growth
2. low and high population growth
3. low and high fuel efficiency improvements
4. a combined result for low emission growth (low economic and population growth plus optimistic fuel efficiency improvements)
5. a combined result for high emission growth (high economic and population growth plus pessimistic fuel efficiency improvements).

Note that in tables 2.3–2.6 'Other' transport here includes buses, motorcycles, rail transport (non-electric), water transport (coastal shipping, ferries and small pleasure craft), and unregistered off-road motor vehicles.

Also note that the different settings of the various underlying variables (such as economic growth) used in the sensitivity tests do not necessarily represent alternative 'probable' scenarios for future growth. They simply relate to value ranges specified by the AGO to test the response of the base case results to variations in underlying assumptions.

Sensitivity analysis 1: Low and high economic growth

Table 2.1 shows the result for the sector of assuming that the economic growth rate is 0.5 per cent per year higher or lower than in the base case. The base case GDP growth assumptions are listed in appendix table VI.3 and imply average compound GDP growth of approximately 3 per cent per annum from 2000 to 2020. Overall, since car use and ownership are tending to saturate with regard to income, and since some sub-sectors are independent of Australian economic growth (e.g. commodity exports), the effect on total emissions is somewhat muted. For example, the high growth assumption has GDP increasing 10.5 per cent more than in the base case by 2020, whereas transport emissions are only 6.7 per cent higher. The sub-sectors most responsive to economic growth are road freight and aviation.

TABLE 2.1 SUMMARY OF CO_2 EQUIVALENT EMISSIONS UNDER SENSITIVITY 1—ECONOMIC GROWTH

(Gigagrams)

Sector	1990 Base	1998 Base	2010 Base	2010 Scenario	2010 Change from BAU (%)	2010 Base	2010 Scenario	2010 Change from BAU (%)
High GDP growth scenario (approximately 3.5 per cent per annum from 2000 to 2020)								
Cars	34220	39170	47792	48474	1.4	50110	51616	3.0
LCVs	7397	8489	11547	12313	6.6	14431	16279	12.8
Trucks	9924	11779	14606	15581	6.7	17443	19695	12.9
Aviation	2565	4846	7792	8092	3.9	11922	12812	7.5
Other	5569	5328	5700	5797	1.7	6302	6533	3.7
Total transport	59676	69612	87437	90257	3.2	100208	106935	6.7
Low GDP growth scenario (approximately 2.5 per cent per annum from 2000 to 2020)								
Cars	34220	39170	47792	47114	–1.4	50110	48626	–3.0
LCVs	7397	8489	11547	10827	–6.2	14431	12788	–11.4
Trucks	9924	11779	14606	13689	–6.3	17443	15440	–11.5
Aviation	2565	4846	7792	7504	–3.7	11922	11110	–6.8
Other	5569	5328	5700	5604	–1.7	6302	6079	–3.5
Total transport	59676	69612	87437	84738	–3.1	100208	94043	–6.2

Note: A gigagram is equal to 1000 tonnes
Source: BTRE estimates.

Sensitivity analysis 2: Low and high population growth

The base case projections were made on the assumption of a 0.74 per cent per annum average rate of population growth over the period from 2000 to 2020. Table 2.2 shows the result for the sector when either a 0.55 rate or a 0.84 rate is assumed. In other words, population in 2020 is 3.6 per cent below the base case or 2.1 per cent above the base case. These ranges essentially correspond to the differences between the high, middle and low series in the ABS (2001b) population projections. Again, the effect is muted, with estimated transport emissions, in 2020, respectively 3.5 per cent below the base case or 2 per cent above.

TABLE 2.2 SUMMARY OF CO_2 EQUIVALENT EMISSIONS UNDER SENSITIVITY 2—POPULATION GROWTH

(Gigagrams)

Sector	1990 Base	1998 Base	2010 Base	2010 Scenario	2010 Change from BAU (%)	2020 Base	2020 Scenario	2020 Change from BAU (%)
High population growth scenario (approximately 0.55 per cent per annum from 2000 to 2020)								
Cars	34220	39170	47792	48227	0.9	50110	51104	2.0
LCVs	7397	8489	11547	11697	1.3	14431	14795	2.5
Trucks	9924	11779	14606	14796	1.3	17443	17886	2.5
Aviation	2565	4846	7792	7854	0.8	11922	12113	1.6
Other	5569	5328	5700	5728	0.5	6302	6405	1.6
Total transport	59676	69612	87437	88302	1.0	100208	102303	2.1
Low population growth scenario (approximately 0.84 per cent per annum from 2000 to 2020)								
Cars	34220	39170	47792	47040	–1.6	50110	48380	–3.5
LCVs	7397	8489	11547	11284	–2.3	14431	13804	–4.3
Trucks	9924	11779	14606	14271	–2.3	17443	16677	–4.4
Aviation	2565	4846	7792	7669	–1.6	11922	11552	–3.1
Other	5569	5328	5700	5661	–0.7	6302	6255	–0.7
Total transport	59676	69612	87437	85925	–1.7	100208	96668	–3.5

Note: For those models essentially driven solely by growth in aggregate income levels, this sensitivity was conducted by assuming per capita GDP remained the same as in the base case.
Source: BTRE estimates.

Sensitivity analysis 3: Low and high fuel efficiency improvements

Fuel efficiency improvement sensitivity tests needed to be specified sub-sector by sub-sector.

For cars, the assumed base case improvement in sales-weighted *new* car fuel use, over the standard test cycle used to evaluate National Average Fuel Consumption (NAFC) values, was from 8.36 litres per 100 kilometres in 1999 to 6.7 litres per 100 kilometres in 2020. A ‘pessimistic’ outcome was assessed with fuel intensity unchanged at 8.36 litres per 100 kilometres, while an ‘optimistic’ sensitivity assumed a new car fuel intensity of 3.44 litres per 100 kilometres in 2020 (a level which would probably require radical new automotive technologies to become the norm).

For trucks, the base case assumptions were that *new* LCV fuel efficiency would improve by 0.25 per cent per year, *new* rigid trucks by 0.1 per cent and that *new* articulated trucks would have no improvement (as increasingly large trucks would become commonplace). For the pessimistic outcome, LCV fuel improvements per year were assumed to be 0.15, rigid trucks 0.0 and articulated trucks –0.1. For the optimistic outcome, LCVs were set at 0.35 per cent per year improvement, rigid trucks at 0.2 per cent and articulated trucks at 0.1 per cent.

For aviation, the base case assumption was for average increases in *total fleet* fuel efficiency of about 28 per cent from 2000 to 2020. The optimistic outcome raised this to 34 per cent, while the pessimistic outcome lowered it to 18 per cent.

For 'other' transport, the fuel intensity was varied by ± 10 per cent by 2020.

The fuel intensity sensitivity results are presented in table 2.3. The impact on emissions is greatest for cars and aviation, where the parameter ranges of the sensitivity tests are the largest. Projected transport emissions range from 9.1 per cent above to 17.1 per cent below the base case in 2020.

TABLE 2.3 SUMMARY OF CO_2 EQUIVALENT EMISSIONS UNDER SENSITIVITY 3—FUEL INTENSITY

(Gigagrams)

			2010			2020		
Sector	1990 Base	1998 Base	Base	Scenario	Change from BAU (%)	Base	Scenario	Change from BAU (%)
Pessimistic fuel intensity scenario								
Cars	34220	39170	47792	49584	3.7	50110	56590	12.9
LCVs	7397	8489	11547	11590	0.4	14431	14592	1.1
Trucks	9924	11779	14606	14669	0.4	17443	17660	1.2
Aviation	2565	4846	7792	8335	7.0	11922	13577	13.9
Other	5569	5328	5700	5871	3.0	6302	6932	10.0
Total transport	59676	69612	87437	90049	3.0	100208	109351	9.1
Optimistic fuel intensity scenario								
Cars	34220	39170	47792	42403	–11.3	50110	35006	–30.1
LCVs	7397	8489	11547	11509	–0.3	14431	14275	–1.1
Trucks	9924	11779	14606	14552	–0.4	17443	17234	–1.2
Aviation	2565	4846	7792	7447	–4.4	11922	10866	–8.9
Other	5569	5328	5700	5534	–2.9	6302	5729	–9.1
Total transport	59676	69612	87437	81445	–6.9	100208	83110	–17.1

Source: BTRE estimates.

Sensitivity analyses 4 and 5: Highest and lowest combined scenarios

The above sensitivity analyses (1–3) were then combined in two scenarios: sensitivity 4—the 'most optimistic' combination (where all the variables are chosen so as to give the lowest projected emission values); and sensitivity 5—the 'most pessimistic' (with the highest projections). As can be seen in table 2.4, the most optimistic scenario implies a 10.4 per cent reduction over the base case by 2010, and the most pessimistic scenario a 7.8 per cent increase (with a 23.7 per cent reduction and a 20 per cent increase, respectively by 2020).

Given the wide range covered by the input variables to these two scenarios, it is highly likely that any *realistic* base case scenario for the next 20 years (i.e. with the basic parameters projected according to current trends) would fall between these bounds. In fact, in order to attain the lower scenario value, large-scale changes to the Australian vehicle fleet probably would be required (e.g. having to convert the entire new vehicle market to hybrid or fuel cell vehicles by 2020).

SENSITIVITY ANALYSES FOR CARS

Due to the major contribution to total transport emissions by road passenger vehicles, and the relative complexity of their modelling framework, additional sensitivity analyses were performed for the car sub-sector.

TABLE 2.4 SUMMARY OF CO_2 EQUIVALENT EMISSIONS UNDER SENSITIVITIES 4 & 5 —HIGHEST AND LOWEST COMBINED SCENARIOS

(Gigagrams)

			2010			2020		
Sector	*1990 Base*	*1998 Base*	*Base*	*Scenario*	*Change from BAU (%)*	*Base*	*Scenario*	*Change from BAU (%)*
Most pessimistic scenario								
Cars	34220	39170	47792	50778	6.2	50110	59498	18.7
LCVs	7397	8489	11547	12361	7.0	14431	16467	14.1
Trucks	9924	11779	14606	16479	12.8	17443	22468	28.8
Aviation	2565	4846	7792	8659	11.1	11922	14592	22.4
Other	5569	5328	5700	5971	4.8	6302	7186	14.0
Total transport	59676	69612	87437	94248	7.8	100208	120211	20.0
Most optimistic scenario								
Cars	34220	39170	47792	41260	–13.7	50110	32936	–34.3
LCVs	7397	8489	11547	10793	–6.5	14431	12656	–12.3
Trucks	9924	11779	14606	13642	–6.6	17443	15262	–12.5
Aviation	2565	4846	7792	7172	–8.0	11922	10125	–15.1
Other	5569	5328	5700	5441	–4.5	6302	5527	–12.3
Total transport	59676	69612	87437	78308	–10.4	100208	76506	–23.7

Source: BTRE estimates

Response of vehicle use to income growth

Since personal travel budgets are not unlimited, passenger vehicle kilometres per capita cannot grow in a totally unconstrained fashion. In fact, there are indications that many of the world's developed countries are tending towards saturation in private vehicle use. For Australia, the BTRE has modelled per capita car use as a saturating function in per capita real GDP. The base case projections are calculated using a logistic function with an asymptote in car travel of slightly above 9000 kilometres per person per annum.

However, the overall response of this projection process to variation in assumed GDP growth rates is dependent on the form and parameters of the chosen saturating function.

If the curve is constrained such that saturation in car use is effectively attained soon after the 2020 baseline, then the responses to GDP variations over the projection period are minor. For example, for a utilisation curve close to full saturation by 2020, the high GDP growth scenario (as described earlier in Sensitivity 1) would have CO_2 equivalent emissions from cars only 0.4 per cent higher than the base case in 2020.

Alternatively, the view could be taken that the logistic function roughly gives the properly shaped trend in future vehicle use (i.e. with a declining rate of growth over time), but that full saturation is unlikely in the medium term. For the response to GDP variations, a suitable 'upper bound' scenario (as opposed to the 'lower bound' set by the full saturation case) could be derived by assuming that the car use trend curve is shifted up with respect to current income elasticities. Using Sensitivity 1 high GDP growth and an average implied income elasticity of 0.7 (constant over the projection period), gives CO_2 equivalent emissions as 7.1 per cent higher than the base case in 2020.

A scenario approximately midway between these two upper and lower bounding cases was also calculated (and used for table 2.1—the summary table for Sensitivity 1: economic growth). This case used a constant income elasticity of 0.3, giving (under parameter assumptions for the high GDP growth scenario outlined in Sensitivity 1) emissions 3.0 per cent higher than the base case in 2020.

The impacts on CO_2 equivalent emissions from cars of the different economic growth scenarios are listed in table 2.5.

Vehicle saturation levels

Related to the above sensitivity analyses—for car travel in response to changes in GDP assumptions—is the question of the dependence of the projections on the exact saturation parameter in the model's functional form.

A further sensitivity was run by allowing the asymptote in vehicle ownership to vary—such that by 2010 onwards, the level of cars per person was ± 10 per cent that of the base case. Vehicle kilometres travelled (VKT) per car was allowed to respond to the resulting variation in the vehicle availability. The resulting CO_2 equivalent emissions from cars, for this sensitivity scenario, differed by approximately 6 per cent from the base case values for 2020.

If the saturation assumption is relaxed entirely (i.e. future vehicle use is unconstrained over the medium term and is allowed to grow in line with current behavioural parameters), a considerably higher set of projections results. A scenario of no saturation in future vehicle travel gives projections of CO_2 equivalent emissions from cars nearly 22 per cent higher than the base case by 2020. (It should be noted that the saturation assumption is probably the primary difference between results obtained by several recent top-down and our bottom-up modelling approaches for vehicle travel—see figure 2.1 at the end of this chapter).

The impacts on CO_2 equivalent emissions from cars of the different vehicle saturation scenarios are also listed in table 2.5.

Rebound travel

The sensitivity results for car fuel intensity variations (as presented in Sensitivity 3) were calculated by keeping average VKT per car the same as the base case.

However, the optimistic scenario, which has the average fuel consumption rate of cars falling to very low levels, could also be run with an allowance for possible 'rebound' travel. Rebound travel refers to extra vehicle use induced by lower travel costs—here brought on by significantly lower fuel consumption rates. It is assumed here that the improvements to fuel efficiency are not obtained in part through increased fuel prices.

Such a sensitivity run, using the 'Optimistic fuel intensity scenario' from Sensitivity 3 (with a NAFC of 3.44 litres per 100 kilometres by 2020), gives emissions in 2020 of 25.9 per cent below the base case (see table 2.5). This is compared with 30.1 per cent below for the 'no-rebound' case given previously (see table 2.3).

Four-wheel drive passenger vehicles

The base case projection results are also sensitive to the input assumptions made about the future composition of the four-wheel drive (4WD) passenger vehicle fleet (also often called All Terrain Wagons).

The base case assumes that the share of 4WDs in the passenger car fleet will grow to be 20 per cent of new vehicle sales by 2020 (from their current market share of slightly above 15 per cent), and that their average new vehicle fuel intensity improves by 30 per cent. Note that in the United States, Ford have a target of a 25 per cent improvement in the average fuel efficiency of their sports utility vehicles by 2005. The base case scenario thus has 4WDs at 20 per cent market share and 9.32 litres per 100 kilometres on-road fuel consumption for new vehicles by 2020.

A variety of sensitivity scenarios were run (summarised in table 2.5) with different combinations of 4WD market share and fuel use. An upper bound was set by having new 4WDs remain at their current on-road fuel intensity over the whole projection period, and grow to be 30 per cent of car sales by 2020. This case, with 4WDs at 30 per cent and fuel use at 13.3 litres per 100 kilometres, gives 8.8 per cent higher emissions in 2020 than the base case.

A second scenario assumed that 4WD fuel intensity decreases by the same percentage as cars overall in the base case (around 22 per cent) and that sales still grow to be 30 per cent of cars by 2020. This case, with 4WDs at 30 per cent and fuel use at 10.4 litres per 100 kilometres, gives 3.6 per cent higher emissions in 2020 than the base case.

A third case, with 4WDs at 30 per cent market share and fuel use at the base case value of 9.3 litres per 100 kilometres, gives 2.1 per cent higher emissions in 2020 than the base case. (Note that almost identical results to this case are obtained under the assumptions of a 20 per cent share and 10.4 litres per 100 kilometres fuel use by 2020.)

A low scenario was also conducted—with 4WDs assumed to remain at a 15 per cent market share and fuel use set at the base case values (9.3 litres per 100 kilometres by 2020)—giving 0.7 per cent lower emissions in 2020 than the base case.

Vehicle deterioration rates

Parameters within CARMOD (the BTRE's passenger vehicle fleet model) include rates for vehicle deterioration over time. For fuel efficiency, the default values have vehicles getting approximately 1 per cent worse each year. This is until vehicles reach a plateau of about 10 per cent higher fuel use than when new (after about 10 years of ageing).

Sensitivity tests to these input parameters were conducted—a high case (with the current deterioration factors doubled) and a low case (with the deterioration factors set to zero). The high case resulted in projected emissions 4.8 per cent higher in 2020 than the base case.

Vehicle scrappage rates

Forcing the scrappage of, on average, an extra 50 000 cars per annum above the number of vehicles scrapped in the base case, resulted in projected end-use emissions 1.1 per cent lower in 2020 than the base case. Note that if emissions over the full vehicle lifecycle were considered (i.e. including emissions due to production and disposal of the vehicle), this emission benefit could be significantly reduced— possibly even negated. Since this study focuses on vehicle fuel use, such additional lifecycle effects are not dealt with here. The extra scrappage was spread over the entire fleet, although it was concentrated more heavily on older vehicles.

Nitrous oxide emissions

To aid comparability with other published results, a model run was also conducted using the current N_2O emission rates (for catalytic converter equipped cars) from the National Greenhouse Gas Inventory (NGGI) process—see NGGIC (1998a), AGO (2001a) and <www.greenhouse.gov.au/inventory/methodology/pubs/98workbook3.pdf>. These rates, in our view, significantly overestimate actual N_2O emissions from catalyst-equipped cars. Using the N_2O emission rate assumptions currently in the NGGI for such cars, gives projected CO_2 equivalent emissions 9.1 per cent higher in 2020 than the current BTRE base case value for the car fleet (compared to a 4.8 per cent difference in 2000).

The N_2O emission rates used by BTRE for our base case scenario are based on data presented previously by the Bureau (e.g. BTCE 1995a, p.182), and on rates used by the United States Environmental Protection Agency e.g. table D 12 of <http://yosemite.epa.gov/OAR/globalwarming.nsf/uniquekeylookup/shsu5bnglk/$file/annex-d.pdf>.

Fuel price

A high fuel price scenario (with crude remaining at the 2001 level of US$29.57 per barrel over the period) was conducted using two long-term price elasticities, –0.2 and –0.4. (Note that the base case uses a fuel price forecast trend specified by AGO, that results in crude oil prices of around US$22.70 per barrel by 2020.)

Under the less responsive demand scenario, the high fuel price resulted in projected emissions 3.5 per cent lower in 2020 than in the base case. Under the more responsive demand case, the high fuel price resulted in projected emissions 6.9 per cent lower in 2020 than under the base case. Recent BTRE modelling suggests that the long-run price elasticity of demand for automotive fuel is probably closer to –0.2 than –0.4.

Urban congestion

Sensitivity to the input parameter for the effect of future urban congestion levels on car fuel use was also conducted. Firstly, a high case was estimated, in which the default factors in CARMOD relating increases in VKT to consequent increases in fuel intensity were doubled. Then a low case was conducted, where the congestion factors for extra fuel consumption were removed from the model run. Using results from BTCE Report 92 *Traffic Congestion and Road User Charges in Australian Capital Cities* (1996a), the base case assumption is that increasing trends in traffic volumes will increase average urban fuel intensity (by 2020) by around 17 per cent above the level it would otherwise have reached.

The high sensitivity case resulted in projected emissions 10.4 per cent higher in 2020 than the base case.

TABLE 2.5 CO_2 EQUIVALENT EMISSIONS FROM ROAD PASSENGER VEHICLES: RESPONSE TO SENSITIVITY ANALYSIS

(Gigagrams)

Scenario			Year			
			2010		2020	
	1990	*1998*	*Gg*	*Change from BAU (%)*	*Gg*	*Change from BAU (%)*
Base case	34220	39170	47792		50110	
Economic growth						
Case 1: Saturation after 2020		High	48108	0.7	50317	0.4
		Low	47405	–0.8	49847	–0.5
Case 2: Income elasticity of 0.3		High	48474	1.4	51616	3.0
		Low	47114	–1.4	48626	–3.0
Case 3: Income elasticity of 0.7		High	49392	3.3	53659	7.1
		Low	46219	–3.3	46684	–6.8
Saturation levels						
Case 1: Vehicle ownership ±10%		High	50128	4.9	53086	5.9
		Low	45107	–5.6	46719	–6.8
Case 2: No saturation			50996	6.7	61058	21.8
Rebound travel[a]						
NAFC 3.44 L/100km by 2020			43402	..	37143	..
4WD fleet						
Case 1: 30% share, 13.3 L/100km			48770	2.0	54500	8.8
Case 2: 30% share, 10.4 L/100km			48340	1.1	51922	3.6
Case 3: 30% share, 9.3 L/100km			48109	0.7	51146	2.1
Case 4: 15% share, 9.3 L/100km			47632	–0.3	49753	–0.7
Vehicle deterioration rates		High	49741	4.1	52521	4.8
		Low	44991	–5.9	46687	–6.8
Vehicle scrappage rates						
Extra 50 000 cars p.a. scrapped			47659	–0.3	49546	–1.1
NGGI N_2O emission rate			51636	8.0	54663	9.1
Fuel price						
Elasticity = –0.2			46286	–3.2	48377	–3.5
Elasticity = –0.4			44998	–5.8	46644	–6.9
Urban congestion		High	49935	4.5	55313	10.4
		Low	45477	–4.8	44905	–10.4

.. not applicable

a. The relevant comparison here is to the 'Optimistic fuel intensity scenario' (table 2.3), rather than the base case (BAU scenario), with differences in 2010 and 2020 of 2.4 per cent and 6.1 per cent respectively.

Source: BTRE estimates.

SENSITIVITY ANALYSES FOR TRUCKS

Additional sensitivity analyses were also performed for the commercial road vehicle sub-sector.

For commercial vehicles, the additional sensitivity analyses covered changes in the following key variables:

- real road freight rates
- aggregate vehicle scrappage rates
- average new vehicle fuel intensity
- average loads.

Real road freight rates

Real road freight rates declined by 2.9 per cent per annum between 1971 and 1991, a significant factor in the strong growth in road freight transport activity over that period. Most of the decline in real road freight rates, however, were achieved by the early 1980s. Since 1980, real road freight rates have fallen by only 1.65 per cent per annum. Under the base case, the BTRE has assumed that real freight rates will decline by approximately 0.5 per cent per annum, due to continuing improvements in freight vehicle technology and trends to larger mass and dimension vehicles. The sensitivity analysis scenarios include a 'high freight growth' case—real freight rates assumed to decline by 1.65 per cent per annum (the post-1980 experience); and a 'low freight growth' case—no decline in real freight rates from 2000.

The impacts on CO_2 equivalent emissions of the different freight rate growth scenarios are listed in table 2.6. The high freight growth case implies CO_2 equivalent emissions would be 4.8 per cent and 9.6 per cent higher than the base case in 2010 and 2020, respectively. And for the low freight growth case, CO_2 equivalent emissions would be 11 per cent and 19.8 per cent lower than the base case in 2010 and 2020 respectively.

Aggregate vehicle scrappage rates

TRUCKMOD (the BTRE's truck and LCV fleet model) contains two scrappage functions: an age specific scrappage function and a fleet average scrappage function. Together, the two functions control the rate of vehicle scrappage for each vehicle vintage in any given year. The age specific scrappage functions were estimated using an econometric model and observed historical vehicle survival rates. The forecast aggregate annual scrappage rates are based on historical values.

For the scenario analysis, the BTRE estimated the impact on total end-use emissions of aggregate vehicle scrappage rates one full percentage point above and below the base case. (Note that as for cars, extra energy use from vehicle production and disposal is not included.)

The sensitivity analysis shows that changes to the scrappage rate have only a small effect on total CO_2 equivalent emissions. One percentage point difference in the aggregate scrappage rate changes total CO_2 equivalent emissions from commercial vehicles by under 0.15 per cent in 2020. The small impact of aggregate vehicle scrappage rates on total CO_2 equivalent emissions is due to the fact that only a relatively small number of vehicles are replaced by more fuel efficient vehicles under a 1 per cent increase in the aggregate scrappage rate.

Average new vehicle fuel intensity

The base case emissions projection assumed that on-road new vehicle fuel efficiencies would improve by 0.25, 0.1 and zero per cent per annum for LCVs, rigid trucks and articulated trucks, respectively. The base case fuel efficiency improvement assumptions included in TRUCKMOD are, arguably, optimistic, particularly in the case of articulated trucks. The latest *Survey of Motor Vehicle Use* (ABS 2001a) shows a possible worsening in recent years for the average fuel efficiency of articulated trucks, as the average truck size has grown. For the low sensitivity analysis, the BTRE estimated the impact of varying the average new vehicle fuel efficiency by 0.1 litres per 100 kilometres below the base case assumptions for each vehicle type. For the high emissions scenario, the fuel efficiency of the lighter commercial vehicles was increased by 0.1 litres per 100 kilometres; but new articulated truck average fuel efficiencies were set to be significantly worse than in the base case (assumed to decline by 1 per cent per annum from 2000).

Because penetration of more fuel efficient vehicles takes time, the impact of new vehicle fuel efficiency on total greenhouse emissions becomes progressively greater towards the end of the forecast period. The pessimistic new vehicle fuel intensity scenario implies that CO_2 equivalent emissions would be 3.3 per cent higher in 2010 and 8.0 per cent higher in 2020 than under the base case.

Average loads

Under the base case, average loads were assumed to grow by 0.5, 1.0 and 1.64 per cent per annum for LCVs, rigid and articulated trucks. The high and low scenarios assume growth 10 per cent higher and lower than the base case projections for each vehicle type. (Higher and lower average loads than those specified in the base case would affect freight rates and the on-road fuel efficiency, and hence greenhouse gas emissions, but these effects are not included in this analysis.)

The impact of a 10 per cent increase and decrease in average vehicle loads is a 10 per cent increase and decrease, respectively, in estimated CO_2 equivalent emissions. TRUCKMOD assumes that a 'fixed' freight task is undertaken by a 'variable' number of commercial vehicles at their 'fixed' load and utilisation intensities. An exogenous increase in the average load of freight vehicles, therefore, translates into a direct proportional reduction in vehicle travel and, assuming fixed usage across vehicle types, CO_2 equivalent emissions.

TABLE 2.6 CO_2 EQUIVALENT EMISSIONS FROM COMMERCIAL ROAD VEHICLES: RESPONSE TO SENSITIVITY ANALYSIS

(Gigagrams)

			Year			
			2010		2020	
Scenario	*1990*	*1998*	*Gg*	*Change from BAU (%)*	*Gg*	*Change from BAU (%)*
Base case	17321	20268	26153		31874	
Real freight rates						
High			27405	4.8	34942	9.6
Low			23284	–11.0	25576	–19.8
Aggregate scrappage rates						
High			26185	0.1	31921	0.1
Low			26126	–0.1	31837	–0.1
Average new vehicle fuel intensity						
High			27005	3.3	34440	8.1
Low			26061	–0.4	31509	–1.1
Average loads						
High			28760	10.0	35064	10.0
Low			23783	–9.1	28974	–9.1

Source: BTRE estimates.

BOTTOM-UP AND TOP-DOWN DIFFERENCES

As noted earlier, one of the main differences between the projection results obtained by the BTRE bottom-up modelling approach and those obtained to date by most top-down models is the assumption regarding the trend towards saturation in car utilisation per person.

The remaining differences between the results of most current top-down approaches could relate to four other main effects:

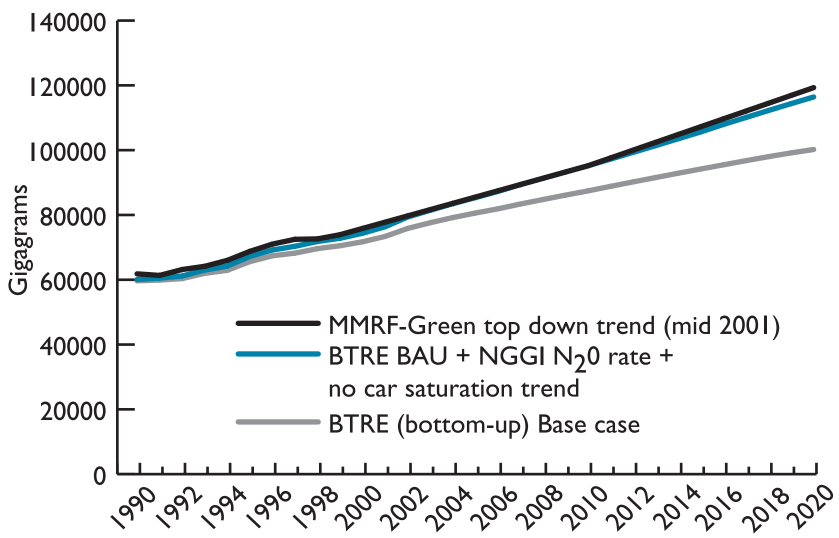
1. BTRE bottom-up projections allow for increased future traffic congestion
2. BTRE projections also allow for vehicle deterioration in fuel efficiency with the age of the vehicle
3. current BTRE projections of annual growth in fuel use by road freight appear to be slightly lower than for most current top-down results
4. BTRE vehicle fleet models use N_2O emission rates for cars equipped with a catalytic converter that are significantly lower than that of the current NGGI. This will tend to give any top-down models using NGGI

aggregate rates (AGO 2001a), a higher factor for converting fuel use into CO_2 equivalent emissions than is inherent in BTRE's CARMOD results.

Within the bottom-up calculations the magnitudes of factors 1 and 2 above presently combine to roughly counterbalance the effect of factor 3. Allowing for the methodological disagreement regarding N_2O (factor 4), combined with relaxing the model constraint specifying the approach to car use saturation, gives a projection level very similar to that obtained by one of the previous top-down approaches (see figure 2.1). This level was derived in mid 2001 using an earlier version of the Monash Multi-Regional Forecasting–Green (MMRF–Green) model specification[4] than the one currently being used by the BTRE.

As discussed in Chapter 1, the two BTRE emission modelling approaches (top-down and bottom-up) now yield essentially equivalent results (in terms of projected trends). This is largely due to the top-down modelling now using inputs (such as fuel efficiency trends and expected growth in personal travel) derived from the bottom-up modelling.

FIGURE 2.1 EMISSION PROJECTIONS FOR DIFFERENT 2001 MODEL SPECIFICATIONS



Source: BTRE estimates.

4 For details about MMRF–Green, see <http://www.monash.edu.au/policy/ftp/workpapr/op-94.pdf>.

chapter 3

STATE, TERRITORY AND URBAN TRANSPORT EMISSION PROJECTIONS

In this chapter the BTRE presents its estimates of CO_2 equivalent emissions for each State and Territory, and for the State and Territory capital cities. Estimates for rail transport have been calculated to allow for emissions from the generation of electricity (used for traction). Estimates for other modes of transport relate solely to energy end-use (i.e. direct combustion of fuel in vehicles).

STATE AND TERRITORY TRANSPORT EMISSIONS

Total State and Territory (domestic civil) transport emissions by mode are listed in tables 3.1A and 3.1B.

Due to data limitations, attribution of transport emissions to States and Territories varies according to transport mode. Wherever the data availability permits, emissions are attributed to the State and Territory within which the transport activity occurs.

In summary, transport emissions have been attributed by the following means.

- Passenger car emissions are based on the State or Territory of vehicle *registration*. Approximately 95 per cent of total passenger vehicle kilometres are performed within the relevant State or Territory of registration.
- Commercial vehicle emissions are based on the State or Territory of vehicle *operation*—i.e. where the appropriate portion of the travel is undertaken. For LCVs and rigid trucks, over 95 per cent of vehicle kilometres travelled (VKT) are within the State or Territory of registration; but over a quarter of total VKT by articulated trucks are outside the State or Territory of registration.
- Rail emissions are based on the State or Territory of operation (by the various rail systems).
- Aviation emissions are based on the State or Territory in which the fuel is sold (or 'uplifted').

- Coastal shipping emissions are based on the tonne–kilometres performed for each State or Territory sea freight task , using a weighted average of freight loaded and discharged within the ports of each State or Territory.

All estimated State by State splits for road transport are done on a dynamic basis (i.e. the input variables determining the splitting factors vary from year to year of the projection period). The estimation methods for non-road modes rely primarily on constant splitting factors.

While developing its State by State disaggregations, the BTRE sought comment from various State and Territory officials regarding the methodologies it proposed to use in forecasting freight and passenger transport for each region. There was general agreement that the proposed methods were fully acceptable, especially at the level of detail to be considered.

In fact, only one State reported having developed an aggregate projection methodology of its own that had any appreciable differences from the default BTRE processes. Even though this projection modelling approach, used within the New South Wales government, seems fairly similar to the BTRE methods, it also appears to incorporate somewhat more detail on the State level than our State by State modelling (which is essentially based on our national level approach). For example, one of the main differences appears to be their inclusion of an explicit allowance for the effects of the likely ageing of the State population on future levels of personal travel. Yet, the BTRE projection model for passenger car travel includes a rough adjustment factor for the possible effects of an ageing national population (see Appendix I). It is probable that trends projected using the two methods would be roughly consistent.

State authorities often have access to detailed data or models for some components of their transport systems. However, typically there is not enough consistent information, at the detailed level, to compile a full *bottom-up* inventory of their State's entire transport activity. In general, when scaling (localised) estimates of transport activity to State totals, State bodies tend to use the same basic aggregate data as used here by the BTRE. For example, State estimates of road use are often taken from the ABS *Survey of Motor Vehicle Use,* or derived from fuel sales data by the State marketing areas.

TABLE 3.1A STATE AND TERRITORY CO_2 EQUIVALENT EMISSIONS—ALL TRANSPORT, INCLUDING EMISSIONS FROM ELECTRIC RAIL

(Gigagrams)

Year	*NSW*	*Vic.*	*Qld*	*SA*	*WA*	*Tas.*	*NT*	*ACT*	*Total*
1990	19238	15130	11728	4984	6945	1394	886	846	61152
1991	19311	15129	11691	5045	7112	1376	873	846	61383
1992	19297	15210	11966	5008	7226	1386	904	891	61888
1993	19743	15615	12452	5136	7306	1414	907	929	63502
1994	20018	15829	12687	5189	7430	1423	921	953	64448
1995	20833	16437	13383	5316	7776	1475	996	988	67204
1996	21542	16894	13640	5364	7964	1513	1027	1006	68950
1997	21879	17099	13850	5367	8071	1552	1043	1021	69882
1998	22362	17618	13852	5552	8260	1546	1026	1028	71244
1999	22597	17972	14122	5522	8245	1613	1057	1054	72183
2000	22988	18264	14483	5707	8242	1647	1031	1095	73456
2001	23480	18660	14875	5760	8478	1661	1066	1118	75098
2002	24198	19290	15435	5921	8777	1696	1111	1156	77585
2003	24746	19728	15814	6023	9014	1716	1147	1180	79368
2004	25215	20100	16222	6107	9227	1729	1180	1199	80979
2005	25622	20424	16592	6177	9419	1738	1211	1216	82400
2006	26011	20713	16951	6235	9604	1742	1239	1229	83723
2007	26452	21052	17351	6304	9809	1752	1269	1246	85236
2008	26859	21358	17736	6365	10007	1757	1302	1261	86646
2009	27238	21653	18121	6430	10208	1763	1342	1275	88031
2010	27611	21932	18502	6485	10403	1766	1378	1288	89365
2011	27985	22228	18906	6555	10617	1774	1426	1302	90793
2012	28372	22514	19305	6613	10823	1780	1466	1316	92190
2013	28728	22786	19704	6677	11035	1784	1516	1329	93559
2014	29084	23053	20107	6736	11247	1789	1566	1341	94924
2015	29411	23305	20508	6797	11460	1791	1623	1353	96248
2016	29768	23560	20898	6851	11664	1793	1665	1365	97564
2017	30119	23809	21289	6904	11867	1795	1709	1377	98868
2018	30459	24047	21675	6953	12068	1795	1752	1388	100137
2019	30770	24260	22046	6996	12261	1793	1796	1398	101321
2020	31049	24446	22400	7031	12443	1789	1840	1407	102406

Note: Estimates include minor sources (e.g. pleasure boats) and power generation emissions for electric rail. Emissions for modes other than electric rail relate to energy end-use.

Sources: BTRE estimates, Apelbaum Consulting Group (2001), ABARE (1999), ABS (2001a).

TABLE 3.1B STATE AND TERRITORY CO_2 EQUIVALENT EMISSIONS (END-USE)— DOMESTIC TRANSPORT, EXCLUDING EMISSIONS FROM ELECTRIC RAIL

(Gigagrams)

Year	*NSW*	*Vic.*	*Qld*	*SA*	*WA*	*Tas.*	*NT*	*ACT*	*Total*
1990	18506	14865	11249	4983	6945	1394	886	846	59676
1991	18576	14867	11211	5044	7104	1376	873	846	59897
1992	18587	14935	11436	5007	7210	1386	904	891	60357
1993	19028	15353	11937	5135	7277	1414	907	929	61980
1994	19276	15573	12202	5188	7387	1423	921	953	62921
1995	20049	16171	12881	5315	7725	1475	996	988	65600
1996	20806	16605	13158	5363	7916	1513	1027	1006	67393
1997	21119	16782	13328	5366	8011	1552	1043	1021	68223
1998	21611	17314	13335	5551	8202	1546	1026	1028	69612
1999	21848	17655	13569	5521	8185	1613	1057	1054	70502
2000	22215	17933	13913	5705	8181	1647	1031	1095	71720
2001	22716	18338	14303	5759	8419	1661	1066	1118	73380
2002	23429	18963	14854	5920	8716	1696	1111	1156	75846
2003	23968	19397	15224	6021	8952	1716	1147	1180	77606
2004	24431	19764	15622	6106	9165	1729	1180	1199	79194
2005	24829	20083	15984	6176	9356	1738	1211	1216	80592
2006	25209	20368	16332	6233	9540	1742	1239	1229	81892
2007	25642	20703	16722	6303	9744	1752	1269	1246	83381
2008	26040	21004	17097	6364	9941	1757	1302	1261	84767
2009	26411	21294	17472	6429	10141	1763	1342	1275	86127
2010	26775	21568	17843	6484	10335	1766	1378	1288	87437
2011	27140	21859	18236	6554	10548	1774	1426	1302	88840
2012	27518	22140	18625	6612	10754	1780	1466	1316	90211
2013	27865	22407	19013	6675	10964	1784	1516	1329	91554
2014	28212	22669	19405	6734	11176	1789	1566	1341	92893
2015	28530	22916	19794	6796	11388	1791	1623	1353	94190
2016	28877	23165	20173	6849	11590	1793	1665	1365	95479
2017	29219	23409	20552	6902	11793	1795	1709	1377	96756
2018	29549	23642	20927	6951	11993	1795	1752	1388	97997
2019	29850	23849	21286	6994	12185	1793	1796	1398	99153
2020	30119	24030	21627	7030	12366	1789	1840	1407	100208

Note: Estimates include minor sources (e.g. pleasure boats).
Sources: BTRE estimates, Apelbaum Consulting Group (2001), ABARE (1999), ABS (2001a).

Note that it is not totally appropriate to split rail emissions across the States solely on the basis of end-use emissions (i.e. leaving out power generation emissions for electric rail). Table 3.1B is included only for the sake of completeness (e.g. for emission inventory accounting purposes, where State by State subtotals are required to sum to the national end-use total).

Passenger vehicles

The BTRE (bottom-up) base case projections of CO_2 equivalent emissions from the Australian car fleet were calculated on a national basis, using a model based on national average fleet characteristics and utilisation values.

To produce regional level estimates for passenger vehicle emission trends, the national data had to be apportioned between the various States and Territories. That is, the estimation process had the following value constraints that the State by State breakdowns must sum to:

- national CO_2 equivalent emissions
- national number of vehicles (by vehicle type)
- total Australian fuel consumption
- national VKT (by vehicle type)
- aggregate levels of population.

The first step in the process involved splitting the national population projections into State by State projections. This was achieved by using current ABS projected trends for each State and Territory population, as specified by the AGO.

From vehicle registration data (ABS 1993, 2000b and 2001a) the BTRE estimated recent trend curves for cars per person for each State and Territory. From 2000 onwards, each State curve was assumed to follow the same (slowly saturating) shape as the curve projected for national car ownership. That is, BTRE assumed that differences between the States in car ownership levels are largely structural, and that these differences will continue to remain roughly constant over time. The resulting curves were then calibrated so that their sum equalled the national projection of cars per person. (Theoretically, given the requisite data, the default process of assuming a constant relativity across States for the approach to saturation, could be varied. Car fleets for States with relatively low car ownership per person—such as NSW—could be allowed to grow somewhat more strongly over the projection period than States with already high car ownership levels, such as South Australia. However, such a modification would probably cause very little variation to the total emission estimates.)

Multiplying the State population levels by the estimates of State cars per person then gives State by State projections of vehicle fleet size.

Average utilisation values were derived for each State (i.e. average VKT per annum by cars registered in that State) using the ABS *Survey of Motor Vehicle Use* and *Motor Vehicle Census*, and sales data for automotive fuels—for State marketing areas—collated by the then Department of Industry, Science and Resources (DISR) and the Australian Institute of Petroleum (AIP). (Note that DISR has since changed to the Department of Industry, Tourism and Resources—see <www.industry.gov.au>.)

Multiplying average VKT for each State by the relative number of cars in the State then gives an estimate of total VKT for each State. The default assumption for the projection period is to keep each State's average VKT constant relative to the previously projected national average. The resulting State by State VKT projections were then calibrated to sum to the national projection of VKT. (Theoretically, separate trend curves could be done for each State—perhaps based on Gross State Product data—but since State by State average VKT relativities appear to have altered little over recent years, this was deemed unwarranted.)

Finally, national average fuel consumption rates for cars (L/100 km) were used to convert the VKT estimates into State by State projections for car fuel consumption and thus emissions (table 3.2). The default assumption for this part of the State breakdown has each State assigned the same trend in future car fuel intensity (since ABS SMVU data imply the various State car fleets exhibit little difference in average L/100 km).

Commercial vehicles

The BTRE has estimated State and Territory road freight task by State and Territory of operation[5] using SMVU data. The estimated State and Territory road freight tasks were then modelled as a function of Gross State Product and real road freight rates. The model was used to forecast State and Territory road freight tasks to 2020. Each State's share of the aggregate of these State forecasts was then multiplied by the national level forecast of total tonne–kilometres (tkm) to derive final estimates of the State and Territory road freight projections.

The share of the road freight task undertaken by different commercial vehicle types varies across States and Territories, and this affects the relative fuel efficiency of vehicle fleets across the different regions. For the projections, BTRE has taken into account the variation in fuel efficiency attributable to the differences in the mix of vehicles undertaking the road freight task. The State and Territory emission projections have been derived using the product of State or Territory freight task (in tkm) times the share of tkm by each vehicle type times the average emission intensity of that vehicle type, summed over the

5 State and Territory of operation measures the freight task carried within a particular State and Territory. The Survey of Motor Vehicle Use also records freight task by State of vehicle registration.

vehicle types. The State and Territory emission estimates were also calibrated so that their sum, for each vehicle type, was consistent with the national totals (see table 3.3).

Aviation

The State and Territory estimates of aviation emissions (tables 3.5–3.6) are based on the State or Territory in which the fuel is uplifted (ABARE 1999). Note that fuel sales statistics are based on State marketing areas, which differ slightly from State geographical areas. For example, the ACT is included as part of the NSW State marketing area. For the BTRE projections, ACT estimates of aviation emissions have been attributed on the basis of population. The BTRE has also attributed international aviation emissions by State and Territory, as shown in table 3.7, but these are not included in total domestic emissions.

Rail

State and Territory rail emissions (tables 3.9–3.10) were derived by separately accounting for the electric and non-electric, passenger and freight rail transport tasks. Passenger rail emissions were attributed to States and Territories on the basis of the share of total passenger–kilometres (pkm) travelled. Freight rail emissions were attributed to States and Territories on the basis of the share of total rail freight tonne–kilometres undertaken within each State.

Allowing for the possible provision of major new rail infrastructure during the projection period was considered by BTRE as overly speculative and has not been included in the analysis.

Shipping

The BTRE calculated coastal shipping emissions from the product of total tonne–kilometres and fuel intensity (measured in fuel consumption per tonne–kilometre performed). State and Territory coastal shipping emissions, listed in table 3.11, were derived by apportioning the forecast national emissions according to the State/Territory share of total coastal freight volumes—calculated by averaging over tonnages loaded and discharged with the State/Territory. Shipping data by State and Territory was taken from the Bureau's Coastal Shipping Database (BTRE 2002c) for the period 1993–94 to 1999–2000. For the forecast horizon, 2000 to 2020, the BTRE assumed that the State and Territory task shares remained constant at the 1999–2000 shares.

Other minor sources

Emissions for the remaining transport sources (such as buses, motorcycles, ferries, off-road recreational vehicles and small pleasure craft) are minor, comprising only around 3 per cent of total transport emissions. Their overall emission levels have therefore only been roughly estimated and are included solely for the sake of completeness when presenting tables giving 'total' transport emission estimates. Bus and motorcycle emissions (table 3.4) have been apportioned to the appropriate States/Territories using relative utilisation data from the ABS SMVU. Emissions for the other minor sources (table 3.12) have been very roughly apportioned, primarily on the basis of population. The State by State division of the minor source totals is thus merely indicative.

International transport

There is no universally agreed way of apportioning emissions due to international transport to various jurisdictions. Again, for the sake of completeness, a roughly estimated State by State division has been provided, based on the shares of total volumes of Avtur and fuel oil sold to international operators in the relevant States/Territories. As for the minor source allocation, this State by State division of international aviation (table 3.7) and international shipping (table 3.8) is also merely indicative.

TABLE 3.2 STATE AND TERRITORY CO_2 EQUIVALENT EMISSIONS (END-USE)—PASSENGER CARS

(Gigagrams)

Year	*NSW*	*Vic.*	*Qld*	*SA*	*WA*	*Tas.*	*NT*	*ACT*	*Total*
1990	10718	9675	6234	2720	3226	794	215	638	34220
1991	10772	9679	6115	2764	3384	776	228	633	34351
1992	10838	9757	6273	2788	3485	801	244	662	34847
1993	11072	9968	6408	2848	3560	819	249	676	35600
1994	11242	10121	6507	2892	3615	831	253	687	36148
1995	11661	10499	6749	3000	3750	862	262	712	37496
1996	11929	10740	6904	3068	3836	882	268	729	38355
1997	12007	10810	6949	3089	3861	888	270	734	38607
1998	12078	11054	6936	3228	4005	868	278	725	39170
1999	12257	11294	7202	3245	4075	908	280	749	40009
2000	12563	11436	7343	3315	4065	934	288	752	40696
2001	12799	11665	7515	3357	4158	940	295	763	41491
2002	13310	12144	7856	3475	4339	966	307	790	43187
2003	13572	12391	8051	3528	4440	973	313	801	44070
2004	13772	12578	8210	3567	4521	975	318	807	44748
2005	13974	12766	8371	3605	4602	977	322	813	45431
2006	14113	12897	8495	3626	4664	974	326	816	45910
2007	14293	13065	8645	3657	4739	974	329	820	46523
2008	14430	13195	8770	3678	4801	970	333	822	46999
2009	14553	13312	8887	3694	4857	966	335	822	47426
2010	14656	13411	8992	3705	4908	960	338	822	47792
2011	14769	13519	9104	3719	4962	955	340	822	48189
2012	14868	13613	9207	3729	5011	948	343	821	48540
2013	14952	13694	9302	3736	5056	941	345	819	48843
2014	15026	13766	9391	3740	5098	932	346	817	49116
2015	15086	13825	9471	3740	5134	923	348	814	49342
2016	15140	13877	9547	3739	5169	914	349	810	49547
2017	15191	13927	9622	3738	5203	904	351	807	49742
2018	15230	13966	9689	3733	5232	893	352	802	49898
2019	15259	13996	9750	3727	5258	882	353	797	50021
2020	15278	14016	9804	3717	5281	870	353	792	50110

Sources: BTRE estimates, Apelbaum Consulting Group (2001), ABARE (1999), ABS (2001a).

TABLE 3.3 STATE AND TERRITORY CO_2 EQUIVALENT EMISSIONS (END-USE)—COMMERCIAL VEHICLES[a]

(Gigagrams)

Year	*NSW*	*Vic.*	*Qld*	*SA*	*WA*	*Tas.*	*NT*	*ACT*	*Total*
1990	5555	3946	3285	1447	2157	399	388	144	17321
1991	5446	3869	3220	1419	2115	391	381	142	16982
1992	5399	3818	3257	1386	2075	381	341	154	16810
1993	5582	4060	3517	1436	2122	389	326	175	17607
1994	5609	4121	3566	1432	2123	381	304	186	17722
1995	5806	4248	3772	1426	2187	391	313	188	18329
1996	6070	4389	3919	1425	2261	424	346	183	19018
1997	6213	4449	3912	1408	2237	443	350	191	19203
1998	6599	4689	4076	1495	2347	481	375	205	20268
1999	6749	4797	4104	1449	2325	512	393	208	20537
2000	6778	4925	4066	1536	2358	502	356	243	20762
2001	6948	5052	4202	1567	2434	511	365	251	21329
2002	7082	5157	4321	1591	2499	518	373	258	21798
2003	7255	5289	4466	1622	2578	527	383	267	22386
2004	7432	5425	4616	1654	2660	537	393	276	22992
2005	7543	5513	4727	1672	2719	542	400	283	23399
2006	7686	5622	4857	1697	2791	548	409	290	23902
2007	7840	5742	4999	1724	2868	556	418	299	24445
2008	8000	5865	5146	1752	2948	564	428	307	25010
2009	8161	5990	5297	1780	3029	572	438	316	25583
2010	8320	6114	5448	1808	3111	579	448	325	26153
2011	8492	6247	5611	1838	3199	588	458	335	26768
2012	8662	6379	5774	1868	3287	596	469	345	27379
2013	8831	6510	5938	1897	3377	604	480	354	27991
2014	9001	6642	6106	1927	3468	611	491	364	28610
2015	9166	6771	6274	1955	3558	619	502	374	29216
2016	9328	6897	6441	1982	3648	626	513	383	29817
2017	9482	7017	6605	2008	3736	632	523	393	30396
2018	9632	7134	6767	2032	3824	638	533	402	30962
2019	9759	7234	6917	2052	3903	642	543	410	31459
2020	9859	7314	7048	2067	3974	644	551	417	31874

a. Includes light commercial vehicles, articulated trucks, rigid and other truck types.

Sources: BTRE estimates, Apelbaum Consulting Group (2001), ABARE (1999), ABS (2001a).

TABLE 3.4 STATE AND TERRITORY CO_2 EQUIVALENT EMISSIONS (END-USE)—OTHER ROAD TRANSPORT[a]

(Gigagrams)

Year	*NSW*	*Vic.*	*Qld*	*SA*	*WA*	*Tas.*	*NT*	*ACT*	*Total*
1990	445	321	283	120	145	38	39	28	1420
1991	442	319	281	119	144	38	39	28	1410
1992	442	319	281	119	144	38	39	28	1410
1993	442	319	281	119	144	38	39	28	1410
1994	445	321	283	120	145	38	39	28	1420
1995	448	323	285	121	146	39	40	28	1430
1996	451	325	287	122	147	39	40	28	1440
1997	454	328	289	123	148	39	40	28	1450
1998	457	330	291	124	149	40	41	29	1460
1999	461	332	293	124	150	40	41	29	1470
2000	458	330	292	124	150	40	41	29	1462
2001	462	334	296	124	151	39	41	29	1475
2002	466	337	300	124	153	39	41	29	1488
2003	469	339	303	125	155	39	42	29	1501
2004	473	342	307	125	157	39	42	29	1514
2005	477	345	311	126	158	39	42	29	1527
2006	480	348	315	126	160	38	43	29	1540
2007	484	350	319	127	162	38	43	29	1552
2008	487	353	323	127	164	38	43	29	1564
2009	491	356	327	127	165	38	44	29	1577
2010	494	358	331	128	167	38	44	29	1589
2011	498	361	334	128	169	37	44	29	1600
2012	501	363	338	128	170	37	44	29	1610
2013	504	365	342	129	172	37	45	29	1621
2014	507	368	345	129	173	36	45	29	1632
2015	510	370	349	129	175	36	45	29	1643
2016	512	372	352	129	176	36	46	29	1653
2017	515	374	356	130	178	36	46	28	1663
2018	518	376	359	130	180	35	46	28	1673
2019	521	378	363	130	181	35	46	28	1683
2020	524	381	366	130	183	35	47	28	1693

a. Includes buses and motor cycles.

Sources: BTRE estimates, Apelbaum Consulting Group (2001), ABARE (1999), ABS (2001a).

TABLE 3.5 STATE AND TERRITORY CO_2 EQUIVALENT EMISSIONS (END-USE)—AVIATION GASOLINE, ON A FUEL UPLIFT BASIS

(Gigagrams)

Year	NSW	Vic.	Qld	SA	WA	Tas.	NT	ACT	Total
1990	65.0	48.7	71.5	29.2	45.5	9.7	26.0	3.2	298.8
1991	56.9	34.4	59.7	25.2	36.7	6.9	20.6	2.8	243.2
1992	49.7	34.1	49.9	22.7	34.1	9.1	27.2	2.5	229.3
1993	54.5	38.1	57.2	26.2	33.4	9.5	21.5	2.7	243.1
1994	52.8	33.7	57.8	24.1	33.7	9.6	21.7	2.6	236.0
1995	43.2	34.0	58.9	27.2	36.3	6.8	31.7	2.1	240.2
1996	46.2	30.0	62.4	18.5	39.3	4.6	27.7	2.3	231.0
1997	46.7	35.0	60.7	21.0	39.7	4.7	25.7	2.3	235.8
1998	48.3	32.2	64.4	20.7	36.8	6.9	25.3	2.3	236.9
1999	48.2	34.4	66.6	20.7	36.7	6.9	27.5	2.3	243.3
2000	46.9	32.1	62.1	21.4	36.4	6.4	30.0	2.3	237.6
2001	46.9	32.1	62.1	21.4	36.4	6.4	30.0	2.3	237.6
2002	48.6	31.8	61.5	21.2	36.1	6.4	29.7	2.3	237.6
2003	48.6	31.8	61.5	21.2	36.1	6.4	29.7	2.3	237.6
2004	48.6	31.8	61.5	21.2	36.1	6.4	29.7	2.3	237.6
2005	50.2	31.5	61.0	21.0	35.7	6.3	29.4	2.4	237.5
2006	50.3	31.5	61.0	21.0	35.7	6.3	29.4	2.3	237.5
2007	50.3	31.5	61.0	21.0	35.7	6.3	29.4	2.3	237.5
2008	51.8	31.3	60.4	20.8	35.4	6.3	29.2	2.4	237.6
2009	51.8	31.3	60.4	20.8	35.4	6.3	29.2	2.4	237.6
2010	51.4	31.0	62.0	20.7	35.1	6.2	28.9	2.3	237.6
2011	51.4	31.0	62.0	20.7	35.1	6.2	28.9	2.3	237.6
2012	52.9	30.7	61.4	20.5	34.8	6.1	28.7	2.4	237.5
2013	53.0	30.7	61.4	20.5	34.8	6.1	28.7	2.3	237.5
2014	53.0	30.7	61.4	20.5	34.8	6.1	28.7	2.3	237.5
2015	53.0	30.7	61.4	20.5	34.8	6.1	28.7	2.3	237.5
2016	53.0	30.7	61.4	20.5	34.8	6.1	28.7	2.3	237.5
2017	53.0	30.7	61.4	20.5	34.8	6.1	28.7	2.3	237.5
2018	53.0	30.7	61.4	20.5	34.8	6.1	28.7	2.3	237.5
2019	53.1	30.7	61.4	20.5	34.8	6.1	28.7	2.2	237.5
2020	53.1	30.7	61.4	20.5	34.8	6.1	28.7	2.2	237.5

Sources: BTRE estimates, Apelbaum Consulting Group (2001), ABARE (1999).

TABLE 3.6 STATE AND TERRITORY CO_2 EQUIVALENT EMISSIONS (END-USE)— DOMESTIC AVIATION TURBINE FUEL, ON A FUEL UPLIFT BASIS

(Gigagrams)

Year	*NSW*	*Vic.*	*Qld*	*SA*	*WA*	*Tas.*	*NT*	*ACT*	*Total*
1990	666	418	421	188	299	53	189	32	2266
1991	827	524	612	270	378	69	179	41	2899
1992	888	593	677	257	414	63	228	45	3163
1993	944	548	784	257	414	69	247	47	3310
1994	944	546	869	258	454	74	278	49	3471
1995	1073	645	1049	282	524	81	323	56	4034
1996	1273	709	1097	300	571	73	319	63	4405
1997	1319	737	1137	309	620	88	328	66	4604
1998	1389	792	1090	312	616	67	275	67	4609
1999	1355	781	1030	333	628	64	281	65	4538
2000	1398	794	1183	340	626	67	281	68	4758
2001	1497	846	1263	325	670	69	300	73	5042
2002	1553	883	1338	345	711	72	325	76	5303
2003	1649	934	1351	360	756	76	345	80	5551
2004	1724	974	1422	373	794	77	363	84	5812
2005	1796	1013	1494	387	833	81	384	88	6075
2006	1884	1055	1568	397	871	81	398	92	6347
2007	1972	1098	1647	407	911	85	415	96	6631
2008	2060	1142	1729	419	954	86	436	100	6926
2009	2136	1186	1816	439	1002	89	463	104	7234
2010	2226	1234	1906	453	1049	91	486	109	7555
2011	2295	1280	2002	478	1106	96	521	113	7893
2012	2390	1332	2102	496	1160	101	548	118	8248
2013	2472	1383	2207	522	1220	106	585	123	8619
2014	2562	1437	2317	546	1283	111	622	129	9007
2015	2642	1492	2433	577	1352	115	666	134	9413
2016	2761	1559	2543	603	1413	120	696	140	9836
2017	2884	1629	2656	630	1476	126	727	146	10275
2018	3012	1701	2774	658	1542	131	759	153	10730
2019	3144	1776	2895	687	1609	137	793	160	11200
2020	3280	1852	3021	717	1679	143	827	166	11684

Sources: BTRE estimates, Apelbaum Consulting Group (2001), ABARE (1999).

TABLE 3.7 STATE AND TERRITORY CO_2 EQUIVALENT EMISSIONS (END-USE)— INTERNATIONAL AVIATION, ON A FUEL UPLIFT BASIS

(Gigagrams)

Year	NSW[a]	Vic.	Qld	SA	WA	Tas.	NT	Total
1990	1932	785	747	199	423	39	187	4312
1991	1951	800	884	232	435	42	143	4487
1992	2035	879	951	215	464	37	178	4759
1993	2231	838	1136	222	477	42	198	5144
1994	2212	828	1247	220	519	44	222	5292
1995	2371	923	1420	228	566	46	243	5795
1996	2722	982	1437	234	596	40	232	6243
1997	2798	1012	1477	239	642	48	237	6452
1998	3212	1186	1545	263	696	40	216	7159
1999	3048	1137	1420	273	690	37	215	6819
2000	2798	1029	1451	249	612	34	191	6363
2001	3351	1224	1732	265	732	40	229	7572
2002	3570	1313	1884	289	797	43	254	8151
2003	3845	1409	1930	307	861	45	274	8671
2004	4085	1494	2065	323	919	47	293	9226
2005	4331	1581	2207	341	981	50	315	9805
2006	4613	1671	2353	355	1041	51	332	10416
2007	4906	1767	2510	370	1107	54	351	11066
2008	5210	1869	2680	387	1178	56	375	11755
2009	5504	1978	2867	413	1260	59	406	12486
2010	5835	2093	3062	434	1343	62	434	13263
2011	6140	2216	3282	467	1445	66	474	14091
2012	6508	2346	3507	493	1542	71	508	14974
2013	6864	2484	3755	529	1654	75	552	15914
2014	7248	2630	4017	564	1773	81	599	16913
2015	7628	2788	4305	608	1906	85	654	17974
2016	8106	2963	4575	647	2026	91	695	19102
2017	8614	3148	4861	687	2153	97	739	20297
2018	9151	3344	5164	730	2287	103	785	21563
2019	9719	3552	5485	775	2429	109	834	22902
2020	10320	3772	5824	823	2579	116	885	24318

a. ACT included here with NSW.

Sources: BTRE estimates, Apelbaum Consulting Group (2001), ABARE (1999).

TABLE 3.8 STATE AND TERRITORY CO_2 EQUIVALENT EMISSIONS (END-USE)—INTERNATIONAL SHIPPING, ON A FUEL UPLIFT BASIS

(Gigagrams)

Year	*NSW*	*Vic.*	*Qld*	*SA*	*WA*	*Tas.*	*NT*	*Total*
1990	719	649	417	93	371	46	23	2319
1991	650	587	378	84	336	42	21	2098
1992	626	565	363	81	323	40	20	2019
1993	621	561	360	80	320	40	20	2002
1994	643	581	373	83	332	41	21	2075
1995	766	692	445	99	395	49	25	2470
1996	753	680	437	97	389	49	24	2430
1997	806	728	468	104	416	52	26	2599
1998	692	625	402	89	357	45	22	2232
1999	694	627	403	90	358	45	22	2239
2000	715	646	415	92	369	46	23	2308
2001	727	657	422	94	375	47	23	2346
2002	730	659	424	94	377	47	24	2354
2003	732	661	425	94	378	47	24	2362
2004	735	664	427	95	379	47	24	2370
2005	737	665	428	95	380	48	24	2376
2006	739	667	429	95	381	48	24	2382
2007	740	669	430	96	382	48	24	2388
2008	742	670	431	96	383	48	24	2393
2009	743	671	431	96	384	48	24	2397
2010	744	672	432	96	384	48	24	2401
2011	745	673	433	96	385	48	24	2404
2012	746	674	433	96	385	48	24	2407
2013	747	675	434	96	385	48	24	2409
2014	748	675	434	96	386	48	24	2411
2015	748	676	434	97	386	48	24	2413
2016	748	676	435	97	386	48	24	2414
2017	749	676	435	97	386	48	24	2415
2018	749	676	435	97	387	48	24	2416
2019	749	677	435	97	387	48	24	2417
2020	749	677	435	97	387	48	24	2417

Sources: BTRE estimates, Apelbaum Consulting Group (2001), ABARE (1999).

TABLE 3.9 STATE AND TERRITORY CO_2 EQUIVALENT EMISSIONS—PASSENGER RAIL

(Gigagrams)

Year	*NSW*	*Vic.*	*Qld*	*SA*	*WA*	*Tas.*	*Total*
1990	607	300	120	32	24	0	1083
1991	641	297	134	29	31	0	1133
1992	595	306	130	26	38	0	1094
1993	551	290	133	27	46	0	1046
1994	607	284	147	30	53	0	1121
1995	640	296	147	28	58	0	1169
1996	650	320	150	29	55	0	1204
1997	663	347	155	29	67	0	1262
1998	660	334	150	29	65	0	1238
1999	672	348	162	29	67	0	1277
2000	689	362	155	29	68	0	1304
2001	683	353	157	30	66	0	1288
2002	688	357	158	30	68	0	1301
2003	697	361	159	30	69	0	1316
2004	703	366	161	30	69	0	1330
2005	712	371	161	30	70	0	1345
2006	720	375	163	30	71	0	1360
2007	728	380	164	31	72	0	1375
2008	737	385	166	31	73	0	1390
2009	745	389	167	31	74	0	1406
2010	754	394	168	31	74	0	1421
2011	762	399	170	31	75	0	1437
2012	771	404	171	31	76	0	1454
2013	780	409	172	31	77	0	1470
2014	789	414	174	31	78	0	1487
2015	798	419	175	32	79	0	1504
2016	808	425	177	32	80	0	1521
2017	817	430	178	32	81	0	1538
2018	827	435	180	32	82	0	1556
2019	836	441	181	32	83	0	1574
2020	846	446	183	32	84	0	1591

Notes: Estimates include power generation emissions for electric rail.
Emissions for diesel rail relate to energy end-use.
ABARE data attribute no rail energy consumption to NT or ACT.

Sources: BTRE estimates, Apelbaum Consulting Group (2001), ABARE (1999).

TABLE 3.10 STATE AND TERRITORY CO_2 EQUIVALENT EMISSIONS—FREIGHT RAIL

(Gigagrams)

Year	*NSW*	*Vic.*	*Qld*	*SA*	*WA*	*Tas.*	*Total*
1990	498.0	127.5	774.9	265.2	452.0	17.3	2134.9
1991	473.7	123.8	757.3	244.8	463.4	16.7	2079.6
1992	450.6	106.5	802.4	240.2	495.0	16.3	2111.0
1993	475.9	118.4	786.4	257.8	462.6	16.0	2117.1
1994	499.5	130.3	775.6	268.8	485.9	15.4	2175.5
1995	487.7	102.6	789.3	252.6	496.2	14.8	2143.2
1996	472.3	98.3	709.7	228.6	503.2	13.4	2025.5
1997	530.0	106.5	793.0	227.0	533.4	13.7	2203.7
1998	513.7	120.3	774.6	184.7	530.7	12.8	2136.7
1999	502.6	120.0	807.1	174.3	504.1	12.7	2120.8
2000	525.6	124.6	853.2	181.5	516.4	13.2	2214.5
2001	527.9	124.2	868.4	180.9	555.8	13.1	2270.4
2002	535.2	125.0	891.2	181.8	566.9	13.2	2313.2
2003	542.7	125.8	914.8	182.7	578.3	13.3	2357.5
2004	550.4	126.6	938.9	183.6	589.9	13.4	2402.7
2005	558.1	127.5	963.5	184.5	601.7	13.4	2448.8
2006	565.9	128.3	988.7	185.4	613.8	13.5	2495.7
2007	573.8	129.1	1014.4	186.4	626.1	13.6	2543.5
2008	581.9	130.0	1040.7	187.3	638.7	13.7	2592.3
2009	590.0	130.8	1067.6	188.2	651.5	13.8	2642.0
2010	598.3	131.7	1095.1	189.1	664.6	13.9	2692.7
2011	606.6	132.6	1123.1	190.1	678.0	14.0	2744.3
2012	615.1	133.4	1151.8	191.0	691.6	14.1	2797.0
2013	623.7	134.3	1181.1	191.9	705.5	14.2	2850.7
2014	632.3	135.2	1211.1	192.9	719.7	14.3	2905.4
2015	641.1	136.0	1241.6	193.8	734.2	14.4	2961.2
2016	650.1	136.9	1272.9	194.7	748.9	14.5	3018.0
2017	659.1	137.8	1304.9	195.7	764.0	14.6	3076.0
2018	668.2	138.7	1337.5	196.6	779.4	14.7	3135.1
2019	677.5	139.6	1370.8	197.6	795.1	14.8	3195.4
2020	686.9	140.6	1406.0	197.5	811.1	14.9	3256.8

Notes: Estimates include power generation emissions for electric rail.
Emissions for diesel rail relate to energy end-use
ABARE data attribute no rail energy consumption to NT or ACT.

Sources: BTRE estimates, Apelbaum Consulting Group (2001), ABARE (1999).

TABLE 3.11 STATE AND TERRITORY CO_2 EQUIVALENT EMISSIONS (END-USE)— COASTAL SHIPPING, ON A FREIGHT TASK BASIS

(Gigagrams)

Year	*NSW*	*Vic.*	*Qld*	*SA*	*WA*	*Tas.*	*NT*	*Total*
1990	512.5	174.5	460.5	144.9	552.6	70.6	23.1	1938.7
1991	478.6	163.0	430.0	135.3	516.1	66.0	21.6	1810.5
1992	460.6	156.9	413.9	130.2	496.7	63.5	20.7	1742.5
1993	445.1	151.6	399.9	125.8	480.0	61.4	20.0	1683.8
1994	439.8	149.8	395.2	124.3	474.2	60.6	19.8	1663.8
1995	493.4	168.0	443.3	139.5	532.0	68.0	22.2	1866.3
1996	468.0	159.4	420.5	132.3	504.6	64.5	21.1	1770.3
1997	461.7	162.3	462.4	122.2	516.4	62.5	23.9	1811.4
1998	430.8	140.7	376.3	119.2	460.4	58.4	27.9	1613.7
1999	367.8	140.5	362.9	107.3	409.6	57.6	29.6	1475.3
2000	341.1	133.0	434.3	120.1	372.3	73.4	30.5	1504.7
2001	326.9	127.5	416.2	115.1	356.9	70.4	29.3	1442.2
2002	323.9	126.3	412.4	114.0	353.6	69.7	29.0	1429.0
2003	321.2	125.2	408.9	113.1	350.6	69.1	28.7	1417.0
2004	318.8	124.3	405.8	112.2	347.9	68.6	28.5	1406.1
2005	316.5	123.4	403.0	111.4	345.5	68.1	28.3	1396.3
2006	314.6	122.6	400.5	110.7	343.4	67.7	28.1	1387.6
2007	312.8	122.0	398.2	110.1	341.4	67.3	28.0	1379.9
2008	311.3	121.4	396.3	109.6	339.8	67.0	27.9	1373.2
2009	310.0	120.9	394.6	109.1	338.4	66.7	27.7	1367.4
2010	308.9	120.4	393.2	108.7	337.2	66.5	27.6	1362.6
2011	308.0	120.1	392.1	108.4	336.2	66.3	27.6	1358.6
2012	307.3	119.8	391.2	108.2	335.4	66.1	27.5	1355.5
2013	306.8	119.6	390.6	108.0	334.9	66.0	27.4	1353.3
2014	306.4	119.5	390.1	107.9	334.5	65.9	27.4	1351.8
2015	306.3	119.4	390.0	107.8	334.3	65.9	27.4	1351.2
2016	306.3	119.4	390.0	107.9	334.4	65.9	27.4	1351.3
2017	306.5	119.5	390.3	107.9	334.6	66.0	27.4	1352.2
2018	306.9	119.7	390.7	108.1	335.0	66.0	27.5	1353.9
2019	307.5	119.9	391.4	108.2	335.6	66.2	27.5	1356.3
2020	308.2	120.2	392.3	108.5	336.4	66.3	27.6	1359.4

Sources: BTRE Coastal Shipping Database, BTRE estimates.

TABLE 3.12 STATE AND TERRITORY CO_2 EQUIVALENT EMISSIONS (END-USE)—OTHER MINOR TRANSPORT SOURCES[a]

(Gigagrams)

Year	*NSW*	*Vic.*	*Qld*	*SA*	*WA*	*Tas.*	*NT*	*ACT*	*Total*
1990	172.1	118.7	78.8	38.8	43.8	12.5	4.4	0.8	470
1991	173.9	119.6	80.4	39.1	44.3	12.6	4.5	0.8	475
1992	175.6	120.4	82.3	39.3	44.9	12.7	4.5	0.8	480
1993	177.1	120.9	84.5	39.5	45.5	12.8	4.6	0.8	486
1994	178.8	121.4	86.5	39.6	46.2	12.8	4.7	0.8	491
1995	180.5	122.1	88.5	39.7	47.0	12.8	4.8	0.8	496
1996	182.5	123.0	90.2	39.7	47.7	12.8	4.9	0.8	502
1997	184.1	124.1	91.6	39.8	48.5	12.7	5.0	0.8	507
1998	185.9	125.4	93.0	40.0	49.3	12.7	5.1	0.8	512
1999	186.0	125.3	93.3	39.7	49.5	12.5	5.1	0.8	512
2000	187.8	126.7	94.6	39.8	50.1	12.5	5.2	0.8	517
2001	189.3	127.9	95.8	39.9	50.8	12.4	5.3	0.8	522
2002	190.8	129.0	97.0	40.1	51.3	12.4	5.3	0.8	527
2003	192.3	130.1	98.3	40.2	51.9	12.3	5.3	0.8	531
2004	193.9	131.2	99.5	40.4	52.5	12.3	5.4	0.8	536
2005	195.4	132.3	100.8	40.5	53.1	12.2	5.4	0.8	540
2006	196.8	133.3	102.0	40.7	53.7	12.1	5.5	0.8	545
2007	198.3	134.3	103.2	40.8	54.2	12.1	5.5	0.8	549
2008	199.7	135.3	104.5	40.9	54.8	12.0	5.5	0.8	554
2009	201.2	136.3	105.7	41.1	55.4	11.9	5.6	0.8	558
2010	202.6	137.3	107.0	41.2	55.9	11.9	5.6	0.8	562
2011	203.8	138.2	108.1	41.3	56.4	11.8	5.7	0.8	566
2012	205.1	139.1	109.2	41.4	57.0	11.7	5.7	0.8	570
2013	206.3	139.9	110.4	41.4	57.5	11.6	5.7	0.8	574
2014	207.5	140.8	111.5	41.5	58.0	11.5	5.8	0.8	577
2015	208.7	141.7	112.7	41.6	58.5	11.4	5.8	0.8	581
2016	209.9	142.5	113.8	41.7	59.0	11.3	5.8	0.8	585
2017	211.0	143.3	114.9	41.8	59.5	11.2	5.9	0.8	588
2018	212.2	144.1	116.1	41.8	60.0	11.1	5.9	0.8	592
2019	213.3	144.9	117.2	41.9	60.6	11.0	5.9	0.8	596
2020	214.5	145.7	118.3	42.0	61.1	10.9	6.0	0.8	599

a. Includes small marine pleasure craft, ferries and unregistered off-road vehicles. Rough indicative estimates only.

Sources: BTRE estimates.

CAPITAL CITY TRANSPORT EMISSIONS

Transport emissions from the Australian State and Territory capital cities (table 3.13) were based on BTRE estimates of the urban transport task. The metropolitan transport task is undertaken mainly by passenger cars, road freight vehicles, urban passenger rail and buses.

Road vehicles

Capital city emissions for passenger cars (table 3.14) were calculated from each State/Territory emission estimate—apportioned using the percentage of the State/Territory population residing in the capital, and a scale factor reflecting the different rate of fuel use between urban and non-urban areas for that State/Territory. Fuel use per person varies due to different vehicle utilisation patterns in urban and non-urban areas. In general, urban areas have higher vehicle fuel consumption rates (primarily as a result of traffic congestion).

Bus emissions (table 3.16) were apportioned between capital city and non-metropolitan values using data on area of vehicle operation from the ABS SMVU.

For commercial vehicles, the BTRE estimated an econometric model of aggregate urban freight movement, and used the model to forecast urban freight movements for each capital city to 2020. The econometric model relates the road freight task in capital cities and provincial urban areas to national per capita gross product, population and real road freight rates. Changes in capital city population have been based on ABS projections of population from 1996 to 2020, as supplied to the BTRE by the AGO.

In estimating urban freight transport fuel use and emissions, the BTRE investigated the difference in fuel efficiency of urban operations relative to non-urban travel. Urban freight transport fuel efficiencies might be expected to be worse than non-urban, because of traffic congestion and the increased level of stop–start operations encountered in urban areas. The 1991 SMVU results, however, did not indicate a substantial difference between the average urban and non-urban fuel intensities. The average urban fuel intensity of LCVs was about 2 per cent higher than the average over all areas. For rigid and articulated trucks, the average fuel intensity in urban areas was estimated by the SMVU to be about 3 per cent lower than the average fuel intensity for all areas. It appears that non-urban trucks having either higher vehicle masses or higher average loads have counterbalanced the traffic effects for freight vehicle fuel consumption. Based on these results, the BTRE has assumed urban fuel intensities equal to the State/Territory average. Urban CO_2 equivalent emissions (end-use) by commercial road vehicles are listed in table 3.15.

Rail

Of urban rail operations, the BTRE has only included emissions from urban passenger rail transport. Rail freight movements within capital cities are likely to be a small proportion of the total rail freight task and therefore have not been included. CO_2 equivalent emissions for metropolitan passenger rail transport are listed in table 3.18.

TABLE 3.13 CAPITAL CITY CO_2 EQUIVALENT EMISSIONS—ALL MAJOR TRANSPORT SOURCES

(Gigagrams)

Year	Syd	Mel	Bne	Adl	Per	Hob	Dar	Cbr	Total
1990	9786	8778	3504	2472	3114	460	210	806	29130
1991	9826	8765	3451	2493	3219	451	214	796	29215
1992	9833	8844	3506	2504	3303	459	221	837	29508
1993	10073	9088	3606	2574	3418	472	228	872	30330
1994	10269	9226	3674	2612	3485	477	230	894	30866
1995	10674	9586	3815	2704	3629	493	238	922	32062
1996	11057	9947	3974	2794	3770	510	248	934	33233
1997	11176	10061	4010	2807	3817	511	249	946	33577
1998	11275	10274	4024	2907	3928	502	253	952	34114
1999	11511	10550	4181	2931	4015	517	257	979	34941
2000	11782	10712	4242	2983	4025	525	262	1017	35548
2001	12149	11045	4398	3057	4165	533	271	1036	36654
2002	12626	11501	4584	3165	4340	545	280	1070	38112
2003	12936	11786	4711	3228	4454	548	286	1090	39039
2004	13209	12033	4825	3281	4555	550	291	1105	39849
2005	13490	12284	4940	3335	4658	552	295	1118	40673
2006	13715	12482	5037	3375	4742	552	299	1128	41328
2007	13986	12724	5152	3425	4843	553	303	1141	42126
2008	14233	12940	5258	3468	4935	553	307	1151	42845
2009	14473	13150	5362	3509	5025	552	310	1161	43543
2010	14703	13348	5463	3546	5111	551	314	1170	44206
2011	14937	13551	5565	3585	5199	550	318	1179	44884
2012	15166	13748	5667	3622	5285	548	321	1188	45546
2013	15387	13937	5766	3657	5368	547	324	1196	46182
2014	15606	14122	5864	3690	5451	545	327	1203	46807
2015	15814	14296	5959	3721	5530	542	330	1210	47402
2016	16021	14469	6054	3751	5608	539	333	1216	47991
2017	16230	14642	6149	3782	5687	536	336	1221	48584
2018	16437	14812	6246	3811	5766	533	339	1226	49170
2019	16633	14972	6337	3837	5840	530	342	1229	49721
2020	16820	15123	6426	3861	5911	526	344	1231	50241

Notes: Estimates comprise emissions from urban railways (including power generation emissions for electric rail), cars, buses, motorcycles, LCVs and trucks. Emissions for modes other than electric rail relate to energy end-use.
Minor sources (such as urban ferry services, outboard motors and unregistered motor vehicles) are excluded.

Sources: BTRE estimates.

TABLE 3.14 CAPITAL CITY CO_2 EQUIVALENT EMISSIONS (END-USE)—PASSENGER CARS

(Gigagrams)

Year	Syd	Mel	Bne	Adl	Per	Hob	Dar	Cbr	Total
1990	6604	6344	2330	1790	2152	311	109	638	20279
1991	6666	6374	2296	1826	2267	304	115	633	20480
1992	6740	6463	2360	1848	2349	315	123	662	20861
1993	6921	6641	2418	1895	2415	322	126	676	21413
1994	7063	6782	2461	1931	2467	328	127	687	21847
1995	7363	7077	2560	2010	2574	341	132	712	22770
1996	7570	7282	2627	2063	2649	349	135	729	23404
1997	7674	7373	2656	2083	2679	352	137	734	23687
1998	7766	7589	2666	2185	2785	344	142	725	24203
1999	7936	7806	2782	2202	2847	360	145	749	24826
2000	8194	7956	2850	2260	2855	370	150	752	25389
2001	8406	8166	2930	2301	2935	372	154	763	26028
2002	8798	8551	3076	2395	3076	382	162	790	27230
2003	9029	8776	3166	2444	3161	385	165	801	27929
2004	9223	8960	3243	2484	3233	386	168	807	28503
2005	9419	9146	3320	2524	3306	386	171	813	29086
2006	9575	9292	3384	2553	3364	385	173	816	29542
2007	9760	9467	3459	2589	3433	385	176	820	30088
2008	9918	9615	3524	2617	3492	384	178	822	30549
2009	10067	9754	3585	2643	3548	382	180	822	30983
2010	10203	9882	3643	2665	3600	380	182	822	31377
2011	10348	10016	3704	2690	3655	378	184	822	31797
2012	10484	10142	3761	2711	3707	375	186	821	32188
2013	10611	10258	3816	2731	3756	373	187	819	32550
2014	10732	10369	3869	2749	3802	369	189	817	32895
2015	10844	10470	3918	2764	3845	366	190	814	33211
2016	10951	10567	3966	2778	3887	362	192	810	33513
2017	11058	10662	4014	2792	3928	358	193	807	33812
2018	11156	10750	4058	2804	3966	354	194	802	34085
2019	11248	10830	4101	2814	4002	350	195	797	34337
2020	11333	10904	4140	2822	4035	346	196	792	34567

Sources: BTRE estimates, Apelbaum Consulting Group (2001), ABS (2001a).

TABLE 3.15 CAPITAL CITY CO_2 EQUIVALENT EMISSIONS (END-USE)—COMMERCIAL VEHICLES

(Gigagrams)

Year	*Syd*	*Mel*	*Bne*	*Adl*	*Per*	*Hob*	*Dar*	*Cbr*	*Total*
1990	2413	1982	989	592	865	130	92	144	7209
1991	2366	1943	970	581	848	128	90	142	7068
1992	2345	1920	970	572	845	126	89	154	7021
1993	2449	1999	1023	594	887	131	93	175	7350
1994	2457	2000	1037	592	895	131	94	186	7391
1995	2531	2055	1081	606	928	134	97	188	7619
1996	2699	2186	1170	642	997	142	104	183	8121
1997	2698	2180	1172	635	1000	140	103	191	8119
1998	2704	2189	1181	632	1006	138	102	205	8157
1999	2759	2233	1208	639	1030	139	103	208	8319
2000	2757	2232	1209	633	1031	136	102	243	8342
2001	2916	2362	1281	665	1093	142	107	251	8818
2002	2994	2426	1320	680	1123	144	110	258	9054
2003	3062	2481	1353	692	1150	145	111	267	9262
2004	3133	2538	1388	705	1178	146	113	276	9476
2005	3206	2596	1424	719	1207	147	114	283	9697
2006	3265	2642	1454	729	1231	148	115	290	9875
2007	3342	2703	1492	743	1261	149	117	299	10106
2008	3421	2765	1530	758	1292	151	119	307	10342
2009	3502	2829	1570	772	1324	152	120	316	10586
2010	3583	2894	1611	787	1356	153	122	325	10832
2011	3662	2956	1650	801	1387	154	123	335	11070
2012	3745	3021	1691	816	1420	155	125	345	11319
2013	3829	3087	1733	831	1453	157	127	354	11571
2014	3915	3155	1776	847	1487	158	128	364	11830
2015	4001	3222	1819	862	1521	159	130	374	12087
2016	4089	3291	1863	878	1556	160	131	383	12352
2017	4180	3362	1909	894	1592	161	133	393	12623
2018	4278	3438	1957	911	1630	162	135	402	12914
2019	4371	3511	2004	928	1667	163	136	410	13190
2020	4462	3581	2050	944	1703	164	138	417	13458

Sources: BTRE estimates, ABS (2001a).

TABLE 3.16 CAPITAL CITY CO_2 EQUIVALENT EMISSIONS (END-USE)—BUSES

(Gigagrams)

Year	Syd	Mel	Bne	Adl	Per	Hob	Dar	Cbr	Total
1990	211	158	72	58	68	16	7	19	611
1991	209	157	72	58	68	16	7	19	606
1992	209	157	72	58	68	16	7	19	606
1993	209	157	72	58	68	16	7	19	606
1994	211	158	72	58	68	16	7	19	611
1995	212	160	73	59	69	16	7	20	616
1996	214	161	73	59	69	16	8	20	621
1997	216	162	74	60	70	16	8	20	626
1998	218	164	74	60	70	17	8	20	631
1999	219	165	75	61	71	17	8	20	636
2000	218	164	74	60	70	17	8	20	631
2001	220	165	75	61	71	16	8	20	636
2002	221	167	76	61	72	16	8	20	642
2003	223	168	77	61	73	16	8	20	647
2004	225	170	78	61	74	16	8	20	652
2005	227	171	79	61	75	16	8	20	658
2006	228	172	80	62	75	16	8	20	663
2007	230	174	81	62	76	16	8	20	668
2008	232	175	82	62	77	16	8	20	673
2009	233	176	83	62	78	16	8	20	678
2010	235	178	84	63	79	16	8	20	683
2011	236	179	85	63	79	16	8	20	687
2012	238	180	86	63	80	16	8	20	691
2013	239	181	87	63	81	15	8	20	695
2014	241	182	88	63	82	15	9	20	700
2015	242	183	89	63	82	15	9	20	704
2016	244	184	90	63	83	15	9	20	708
2017	245	186	91	63	84	15	9	20	712
2018	246	187	92	64	84	15	9	20	716
2019	248	188	93	64	85	15	9	20	720
2020	249	189	94	64	86	14	9	20	724

Sources: BTRE estimates, Apelbaum Consulting Group (2001), ABS (2001a).

TABLE 3.17 CAPITAL CITY CO_2 EQUIVALENT EMISSIONS (END-USE)—MOTORCYCLES

(Gigagrams)

Year	*Syd*	*Mel*	*Bne*	*Adl*	*Per*	*Hob*	*Dar*	*Cbr*	*Total*
1990	35.8	28.6	22.0	5.5	7.3	2.3	1.4	2.1	105.0
1991	35.8	28.6	22.0	5.5	7.3	2.3	1.4	2.1	105.0
1992	35.8	28.6	22.0	5.5	7.3	2.3	1.4	2.1	105.0
1993	35.8	28.6	22.0	5.5	7.3	2.3	1.4	2.1	105.0
1994	35.8	28.6	22.0	5.5	7.3	2.3	1.4	2.1	105.0
1995	35.8	28.6	22.0	5.5	7.3	2.3	1.4	2.1	105.0
1996	35.8	28.6	22.0	5.5	7.3	2.3	1.4	2.1	105.0
1997	35.8	28.6	22.0	5.5	7.3	2.3	1.4	2.1	105.0
1998	35.8	28.6	22.0	5.5	7.3	2.3	1.4	2.1	105.0
1999	35.8	28.6	22.0	5.5	7.3	2.3	1.4	2.1	105.0
2000	36.2	28.9	22.3	5.5	7.4	2.3	1.5	2.1	106.1
2001	36.5	29.2	22.5	5.5	7.5	2.3	1.5	2.1	107.1
2002	36.7	29.4	22.8	5.5	7.6	2.3	1.5	2.1	108.0
2003	37.0	29.7	23.1	5.5	7.6	2.3	1.5	2.1	108.9
2004	37.3	29.9	23.4	5.6	7.7	2.3	1.5	2.1	109.8
2005	37.6	30.2	23.7	5.6	7.8	2.3	1.5	2.1	110.8
2006	37.9	30.4	24.0	5.6	7.9	2.3	1.5	2.1	111.7
2007	38.2	30.6	24.3	5.6	8.0	2.3	1.5	2.1	112.6
2008	38.4	30.9	24.6	5.6	8.1	2.2	1.6	2.1	113.5
2009	38.7	31.1	24.9	5.7	8.2	2.2	1.6	2.1	114.4
2010	39.0	31.3	25.2	5.7	8.2	2.2	1.6	2.1	115.3
2011	39.2	31.5	25.4	5.7	8.3	2.2	1.6	2.1	116.0
2012	39.4	31.7	25.7	5.7	8.4	2.2	1.6	2.1	116.8
2013	39.7	31.9	26.0	5.7	8.5	2.2	1.6	2.1	117.6
2014	39.9	32.1	26.2	5.7	8.5	2.1	1.6	2.1	118.4
2015	40.1	32.3	26.5	5.7	8.6	2.1	1.6	2.1	119.1
2016	40.4	32.5	26.8	5.7	8.7	2.1	1.6	2.1	119.9
2017	40.6	32.7	27.0	5.8	8.8	2.1	1.6	2.1	120.6
2018	40.8	32.9	27.3	5.8	8.8	2.1	1.7	2.1	121.4
2019	41.0	33.0	27.6	5.8	8.9	2.1	1.7	2.1	122.1
2020	41.2	33.2	27.8	5.8	9.0	2.0	1.7	2.1	122.8

Sources: BTRE estimates, ABS (2001a).

TABLE 3.18 CAPITAL CITY CO_2 EQUIVALENT EMISSIONS — PASSENGER RAIL

(Gigagrams)

Year	*Syd*	*Mel*	*Bne*	*Adl*	*Per*	*Hob*	*Dar*	*Cbr*	*Total*
1990	522.0	265.2	90.9	25.1	21.6	0.0	0.0	0.0	924.9
1991	550.4	262.5	92.1	22.5	28.3	0.0	0.0	0.0	955.8
1992	502.5	274.9	82.5	20.4	34.1	0.0	0.0	0.0	914.5
1993	458.2	262.1	72.1	22.1	41.5	0.0	0.0	0.0	856.1
1994	502.2	256.3	81.2	25.2	47.8	0.0	0.0	0.0	912.6
1995	532.2	266.7	78.4	23.4	51.3	0.0	0.0	0.0	952.0
1996	538.9	289.6	81.6	24.0	48.2	0.0	0.0	0.0	982.4
1997	552.3	316.8	86.5	24.0	60.3	0.0	0.0	0.0	1039.9
1998	550.6	304.1	81.0	24.2	58.6	0.0	0.0	0.0	1018.5
1999	560.3	317.1	93.8	24.1	59.9	0.0	0.0	0.0	1055.2
2000	577.1	331.8	86.8	24.2	61.0	0.0	0.0	0.0	1080.8
2001	571.1	321.9	88.2	24.3	59.1	0.0	0.0	0.0	1064.7
2002	576.2	326.9	89.4	24.5	61.2	0.0	0.0	0.0	1078.2
2003	584.8	330.7	90.6	24.6	61.8	0.0	0.0	0.0	1092.6
2004	591.5	335.8	92.5	24.8	62.4	0.0	0.0	0.0	1107.0
2005	600.2	340.7	92.6	25.0	63.2	0.0	0.0	0.0	1121.7
2006	608.5	344.6	94.3	25.2	64.1	0.0	0.0	0.0	1136.6
2007	616.4	349.3	95.6	25.3	65.1	0.0	0.0	0.0	1151.8
2008	624.8	354.0	96.9	25.5	65.9	0.0	0.0	0.0	1167.1
2009	633.1	358.9	98.3	25.6	66.8	0.0	0.0	0.0	1182.7
2010	641.8	363.7	99.5	25.8	67.7	0.0	0.0	0.0	1198.5
2011	650.6	368.5	100.9	25.9	68.6	0.0	0.0	0.0	1214.6
2012	659.5	373.5	102.3	26.0	69.6	0.0	0.0	0.0	1230.9
2013	668.5	378.6	103.7	26.1	70.5	0.0	0.0	0.0	1247.4
2014	677.6	383.7	105.1	26.2	71.5	0.0	0.0	0.0	1264.1
2015	686.9	388.9	106.5	26.4	72.4	0.0	0.0	0.0	1281.1
2016	696.3	394.2	108.0	26.4	73.4	0.0	0.0	0.0	1298.3
2017	705.8	399.5	109.5	26.5	74.4	0.0	0.0	0.0	1315.8
2018	715.5	404.9	111.0	26.6	75.5	0.0	0.0	0.0	1333.5
2019	725.3	410.4	112.5	26.7	76.5	0.0	0.0	0.0	1351.4
2020	735.2	416.0	114.0	26.8	77.5	0.0	0.0	0.0	1369.6

Notes: Estimates include power generation emissions for electric rail.
Emissions for diesel rail relate to energy end-use

Sources: BTRE estimates, Apelbaum Consulting Group (2001), ABARE (1999).

chapter 4

IMPACT OF TRANSPORT SECTOR GREENHOUSE ABATEMENT MEASURES ON TRANSPORT EMISSIONS

As a part of the analysis of transport sector greenhouse emissions, the AGO commissioned the BTRE to review the impact on greenhouse emissions of four existing transport sector greenhouse gas abatement initiatives:

- Compressed Natural Gas Infrastructure Program (CNGIP)
- Alternative Fuels Conversion Program (AFCP)
- Environmental Strategy for the Motor Vehicle Industry (ESMVI)
- Diesel and Alternative Fuels Grants Scheme (DAFGS).

This chapter outlines the possible impacts of the CNGIP, AFCP, ESMVI and DAFGS on road vehicle emissions. Because of the complementary nature of the CNGIP and AFCP, the BTRE has estimated only the combined impact of the two programs.

SUMMARY OF FINDINGS

The BTRE's estimates of the impact of the measures on greenhouse gas emissions in 2010 are outlined in table 4.1. The main findings are summarised below.

- The BTRE estimates that the CNGIP and AFCP would reduce carbon dioxide equivalent (CO_2-e) end-use emissions by 0.04 million tonnes per annum, or 0.05 million tonnes on a full fuel cycle (FFC) basis, in 2004 (given current funding commitments). These savings are based on BTRE assumptions about the average cost of conversion and the number of vehicles converting to LPG and CNG under CNGIP and AFCP, and conclusions drawn by Beer et al. (2001) that CNG vehicles produce 17 per cent less CO_2-e emissions per kilometre than an equivalent diesel vehicle. The BTRE has included estimates of emissions savings for two earlier alternative scenarios for natural gas (NG) vehicle penetration rates (NELA 1999 and ANGVC 2001), which give estimated CO_2-e abatement of 0.05 million tonnes and 0.19 million tonnes respectively in 2010.

- The ESMVI encompasses a range of measures aimed at reducing emissions from passenger motor vehicles. Assuming the proposed NAFC targets under the ESMVI succeed in reducing new passenger car fuel consumption by 15 per cent over base case levels by 2010, the BTRE estimates that this measure would reduce CO_2-e emissions by close to 2 million tonnes in 2010 (about 2.4 million tonnes FFC).
- Introduction of the DAFGS, in July 2001, reduced the cost of diesel and alternative fuels to heavy vehicle transport operators. The BTRE estimates that the reduction in the cost of diesel fuel to heavy vehicle transport will increase emissions from freight vehicles in 2010 by 0.247 million tonnes (0.3 million tonnes FFC) above the level that would have been expected in the absence of the fuel rebate.

TABLE 4.1 SUMMARY OF IMPACTS ON EMISSIONS OF CURRENT TRANSPORT SECTOR ABATEMENT MEASURES

(Gigagrams)

Policy instrument	*Measure*	*CO2-e abated in 2010*
1. CNG infrastructure program (CNGIP) and alternative fuels conversion program (AFCP).	CNG infrastructure network development and rebate payable to eligible, alternative fuel vehicles.	40[a]
2. Environmental strategy for the motor vehicle industry (ESMVI)[b].	NAFC targets under the ESMVI.	1990
3. Diesel and alternative fuels grants scheme (DAFGS).	Grant payable to eligible vehicles per litre of fuel used.	-247

a. CO_2-e abated in 2004. Assumed to remain constant for following years.
b. National average fuel consumption (NAFC) targets under the ESMVI are currently under negotiation.
Source: BTRE estimates.

ALTERNATIVE FUELS PROGRAM

The Compressed Natural Gas Infrastructure Program (CNGIP) aims to establish a network of publicly accessible compressed natural gas (CNG) refuelling stations. The $7.6 million program currently supports 19 sites in NSW (5 sites), Victoria (8), Queensland (2), SA (3) and the ACT (1).

The Alternative Fuels Conversion Program (AFCP) has two objectives: to reduce greenhouse emissions and significantly improve urban air quality. It intends to achieve this by facilitating heavier commercial road vehicles and public transport buses to operate on either CNG or LPG (liquefied petroleum gas) fuels (AGO 2000)[6]. The AFCP currently offers a rebate for conversion of conventional fuelled vehicles to alternative fuels (AF), such as CNG or LPG. Eligible recipients must demonstrate their emissions savings through a chassis dynamometer test and, if eligible, can claim a 50 per cent rebate on the cost of vehicle conversion or, in the case of original equipment manufacturer (OEM) vehicles, half the difference in price between a new alternative fuel vehicle and a diesel-fuelled vehicle. The rebate is only applicable to vehicles over 3.5 tonnes gross vehicle mass (GVM), which excludes passenger cars and LCVs. The total budget for the AFCP is capped at $15 million in 2000–2001 and $20 million in each of the three subsequent years—a total program cost of $75 million.

Vehicle conversions

The BTRE has estimated the potential reduction in greenhouse gas emissions for three separate cases, based on different assumptions about the number and type of vehicles converting to alternative fuels as a result of the CNGIP and AFCP.

Case 1 This case has been based on assumptions by Nelson English, Loxton and Andrews Pty Ltd (NELA 1999) about the number of vehicles converting to CNG. NELA assumed that the AFCP would result in between 2000 and 2500 rigid trucks (of 3.5–15 tonnes GVM) converting to CNG in each year of the program[7].

Case 2 This case has been based on an estimate of total CNG vehicle conversions attributable to the AFCP and CNGIP by the Australasian Natural Gas Vehicles Council's (ANGVC). The estimated reductions in ANGVC's projections do not take into account the budget constraint of the AFCP program.

Case 3 The third case has allowed for a 'budget-constrained' scenario that takes into account the average vehicle conversion cost and the number and mix of vehicles that have applied for funding in the first year of the AFCP program.

Given the level of funding proposed for the measure, Case 3 forms the BTRE's preferred estimates of the impact of the current AFCP and CNGIP programs. Cases 1 and 2 are based on previously published estimates of the number of vehicles expected to be converted under the AFCP and CNGIP programs (NELA 1999 and ANGVC 2001), and have been provided here for comparison with Case 3. (They may also help to give some indication of the emission benefits possible if the future CNG take-up rate is high enough to warrant extension of the measure's proposed budget.)

6 The latter objective is frequently forgotten and Beer et al. (2001) indicates that there are substantial improvements in air quality to be gained from the use of LPG and CNG.

7 NELA (1999) assumed an average conversion cost for rigid trucks between 3.5 and 15 tonnes GVM of $15 000.

Emission characteristics of CNG, LPG and diesel fuelled heavy vehicle engines

The effectiveness of the AFCP depends on the average emission savings from CNG and LPG vehicles relative to diesel vehicles. The CSIRO, on behalf of the AGO, has recently conducted a major review (Beer et al. 2001) of the emissions produced by diesel-fuelled heavy vehicles and a range of alternative-fuelled heavy vehicles, including CNG, LNG (liquefied natural gas) and LPG. Before presenting the BTRE estimates of emission savings for each of the three sets of vehicle conversion assumptions, the following section presents a brief overview of CNG and LPG heavy vehicle engine technology.

The potential reduction in greenhouse gas emissions from substitution of CNG and LPG vehicles for diesel-fuelled vehicles depends on the type of fuel, the size of the vehicle and the method of combustion. The empirical evidence on the emissions performance of heavy vehicle CNG engines exhibits a wide range of variation, from 27 per cent less CO_2-e emissions per vehicle kilometre[8] (AGO, pers. comm., 15 October 2001) to 18 per cent higher CO_2-e emissions[9] (Beer et al. 2001, p. 250 and AGO, pers. comm., 15 October 2001). Broadly, CNG-fuelled vehicles are currently less efficient at extracting the energy content of the fuel than comparable diesel fuelled vehicles. The CNG engines produce, on average, higher methane emissions but considerably lower particulate and CO emissions. Because CNG has less carbon per unit of energy than diesel, direct CO_2 emissions are generally lower per vehicle kilometre.

CNG fuel storage systems generally require high-pressure cylinders that are heavier and take up more space than diesel fuel tanks (per unit of energy stored). Typically, fuel tanks on CNG vehicles must be three to four times larger than those on conventional vehicles to achieve the same range. The extra weight imposes an additional fuel efficiency penalty on CNG vehicles and the space requirements limit the range of such vehicles between re-fuels. Currently, CNG re-fuelling stations are not widespread, although the CNGIP is increasing the number and distribution of refuelling sites. Consequently, the vehicles most likely to convert to CNG under the AFCP are fleets of specialised heavy vehicles operating close to the existing refuelling sites (e.g. urban bus fleets and urban waste management fleets).

LPG is currently widely available and the AGO believes that there is significant potential for increased penetration of LPG use in smaller commercial vehicles (just over 3.5 tonnes). The driving performance requirements of many heavy vehicles, however, may limit the take-up of LPG among trucks above 9 tonnes GVM (Whiting 2001b).

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8 Based on tests of a NSW State Transit 300 Mercedes–Benz 0405NH CNG powered bus.

9 Based on tests of a Cummins C8.3G+ CNG engine with catalyst.

Review of early research results

There are a number of alternative engine technologies for utilising CNG and LPG in heavy vehicles. Each technology option has different energy efficiencies and, hence, emission rates. The IEA (1993) and Gaines et al. (1998) have identified five different NG-based heavy vehicle engine combustion technology options:

- diesel fuel produced from natural gas via the Fischer–Tropsch (F–T) process used in a conventional diesel engine
- stoichiometric combustion in a spark ignition engine (stoichiometric combustion occurs when the chemically exact amount of fuel is added to the air so that when combustion is completed the chemical formula for the fuel is completed)— stoichiometric combustion offers exceptionally clean combustion and exhaust gases (ANGVC 2001)
- lean-burn in spark ignition engine (lean burn strategies employ an air/gas mixture that has more air than the stoichiometric ratio)
- diesel fuel pilot injection in a compression ignition engine (the diesel pilot fuel injection engine delivers a small injection of diesel into the cylinder and when compression starts the NG is injected at high pressure— the diesel pilot then provides the spark to ignite the CNG)[10]
- direct injection in a high compression ignition engine with a glow plug.

F–T diesel fuel contains essentially no sulphur and no aromatic compounds. Improved processes for producing F–T diesel could yet produce lower full fuel cycle greenhouse gas emissions compared to LNG (Gaines et al., 1998). However, Beer et al. (2001) concluded that F–T diesel produces higher full fuel cycle emissions per vehicle kilometre than low sulphur diesel (LSD), LPG, CNG and LNG.

Stoichiometric and lean-burn combustion strategies are currently less energy efficient than conventional diesel engines. Stoichiometric combustion is only 80 per cent as efficient, while lean-burn spark-ignition combustion is up to 88 per cent as efficient as compression ignition diesel engines (Gaines et al. 1998 and Duggal 2001). The IEA (1992) reported that CNG spark-ignition engines might be up 22 per cent less fuel-efficient than conventional diesel engines.

While there have been a number of studies into compression ignition CNG combustion technology, the majority of them are relatively old and may not reflect the significant improvements in technology that have occurred over the last 5–10 years. The IEA (1993) estimated that compression ignition CNG engines offered combustion efficiencies equivalent to conventional diesel fuelled engines, but methane emissions were much higher. Older studies of the emission performance of heavy vehicles converted to CNG also reported

10 Cummins Westport <www.westport.com/> offer such a system that has the same power and torque ratios of conventional diesel engines.

extremely high hydrocarbon (HC) emissions. For example, Gaines et al. (1993) report HC emissions 30–50 times higher than those of conventional diesel vehicles. Norton and Kelly (1996), in a study of spark-ignition CNG fuelled refuse trucks in New York city, reported HC emissions 5–10 times higher than equivalent diesel-fuelled vehicles.

LPG-fuelled heavy vehicles may also employ stoichiometric or lean-burn combustion in a spark-ignition engine. LPG may also be used with a diesel pilot in compression ignition engines. Beer et al. (2000) note that there have been very few studies of the emissions performance of LPG-fuelled heavy vehicles.

Recent heavy vehicles emissions test evidence

The CSIRO (Beer et al. 2001) undertook a comprehensive review of the emission performance of alternative fuel heavy vehicles for the AGO which captures the improvements in the technology that has occurred over the last 5–10 years. The BTRE has summarised the main findings below. The discussion focuses on CO_2-e emissions from combustion (i.e. fuel end-use).

The BTRE has also referred to results from an earlier CSIRO study (Beer et al. 2000) which was prepared at the request of the AGO over a short timeframe and with little consultation with stakeholders. The purpose of this study was to provide a brief overview of the relative emissions between a range of transport fuels, but did not include a comprehensive examination of all transport fuels. By contrast, Beer et al. (2001) was prepared over six months and involved a more detailed analysis of full fuel cycle emissions with participation from some 90 stakeholders, including industry and government agencies.

Beer et al. (2001)

Beer et al. (2001) cited emissions test results from a range of heavy vehicle CNG tests:

- A Scania 113M was tested engine at the Millbrook Proving Ground (UK) in January 2001 (Andrew 2001). The study compared diesel, CNG and LNG emission performance. Direct CO_2 emissions, per unit of energy output, were 11 per cent lower for CNG vehicles compared to equivalent diesel vehicles.
- A Renault 620–45 CNG engine with catalyst was tested. The quoted test results do not include estimates of direct CO_2 emissions.
- A Cummins C8.3G CNG vehicle was compared with a Cummins ISC280 diesel vehicle. The test results reported emissions per unit of energy output. Direct CO2 emissions were marginally lower for the CNG-fuelled vehicle compared to its diesel counterpart. However, on a CO_2-e emissions basis, CNG vehicle emissions were estimated to be 17 per cent and 7 per cent higher, with and without a catalyst respectively, than for equivalent diesel-powered vehicles.
- In South Australia emission tests were carried out on a MAN NL 202 bus with a D0826 LUH, 6.87 litre engine and a D2866 DUH, 11.97 natural gas engine. The test results did not report CO_2 emissions, but reported quite low hydrocarbon (HC) emissions.
- In New South Wales, EPA tests of a Scania 11 litre Turbo Euro2 technology CNG bus, with and without a catalyst, were conducted (Brown et al. 1999). The findings did not include CO_2 emissions. Methane emissions were between 2 and 3 grams per kilowatt-hour (g/kWh).

On the basis of these results, Beer et al. (2001) concluded that total CO_2-e combustion emissions would be 17 per cent less for a CNG fuelled heavy vehicle compared to the same LSD-fuelled vehicle. However, Beer et al. (2001) noted that the tailpipe emission results were subject to uncertainty, and they quote the uncertainty ranges given by the preliminary work included in Beer et al. (2000). These are presented in table 4.2.

The estimated savings in CO_2-e emissions arising from switching from diesel to CNG presented in Beer et al. (2001) are significantly different from BTRE analysis based on vehicle test data reported in the first CSIRO study (Beer et al. 2000)—17 per cent compared with 2 per cent. Beer et al. (2001) suggest that recent advances in CNG vehicle technology may account for emission improvements. They cite recent engine dynamometer test results for a Daimler–Chrysler M447G CNG engine. This engine produced 7 per cent less CO_2 per unit of energy output than the Scania engine test results (Andrew 2001) and significantly less methane than early CNG engines tested by Motta et al. (1996). Emissions tests undertaken by Daimler–Chrysler (2000), however, reported direct CO_2 emissions 15 per cent higher for a CNG powered bus with a M447 hLAG engine—which appears a similar vehicle to that tested by Andrew (2001)—compared with a Euro III compliant diesel powered bus (OM906 hLA engine).

TABLE 4.2 ESTIMATED ONE STANDARD DEVIATION UNCERTAINTIES IN HEAVY VEHICLE CNG EMISSIONS

(per cent)

Gas	*grams per MJ*	*grams per tonne–kilometre*	*grams per passenger–kilometre*
CO_2	10	2	12
NMHC	135	135	135
NO_x	50	29	72
CO	15	11	22
PM10	60	17	108

Source: Beer et al. (2001, table 8.20, p. 267).

Other factors that may contribute to differences between the findings of more recent test results and those from earlier studies are differences in test cycle and the type of test. Some of the recent evidence, for example, is based on engine dynamometer tests whereas much of the earlier evidence, cited in Beer et al. (2000), was based on chassis dynamometer tests. Much of the earlier test evidence from the United States appears to be based on different test cycles to that of more recent European tests. Beer et al. (2001, p. 251) note that certification procedures based on engine dynamometers may report values that differ substantially from those calculated by chassis dynamometers.

Summary

In summary, the evidence on the net reduction in CO_2-e emissions attributable to CNG heavy vehicles and LPG heavy vehicles over diesel vehicles appears mixed—technology is continually changing and test conditions can vary. Much of the older evidence, such as that quoted by the ERG (1998), Motta et al. (1996) and DOE (2001) was based on chassis dynamometer tests of similar vehicles and reported only modest reductions in CO_2-e emissions from CNG over diesel vehicles when averaged across all vehicles tested. Comparison of emissions test results reported by Motta et al. (1996) and the DOE (2001) for similar-sized engines, however, shows that American CNG heavy vehicles actually produced higher CO_2-e emissions than their diesel counterparts, largely attributable to higher methane emissions. By contrast, more recent emissions test data performed on later generation European CNG engines, also based on chassis dynamometer tests, report significantly lower CO_2-e emissions than for equivalent diesel vehicles. Of course, the emissions performance under on-road driving conditions may differ significantly from test cycle results—depending on traffic conditions, driver behaviour and other factors.

The level of CH_4 emissions from CNG heavy vehicles appears to be critical to the greenhouse benefit of CNG over diesel. The recent European vehicle test results report quite low total hydrocarbon (THC) emissions, including methane from CNG heavy vehicles. The American heavy vehicle test results, in contrast, report quite high methane emissions. The higher methane emissions from American CNG-fuelled urban buses more than offset the slightly lower direct CO_2 emissions to produce higher total CO_2-e emissions in those vehicles.

The CNGIP/AFCP testing procedure employs a chassis dynamometer test to determine eligibility for the grant. Although there is significant uncertainty about the average level of emissions savings, because each vehicle has to demonstrate emissions savings, the AGO is confident the program reduces greenhouse gas emissions.

Total emission reduction estimates

For the NELA (Case 1) and ANGVC (Case 2) based estimates of the impact on greenhouse emissions of the AFCP, the BTRE assumed CNG-fuelled vehicles are 12 per cent less efficient than the equivalent diesel vehicle and assumed no difference in CH_4 emissions. These assumptions are equivalent to assuming CNG vehicles produce 14 per cent lower CO_2-e emissions per kilometre than the equivalent diesel vehicle. For the 'budget-constrained' case (Case 3), the BTRE based the analysis on the estimated reduction in CO_2-e attributable to CNG vehicles by Beer et al. (2001). The text also provides a comparison using the earlier research reviewed in Beer et al. (2000).

TABLE 4.3 SUMMARY OF ESTIMATED CO_2 EQUIVALENT EMISSIONS ABATEMENT FOR CNGIP/AFCP

	Case 1 (NELA)	Case 2 (ANGVC)	Case 3 (Budget-constrained)
Number of vehicles converted per annum	2000	2900	1280
Total number of vehicles converted over full program	8000	29000	5121
Assumed emissions savings per vehicle kilometre (%)	14	14	10–17
Total abatement in 2010 (Gg)	53	189	40[a]
Total abatement in 2020 (Gg)	98	323	40[a]

a. Annual emissions savings in 2004, the final year of funding under the current CNGIP/AFCP program.

Case 1: NELA (1999) assumed heavy vehicle CNG/LPG conversions

NELA (1999) assumed that the AFCP and the CNGIP, together, would result in 2000 to 2500 CNG rigid truck conversions per annum. The BTRE computed the reduction in emissions over the period 2001 to 2020, assuming that 2000 rigid trucks would be converted from diesel to CNG each year to 2020. The total number of vehicles converted and the total stock of converted CNG vehicles remaining in the fleet at the end of each year to 2020 are listed in table 4.4. In computing the number of CNG vehicles remaining in the vehicle fleet, the BTRE assumed that most of the CNG vehicle conversions were to new, or near new, vehicles and that these vehicles were scrapped at the same rate as other rigid trucks of the same vintage.

Table 4.4 also lists the total number of rigid trucks in the fleet under the base case assumptions and the share of CNG rigid trucks as a proportion of total fuel use by all rigid trucks. The share of CNG fuel used is required in order to estimate the emissions reduction within the TRUCKMOD fleet model . TRUCKMOD calculates emissions by apportioning the share of energy use by fuel type. The share of fuel use attributable to CNG-fuelled rigid trucks entered into TRUCKMOD is the equivalent amount of energy that would be required to power a diesel vehicle.

Total CNG energy use, and emissions, were estimated by adjusting the TRUCKMOD results to account for the difference in relative fuel efficiency between CNG and diesel vehicles. As stated above, the BTRE assumed that CNG vehicles were 88 per cent as efficient as their diesel counterparts. Overall, these assumptions imply CNG vehicles produce approximately 14 per cent less direct CO_2 emissions per vehicle kilometre.

The energy density of natural gas sourced from Australian fields ranges from 37.4 MJ/m^3 to 40.8 MJ/m^3 (NGGIC 1998). In calculating emissions from CNG use in road vehicles, the BTRE used the 1998 NGGI estimate of the average energy density for CNG, 39.5 MJ/m^3 (NGGIC 1998). The energy density of diesel is 38.6 MJ/L (BTCE 1995a).

Under these assumptions, the BTRE estimates that CNG use by rigid trucks will increase to just under 9 per cent of total rigid truck fuel energy use by 2020. Under the base case, CNG-fuelled vehicles were assumed to be a negligible share of the total rigid truck energy use.

The BTRE assumed the average load and average VKT of the converted vehicles were equal to fleet-wide average load and average VKT of rigid trucks.

For Case 1, the AFCP measures are estimated to reduce annual CO_2 equivalent emissions by approximately 27 000 tonnes, about 0.1 per cent of total commercial vehicle emissions in 2005, the year after cessation of the current AFCP. If extended to 2020, the expected annual reduction in CO_2-e emissions is approximately 98 000 tonnes, approximately 0.3 per cent of projected commercial vehicle emissions (excluding buses).

TABLE 4.4 CASE 1 (NELA 1999): ESTIMATED REDUCTION IN CO_2 EQUIVALENT EMISSIONS ATTRIBUTABLE TO CNGIP/AFCP

Year	Annual number vehicle conversions	Total number converted vehicles	Total number rigid trucks	Share of energy use by converted vehicles	Rigid truck emissions: Base case	Rigid truck emissions: With CNGIP /AFCP	Rigid truck emissions: Reduction
	(number of vehicles)			(%)	Gigagrams		
2001	2000	2000	372866	0.54	4800.8	4795.3	5.5
2002	2000	3991	375899	1.06	4836.9	4825.9	11.0
2003	2000	5970	380546	1.57	4896.5	4880.0	16.5
2004	2000	7938	385207	2.06	4955.9	4934.0	21.9
2005	2000	9893	386123	2.56	4968.7	4941.4	27.3
2006	2000	11833	389823	3.04	4998.3	4965.7	32.6
2007	2000	13756	392395	3.51	5032.7	4994.8	37.9
2008	2000	15659	394967	3.96	5067.0	5023.9	43.1
2009	2000	17541	397221	4.42	5098.7	5050.4	48.3
2010	2000	19398	399336	4.86	5125.9	5072.5	53.4
2011	2000	21226	402041	5.28	5145.4	5087.1	58.3
2012	2000	23024	404171	5.70	5171.7	5108.5	63.2
2013	2000	24786	406018	6.10	5195.0	5127.0	68.0
2014	2000	26508	407651	6.50	5214.2	5141.5	72.7
2015	2000	28182	408950	6.89	5220.0	5142.9	77.1
2016	2000	29804	409749	7.27	5229.4	5147.9	81.5
2017	2000	31367	409953	7.65	5230.3	5144.6	85.7
2018	2000	32868	409468	8.03	5242.7	5152.6	90.1
2019	2000	34302	408203	8.40	5223.9	5129.9	94.0
2020	2000	35666	406306	8.78	5195.8	5098.1	97.7

Source: BTRE estimates.

Case 2: ANGVC estimates of heavy vehicle CNG/LPG conversions

The Australasian Natural Gas Vehicles Council (ANGVC) projected that the number of CNG-fuelled vehicles would grow to 22 330 vehicles by 2005, attributable largely to the impact of the CNGIP and AFCP (AGO, pers. comm., 4 July 2001). Of those 22 000 vehicles, the ANGVC projects 3825 would be LCVs (25 per cent of total CNG passenger cars and LCVs), 2750 rigid trucks, 1450 articulated trucks and 2720 urban buses. Given that the programs began in January 2001, these estimates imply a total of 957 LCV, 687 rigid truck, 362 articulated truck and 680 urban bus CNG conversions per annum.

In estimating the impact on emissions, the BTRE assumed that the AFCP would continue beyond December 2004 and that the annual number of new and converted CNG vehicles entering the fleet would grow by 2 per cent per annum. The assumed growth in the annual number of CNG vehicles entering the fleet simulates increased rates of adoption as the presence of CNG vehicles becomes more common. For simplicity, the impact of vehicle scrappage and the age profile of vehicle use were ignored for this case. Inclusion of these factors would have minimal effect on the emissions estimates in the early years of the program, but are likely to be significant by 2020. All conversions were assumed to be from diesel-fuelled vehicles. The assumed number of commercial vehicle CNG conversions under these assumptions and the implied fuel share of the vehicle fleet used in TRUCKMOD to estimate emissions from commercial vehicles are listed in table 4.5. Under the base case the share of CNG-fuelled LCVs was assumed to increase to 2.5 per cent of total LCV energy use by 2020; but for rigid and articulated trucks CNG use was assumed to be only a negligible share of total energy use. The assumed number of vehicles converted to CNG, as a result of the CNG measures, were added to the base case assumptions. For buses, the BTRE assumed that all CNG bus conversions were for buses used in urban areas. Each CNG bus was assumed to travel 60 000 kilometres per annum and to have an average fuel consumption rate of 0.52 litres per kilometre.

Table 4.6 lists the estimated impact of the CNG measures on CO2 equivalent emissions from commercial vehicles. The BTRE assumed that CNG vehicles, including buses, were 88 per cent as efficient as their diesel counterparts.

For Case 2, the AFCP measures are estimated to reduce total *annual* CO_2 equivalent emissions from commercial (freight) vehicles by 63 000 tonnes and from buses by 43 000 tonnes in 2005, the first year after the cessation of the current AFCP.

TABLE 4.5 CASE 2 (ANGVC): ADDITIONAL NUMBER OF CNG VEHICLES AND IMPLIED SHARE OF ENERGY USE BY COMMERCIAL VEHICLES UNDER THE CNGIP /AFCP

Year	*Number of Vehicle Conversions*				*Share of energy use by CNG Vehicles*			
	LCV	*Rigid*	*Artic*	*Buses*	*LCV*	*Rigid*	*Artic*	*Buses*
	(number of vehicles)				*(%)*			
2001	934	671	384	680	0.05	0.18	0.59	nc
2002	953	684	392	694	0.10	0.36	1.16	nc
2003	972	698	400	708	0.15	0.54	1.67	nc
2004	991	712	408	722	0.19	0.71	2.12	nc
2005	1011	726	416	736	0.23	0.90	2.51	nc
2006	1031	741	424	751	0.27	1.07	2.81	nc
2007	1052	756	432	766	0.31	1.25	3.05	nc
2008	1073	771	441	781	0.35	1.43	3.21	nc
2009	1094	786	450	797	0.38	1.61	3.31	nc
2010	1116	802	459	813	0.41	1.79	3.35	nc
2011	1138	818	468	829	0.44	1.97	3.34	nc
2012	1161	834	477	846	0.47	2.14	3.29	nc
2013	1184	851	487	863	0.49	2.32	3.22	nc
2014	1208	868	497	880	0.52	2.50	3.13	nc
2015	1232	885	507	898	0.54	2.68	3.02	nc
2016	1257	903	517	916	0.56	2.87	2.91	nc
2017	1282	921	527	934	0.58	3.06	2.80	nc
2018	1308	939	538	953	0.60	3.25	2.69	nc
2019	1334	958	549	972	0.62	3.46	2.59	nc
2020	1361	977	560	991	0.64	3.67	2.49	nc

nc not calculated.
Source: BTRE estimates.

TABLE 4.6 CASE 2 (ANGVC): ESTIMATED REDUCTION IN CO_2 EQUIVALENT EMISSIONS ATTRIBUTABLE TO CNGIP/AFCP

(Gigagrams)

	Commercial vehicles			Urban buses	All vehicles
	Base case	*With CNGIP/AFCP*	*Emissions reduction*	*Emissions reduction*	*Emissions reduction*
2001	21329.4	21312.1	17.3	8.2	25.5
2002	21798.3	21768.9	29.4	16.6	46.0
2003	22386.0	22344.9	41.1	25.2	66.3
2004	22991.7	22939.4	52.3	33.9	86.2
2005	23398.6	23335.9	62.7	42.8	105.5
2006	23901.5	23829.5	72.0	51.9	123.9
2007	24445.3	24365.0	80.3	61.1	141.4
2008	25010.2	24922.6	87.6	70.6	158.2
2009	25583.2	25489.3	93.9	80.2	174.1
2010	26152.8	26053.6	99.2	90.0	189.2
2011	26767.6	26664.1	103.5	100.0	203.5
2012	27378.7	27271.6	107.1	110.3	217.4
2013	27990.5	27880.3	110.2	120.7	230.9
2014	28609.5	28496.8	112.7	131.3	244.0
2015	29216.1	29101.3	114.8	142.2	257.0
2016	29816.5	29699.8	116.7	153.3	270.0
2017	30395.8	30277.3	118.5	164.6	283.1
2018	30961.8	30841.6	120.2	176.1	296.3
2019	31459.0	31337.2	121.8	187.8	309.6
2020	31874.0	31750.9	123.1	199.8	322.9

Source: BTRE estimates.

Case 3: 'Budget-constrained' case

Under the 'budget-constrained' scenario the number of vehicle conversions is restricted by the overall AFCP budget—$75 million over four years. The assumed average cost of vehicle conversion for each vehicle type is listed in table 4.7 (in the case of urban buses, the additional cost of an OEM CNG engine over that of an equivalent diesel-powered engine).

Based on the average cost estimates and the number of vehicle conversions in the first year of the program (AGO, pers. comm., 11 July 2001), the BTRE estimates that a total of just over 4800 commercial vehicles and buses could be converted to alternative fuels under the AFCP. Table 4.8 lists the BTRE estimates of the total number of vehicle conversions, by type of vehicle and type of fuel, under the AFCP program to 2005.

TABLE 4.7 CASE 3 (BUDGET-CONSTRAINED): ASSUMED AVERAGE COST OF VEHICLE CONVERSION

($ per vehicle)

	Existing fuel system	*Average conversion cost*	*AFCP eligible grant*
LPG Conversions			
Articulated trucks	Diesel	45 000[b]	22 500
Rigid trucks	Diesel	9 800 or 32 000[c]	10 000[e]
Buses	Diesel	35 000[d]	17 500
Other[a]	ns	40 500	20 225[f]
CNG Conversions			
Articulated trucks	Diesel	45 000[b]	22 500
Rigid trucks	Diesel	24 000[e]	12 000
Buses	Diesel	35 000[d]	17 500

ns not specified.
a. According to the AGO (pers. comm., AFCP Program Officer, 17 October 2001) ‘Other’ vehicles are predominantly forklifts.
b. BTRE assumption, based on Whiting (2001a, p. 28).
c. Conversion cost of $9 800 for dual-fuel vehicle and $32 000 for a dedicated LPG rigid truck.
d. NSW State Transit (pers. comm. G. Weston, Senior Adviser, Bus Fleet Management, 15 October 2001), Adelaide Metro (pers. comm., R. Mouveri, 15 October 2001).
e. AGO estimate.
f. BTRE estimates based on year 1 AFCP cost data supplied by the AGO.
Sources: NSW State Transit (pers. comm. G. Weston, Senior Advisor, Bus Fleet Management, 15 October 2001), Adelaide Metro (pers. comm. R. Mouveri, 15 October 2001), AGO (pers. comm. L. Arundell, AFCP Program Officer, 17 October 2001), Whiting (2001a and 2001b).

TABLE 4.8 CASE 3 (BUDGET-CONSTRAINED): ASSUMED NUMBER OF VEHICLES CONVERTED UNDER THE AFCP AND THE TOTAL PROGRAM COST

	Existing fuel system	*Number of vehicle conversions (no. of vehicles)*	*Average AFCP grant payable ($ per vehicle)*	*Total cost ($m)*
LPG Conversions				
Articulated trucks	Diesel	–	22 500	–
Rigid trucks	Diesel	1 524	10 000	15.24
Buses	Diesel	4	17 500	0.07
Other[a]	ns	20	225	16.18
CNG Conversions				
Articulated trucks	Diesel	24	22 500	0.54
Rigid trucks	Diesel	136	12 000	1.63
Buses	Diesel	2 362	17 500	41.34
Total		4 850		75.00

ns not specified.
a. Forklifts.
Sources: NSW State Transit (pers. comm. G. Weston, Senior Advisor, Bus Fleet Management, 15 October 2001), Adelaide Metro (pers. comm. R. Mouveri, 15 October 2001), AGO (pers. comm. L. Arundell, AFCP Program Officer, 17 October 2001), Whiting (2001a and 2001b), BTRE estimates.

LPG Conversions

Total LPG conversions are expected to save 4000 tonnes of CO_2-e emissions in 2004 with the majority of emission savings from rigid truck conversions.

Net reduction in emissions from rigid truck conversions to LPG

Recent conversions of diesel fuelled rigid and articulated trucks to LPG, eligible for funding under the AFCP, have been predominantly to dual-fuel (diesel pilot compression ignition) LPG engines. A small number of vehicles have sought funding for converting to LPG spark-ignition engines (AGO, pers. comm., 17 October 2001). The BTRE was unable to obtain estimates of the fuel efficiency and emissions characteristics of LPG use in diesel-pilot compression ignition engines. Consequently, the BTRE has estimated emissions savings based on assuming that all conversions are to spark-ignition engines. Because dual-fuel LPG engines still consume diesel, the effect of this assumption is that the estimated emissions savings will tend to overstate the actual reduction in emissions achievable from the LPG rigid truck conversions.

Beer et al. (2001) have noted that it is rare for LPG to be used in heavy vehicles and that there is a general lack of published data on LPG-fuelled heavy vehicle emissions. They report the findings of one study into the emissions performance of a LPG-fuelled stoichiometric combustion bus, the results of which are listed in table 4.9. The DAF[11] manufactured LPG-fuelled bus produced significantly lower total hydrocarbon emissions (including methane), but fuel consumption was significantly higher than for an equivalent diesel bus, consistent with the lower efficiency of stoichiometric combustion. Based on the fuel consumption rates resulting from the trial, direct CO_2 emissions are broadly similar for LPG and diesel fuelled buses. Default emission factors for LPG-fuelled spark-ignition, medium-sized trucks (BTCE 1995a) are reproduced in table 4.10.

TABLE 4.9 EMISSIONS FROM LPG-FUELLED STOICHIOMETRIC COMBUSTION BUS

	CO	*THC*	*NO_x*	*PM*	*FC*	*Direct CO_2*
	(g/kWh)				*L/km*	*(g/km)*
DAF GG170LPG	0.25	0.01	0.4	0.015	0.5–0.9	763–1373
Diesel comparison	4	1.1	7	0.15	0.3–0.5	807–1345

THC total hydrocarbons
PM particulate matter
FC fuel consumption
Sources: Beer et al. (2001, table 10.2), BTRE estimates.

TABLE 4.10 EMISSION FACTORS FOR LPG FUELLED MEDIUM TRUCKS

Gas	*Medium trucks (g/km)*
CH_4	0.13
N_2O	0.011
CO	24.00
NMVOC	2.46
NO_x	2.82

Source: BTCE (1995a)

Based on the evidence available, Beer et al. (2001, table 10.11, p. 301) concluded that total CO_2-e combustion emissions from LPG-fuelled heavy vehicles would be approximately 10 per cent less than for an equivalent LSD powered vehicle. In computing the emissions savings attributable to LPG-fuelled rigid truck conversions, the BTRE has assumed that new LPG-fuelled rigid trucks would

11 Dutch bus manufacturer

produce 10 per cent less CO_2-e emissions per kilometre than equivalent diesel trucks.

The BTRE assumed an average diesel fuel consumption rate for small rigid trucks, less than 8 tonnes GVM, of 18.6 litres per 100 kilometres—based on SMVU (ABS 2000a) estimates. The SMVU contains estimates of on-road fleet average fuel efficiencies for rigid trucks by fuel type. LPG/CNG/dual-fuel light commercial vehicles (LCVs) and rigid trucks are generally less fuel-efficient, on a per kilometre basis, than their diesel counterparts. Table 4.11 lists average fuel consumption rates for LCVs and rigid trucks. The SMVU only obtained fuel consumption data for LPG/CNG/dual-fuel vehicles under 8 tonnes GVM. As can be seen in table 4.11, there is significant variation in the average LPG fuel consumption rate for rigid trucks, between the 1998 SMVU and 1999 SMVU. This is probably attributable to sampling variability—LPG-fuelled rigid trucks are only a small proportion of the vehicle fleet.

TABLE 4.11 FUEL CONSUMPTION FOR RIGID TRUCKS AND LCVS

(L/100km)

		1999 SMVU		*1998 SMVU*	
Vehicle	*GVM/GCM*	*Diesel*	*LPG/CNG*	*Diesel*	*LPG/CNG*
LCVs		12	16	12.1	16.1
Rigid trucks	< 8t	18.7	28.2	18.6	21.9
	8–20t	25.7	na	26.5	na
	> 20t	43.4	na	43.3	na
	All	28.0	28.2	27.4	21.9

na not available.
GVM/GCM Gross Vehicle Mass / Gross Combination Mass
Sources: ABS (2000a, 2000b).

TABLE 4.12 CASE 3: EMISSION REDUCTIONS FROM LPG CONVERSIONS OF RIGID TRUCKS ATTRIBUTABLE TO CNGIP/AFCP

Year	Annual number of LPG rigid truck conversions (vehicles)	Cumulative LPG rigid truck conversions (vehicles)	Average vehicle utilisation (km/veh/yr)	Average CO_2-e emissions Diesel (g/km)	Average CO_2-e emissions LPG (g/km)	Average CO_2-e reduction (g/km)	Total CO_2-e savings (Gg)
2001	437	437	33000	506.1	455.5	50.6	0.73
2002	362	799	33000	506.1	455.5	50.6	1.33
2003	362	1161	33000	506.1	455.5	50.6	1.94
2004	363	1524	33000	506.1	455.5	50.6	2.55

Note: CO_2-e reduction relative to conventional diesel fuel up to end 2002, thereafter relative to LSD.

Sources: Beer et al. (2001), AGO (pers. comm. 2001), BTRE estimates.

Average utilisation was assumed equal to that of the fleet average for a new rigid truck—33 000 kilometres per annum.

Based on these assumptions, the BTRE estimates that the AFCP would reduce annual CO_2-e emissions by 2500 tonnes in 2004.

Net reduction in emissions from LPG forklift conversions

In the first year of the program, there were a significant number of forklifts converted to LPG that qualified for an AFCP grant. Based on the first year of the program, the BTRE has assumed that there will be 800 forklifts converted over the four years of the AFCP—approximately 15 per cent of the total number of vehicles converted under the program.

The BTRE could not, in the time available, undertake a detailed analysis of the impact of these conversions on CO_2-e emissions, but has provided some approximate estimates (table 4.13). The estimates are based on assuming that conversion to LPG would give the same absolute reduction in emissions, per vehicle, as a rigid truck converted to LPG. These assumptions imply annual CO_2-e emissions would be reduced by 1300 tonnes in 2004.

TABLE 4.13 CASE 3: EMISSION REDUCTIONS FROM LPG CONVERSIONS OF FORKLIFTS ATTRIBUTABLE TO CNGIP/AFCP

Year	*Annual number of LPG Forklift conversions (vehicles)*	*Cumulative LPG forklift conversions (vehicles)*	*Average annual CO_2-e reductions (t /vehicle p.a.)*	*Total CO_2-e savings (gigagrams)*
2001	180	180	1.67	0.30
2002	207	387	1.67	0.64
2003	207	594	1.67	0.99
2004	207	800	1.67	1.34

Note: CO_2-e reduction relative to conventional diesel fuel up to end 2002, thereafter relative to Low Sulphur Diesel (LSD).
Sources: Beer et al. (2001), AGO (pers. comm. 2001), BTRE estimates.

CNG Conversions

Total CNG conversions are expected to save around 35 000 tonnes, with the majority of emission savings from urban buses.

Emission reductions from urban bus conversions to CNG

Australian urban bus operators have committed to major investments in CNG buses over the next three to four years:

- NSW State Transit has ordered 300 Mercedes–Benz 0405NH CNG buses using the Mercedes–Benz M447LG engine
- Brisbane City Council has ordered 120 Scania CNG buses
- Adelaide Metro has ordered 90 CNG buses (MAN NL202) to be added to the fleet over the next three years
- Transperth has plans to use new CNG Daimler–Chrysler buses in place of diesel buses.

In calculating the reduction in CO_2-e emissions from the introduction of CNG- powered buses the BTRE has assumed that 2362 new CNG buses will enter urban bus fleets over the four year period of the AFCP (see table 4.14) and that each bus will travel an average distance of 60 000 kilometres per annum. Based on Beer et al. (2001), the BTRE assumes that, on average, CO_2-e emissions from CNG buses will be 17 per cent less than for the equivalent diesel-powered bus. Based on these assumptions, the BTRE estimates that CNG bus conversions carried out under the AFCP would reduce total CO_2-e emissions by approximately 34 000 tonnes in 2004, the last year of the program (see table 4.14). This represents a saving of approximately 5 per cent of total base case emissions attributable to urban bus operations in capital cities.

TABLE 4.14 CASE 3 – EMISSION REDUCTIONS FROM CNG CONVERSIONS OF URBAN BUSES ATTRIBUTABLE TO CNGIP/AFCP

				Assumed 17% saving in CO_2-e		Assumed 2% saving in CO_2-e	
	Number of CNG bus conversions		Average utilisation	Average CO_2-e reduction	Total CO_2-e reduction	Average CO_2-e reduction	Total CO_2-e reduction
Year	Annual	Cumulative	('000 km/ veh p.a.)	(g/km)	(Gg)	(g/km)	(Gg)
	(vehicles)						
2001	575	575	60	242.4	8.36	31.1	1.07
2002	595	1170	60	242.4	17.02	31.1	2.18
2003	596	1766	60	242.4	25.68	21.9	2.32
2004	596	2362	60	242.4	34.35	21.9	3.10

Note: CO_2-e reduction relative to conventional diesel fuel up to end of 2002, thereafter relative to Low Sulphur Diesel (LSD).

Sources: Beer et al. (2001; 2000), AGO (pers. comm., 11 July 2001), BTRE estimates.

The AGO requested that the BTRE use the assumption that CNG buses produced 17 per cent less CO_2-e emissions than an equivalent diesel bus, based on Beer et al. (2001). If the older data (Beer et al. 2000) are used, with a reduction of only 2 per cent in CO_2-e emissions per kilometre, the abatement would be an order of magnitude lower, at 3000 tonnes in 2004 (see table 4.14).

Net reduction in emissions from truck conversions to CNG

The BTRE has assumed 160 rigid and articulated trucks will be converted or replaced with new CNG vehicles as a result of the AFCP. The CNG engine technology options available for rigid and articulated trucks are similar to those used in buses. The BTRE has assumed that all rigid and articulated truck CNG conversions will be to spark-ignition CNG engine technology.

In the absence of information about the number and type of trucks converting to CNG under the first year of the AFCP, the BTRE decided to assume that the number of trucks switching from diesel to CNG would be proportional to the current stock of registered rigid and articulated trucks: 85 per cent rigid trucks and 15 per cent articulated trucks. The BTRE also assumed that average kilometres travelled by CNG rigid trucks would be equal to the average distance travelled by new rigid trucks— 33 000 kilometres per annum. For articulated trucks, the BTRE assumed that range constraints and a lack of refuelling options will tend to prevent CNG trucks being used on long-distance (inter-capital) routes. Consequently, the BTRE has assumed that the average distance travelled is equal to that of newer articulated trucks undertaking largely urban operations—approximately 70 000 kilometres per annum (K. Hassall, pers. comm., 23 July 2001).

As for the case of CNG bus conversions, the BTRE calculated two sets of CO_2-e reduction estimates. The first was based on Beer et al. (2001)—that CNG heavy vehicles produce approximately 17 per cent lower CO2-e emissions per km than diesel vehicles. The second set was based on earlier data from Beer et al. (2000)—that CNG heavy vehicles produce 2 per cent lower CO_2-e emissions. The average fuel consumption for new diesel-fuelled rigid and articulated trucks, 26.2 litres per 100 kilometres and 48.1 litres per 100 kilometres respectively, were used to compute the diesel reference CO_2-e emissions. When Low Sulphur Diesel (LSD) is introduced (by the beginning of 2003), it will probably slightly reduce the CO_2 emission benefit from converting to diesel (Beer et al. 2000).

TABLE 4.15 CASE 3: EMISSION REDUCTIONS FROM CNG CONVERSIONS OF RIGID AND ARTICULATED TRUCKS ATTRIBUTABLE TO CNGIP/AFCP

	No of CNG bus conversions				*Assumed 17% saving in $C0_2$-e emissions per km*		*Assumed 2% saving in $C0_2$-e emissions per km*	
	Annual	*Cumulative*	*Average utilisation ('000 km/ veh p.a)*	*Base case diesel fuel CO_2-e emissions (g/km)*	*Average CO_2-e reduction (g/km)*	*Total CO_2-e reduction (Gg)*	*Average CO_2-e reduction (g/km)*	*Total CO_2-e reduction (Gg)*
	(vehicles)							
Rigid trucks								
2001	33	33	33	704.9	119.8	0.130	17.6	0.019
2002	35	68	33	704.9	119.8	0.269	17.6	0.040
2003	34	102	33	704.9	119.8	0.403	12.4	0.042
2004	34	136	33	704.9	119.8	0.538	12.4	0.056
Articulated trucks								
2001	6	6	70	1294.1	220.0	0.092	32.4	0.014
2002	6	12	70	1294.1	220.0	0.185	32.4	0.027
2003	6	18	70	1294.1	220.0	0.277	22.8	0.029
2004	6	24	70	1294.1	220.0	0.370	22.8	0.038
All trucks								
2001	39	39	nc	nc	nc	0.223	nc	0.033
2002	41	80	nc	nc	nc	0.454	nc	0.067
2003	40	120	nc	nc	nc	0.681	nc	0.070
2004	40	160	nc	nc	nc	0.907	nc	0.094

nc not calculated.
Note: CO_2-e reduction relative to conventional diesel fuel up to end of 2002, thereafter relative to Low Sulphur Diesel (LSD).
Sources: Beer et al. (2000), AGO (pers. comm., 11 July 2001), BTRE estimates.

Under the assumption that CNG use results in 17 per cent lower emissions than the equivalent diesel vehicle, the BTRE estimates that the total reduction in *annual* CO_2-e emissions, from conversion of rigid and articulated trucks, will be approximately 900 tonnes in 2004 (table 4.15).

Overall reduction in emissions

For Case 3, the AFCP measures are estimated to reduce total *annual* CO_2-e emissions by nearly 40 thousand tonnes in 2004 (table 4.16), assuming CNG bus and truck engines produce 17 per cent less CO_2-e emissions per kilometre than equivalent diesel engines. If, however, the reduction in CO_2-e emissions from CNG vehicles are approximately 2 per cent per vehicle kilometre, the *annual* reduction in emissions from the AFCP would be only 7500 tonnes in 2004.

TABLE 4.16 CASE 3: TOTAL REDUCTION IN EMISSIONS ATTRIBUTABLE TO CNGIP/AFCP

(Gigagrams)

	CNG conversions		*LPG conversions*		
Year	*Buses*	*Trucks*	*Trucks*	*Forklifts*	*All vehicles*
2001	8.36	0.22	0.73	0.30	9.61
2002	17.02	0.45	1.33	0.64	19.45
2003	25.68	0.68	1.94	0.99	29.29
2004	34.35	0.91	2.55	1.34	39.14

Source: BTRE estimates.

ENVIRONMENTAL STRATEGY FOR THE MOTOR VEHICLE INDUSTRY (ESMVI)

The Environmental Strategy for the Motor Vehicle Industry (ESMVI), encompasses a range of measures aimed at significantly enhancing the environmental performance of the automotive industry.

The strategy includes:

- the negotiation with the automotive industry of improved National Average Fuel Consumption (NAFC) targets for new passenger vehicles for 2005 and 2010
- extension of the NAFC framework (particularly to include 4WDs and LCVs)
- continuation of the *Fuel Consumption Guide* and publication of fuel consumption data on the Internet

- negotiations with individual car manufacturers on initiatives they might take to improve the fuel efficiency of the models they produce
- model specific fuel efficiency labels for new passenger motor vehicles
- fuel efficiency targets for the Commonwealth fleet
- the development of partnerships with consumer groups (both private and fleet) to encourage attention to fuel efficiency
- harmonisation of vehicle emission standards.

The only parts of the ESMVI that has been quantified explicitly to date are those relating to the NAFC. Negotiations over extensions to the NAFC aim to obtain at least a 15 per cent improvement in the NAFC of new passenger vehicles (over 'business-a-usual' projections) by 2010.

The BTRE estimates for this measure (following the AGO's proposed scenario) were derived by running CARMOD with an input projection of new car fuel intensity falling by 15 per cent (relative to the base case trend) by 2010, and remaining at 15 per cent below the base case trend-line up to 2020 (see table 4.17A). It should be noted that the base case projections already incorporate a significant declining trend in new car fuel consumption—the BAU drop in average litres per 100 kilometres forecast for 2000 to 2020 is similar in magnitude to that experienced over the last 20 years. Given the Australian public's preference for relatively large, high performance vehicles, the NAFC values used in this ESMVI–NAFC scenario probably form a quite challenging target.

TABLE 4.17A PROJECTED TREND FOR NAFC TO 2020

(L/100 km)

Year	*Base case*	*ESMVI–NAFC scenario*
2000	8.34	8.34
2005	7.91	7.45
2010	7.42	6.31
2015	7.00	5.95
2020	6.70	5.70

Sources: AGO (2001, pers. com.), BTRE estimates.

The lower fuel consumption of the passenger vehicle fleet (table 4.17B), resulting from the improved new car fuel efficiency assumed above, yields an estimated annual emission reduction of around 2 million tonnes of CO_2 equivalent in 2010 (about 4.2 per cent of projected 2010 passenger vehicle emissions) and around 5.4 million tonnes in 2020 (10.8 per cent reduction)—see table 4.18.

TABLE 4.17B ESTIMATED ON-ROAD FUEL CONSUMPTION FOR CAR FLEET, UNDER ASSUMED NAFC CHANGES

(L/100 km)

Year	*Base case*	*ESMVI–NAFC scenario*
2000	11.48	11.48
2001	11.46	11.46
2002	11.45	11.43
2003	11.44	11.40
2004	11.42	11.34
2005	11.41	11.28
2006	11.38	11.20
2007	11.35	11.11
2008	11.31	10.99
2009	11.27	10.87
2010	11.21	10.72
2011	11.19	10.60
2012	11.16	10.48
2013	11.12	10.37
2014	11.09	10.25
2015	11.04	10.13
2016	11.00	10.02
2017	10.96	9.92
2018	10.92	9.81
2019	10.87	9.71
2020	10.82	9.60

Source: BTRE estimates.

TABLE 4.18 ESTIMATED IMPACT OF FUEL EFFICIENCY MEASURES UNDER GOVERNMENT EXPECTATION OF CHANGES TO NAFC TREND

(Gigagrams)

Year	*Base case*	*ESMVI–NAFC*	*Emissions reduction*
2000	40696	40696	..
2001	41491	41476	15
2002	43187	43113	75
2003	44070	43901	169
2004	44748	44451	297
2005	45431	44966	464
2006	45910	45234	676
2007	46523	45587	935
2008	46999	45756	1243
2009	47426	45833	1594
2010	47792	45801	1991
2011	48189	45787	2402
2012	48540	45746	2793
2013	48843	45672	3171
2014	49116	45585	3531
2015	49342	45463	3878
2016	49547	45338	4208
2017	49742	45216	4527
2018	49898	45065	4833
2019	50021	44897	5125
2020	50110	44711	5398

.. not applicable

Note: No rebound travel, due to reduced operating costs from improved fuel efficiency, is accounted for in this scenario.

Source: BTRE estimates.

As a sensitivity scenario, CARMOD was also run by setting the future growth in Australian car ownership unconstrained (i.e. the base case trend towards eventual saturation in cars per person was relaxed) and with the NAFC changes given in table 4.17. The resulting emission reduction estimates (again assuming no rebound travel) were similar to those derived versus the base case (see table 4.19).

TABLE 4.19 SENSITIVITY OF ESTIMATED IMPACT OF ESMVI–NAFC SCENARIO TO FUTURE TREND IN CAR OWNERSHIP

(Gigagrams)

	BAU– with no vehicle saturation	*NAFC scenario with no vehicle saturation*	*Emission reduction*
2000	40696	40696	..
2001	41600	41550	50
2002	43551	43462	89
2003	44534	44357	178
2004	45453	45147	306
2005	46419	45938	481
2006	47345	46639	706
2007	48361	47375	987
2008	49238	47906	1332
2009	50131	48401	1730
2010	50996	48805	2192
2011	51953	49272	2681
2012	52915	49757	3158
2013	53881	50249	3631
2014	54860	50763	4097
2015	55837	51277	4559
2016	56847	51832	5015
2017	57892	52425	5468
2018	58940	53023	5918
2019	59997	53636	6361
2020	61058	54265	6793

.. not applicable
Source: BTRE estimates.

DIESEL AND ALTERNATIVE FUELS GRANTS SCHEME

The Diesel and Alternative Fuels Grants Scheme (DAFGS) pays a rebate on all on-road diesel and alternative fuel use by eligible vehicles. Vehicles eligible for the DAFGS include all vehicles above 20 tonnes gross vehicle mass (GVM) and all vehicle use outside major metropolitan centres of commercial vehicles between 4.5 tonnes GVM and 20 tonnes GVM.

Under the DAFGS, the grant rates for diesel and alternative fuels were set at rates that attempted to maintain the then retail price relativities between different fuels. The DAFGS grant rates at 1 February 2001 were:

- compressed natural gas (CNG) 12.617 cents per cubic metre
- liquefied petroleum gas (LPG) 11.925 cents per litre
- ethanol 20.809 cents per litre
- diesel 18.510 cents per litre

The estimates of the change in emissions resulting from the DAFGS, presented below, are relative to the pre-tax reform circumstances. Note that the impact of the DAFGS on freight demand and fuel use (diesel, CNG and LPG), has already been included in the BTRE's base case emission projections—so the values given in table 4.21 are not to be added to base case results (e.g. table 1.3) when compiling composite 'With Measures' projections.

The greenhouse measure component of the DAFGS is the rebate to alternative fuels. The BTRE has not separately estimated the impact on emissions of inclusion of alternative fuels in the DAFGS scheme. The BTRE would expect, however, that inclusion of alternative fuels in the DAFGS would have had only a very small effect on total emissions. This is because the pay-back period for conversion to an alternative fuel vehicle will have increased.

The DAFGS may also have induced some slight shift between vehicle classes. Those vehicle operators just under the 4.5 tonne or 20 tonne cut-off points, for whom the extra cost of a larger vehicle would now be more than offset by the reduction in fuel costs arising from the DAFGS, will make the switch. The BTRE has not explicitly estimated the impact on emissions of any shift to larger vehicles. The impact of vehicle switching on emissions is likely to be small relative to the increase in emissions resulting from the reduction in all fuel costs due to the DAFGS.

At the time of the analysis, the DAFGS paid 18.51 cents per litre for diesel. The terminal gate price of diesel, including GST, as at 1 August 2001 was around 85–89 cents per litre. Distribution and retail costs and margins add around 5–6 cents to this amount (AIP 2001). Commercial operators can claim excise credits for the GST paid on fuel (one eleventh of the final price) and receive the DAFGS rebate on top of this. Currently, the DAFGS is approximately 28 per cent of the effective fuel cost of commercial operators (table 4.20). Of course, the relative impact of the DAFGS on the price of diesel varies with fluctuations in the world price of oil.

For long-distance (high utilisation) articulated truck operations, fuel can be up to 30 per cent of total operating costs. For articulated trucks as a group, undertaking a mix of long-distance and short-distance (urban) freight task, fuel was assumed to contribute 20 per cent of total costs. The BTRE has estimated the long-run road freight rate elasticity of –0.9 (BTCE 1995a). Based on these assumptions, the BTRE estimates the DAFGS has served to increase the articulated truck freight task by approximately 5 per cent.

TABLE 4.20 APPROXIMATE PRICE OF DIESEL FUEL TO COMMERCIAL VEHICLE OPERATORS

(cents per litre)

Estimated terminal gate price	87.0
Estimated distribution & retail costs and margins	6.0
less GST	–8.45
less DAFGS	–18.51
Effective price to operator	66.04

Sources: Mobil (2001), Shell (2001), BP (2001), AIP (2001), AGO (2001), BTRE estimates.

For rigid trucks, fuel costs are assumed to be approximately 15 per cent of total costs. Only a subset of the total kilometres driven by rigid trucks are eligible for the DAFGS. As at 31 October 1999, 21 per cent of rigid trucks were under 4.5 tonnes GVM while 15 per cent were above 20 tonnes GVM (ABS 2000a). Further, approximately half of all rigid truck vehicle kilometres travelled (VKT) are undertaken in urban areas (ABS 2000a). The BTRE assumed that urban/non-urban vehicle use by rigid trucks were reasonably uniform across different vehicle weights and that about 45 per cent of total rigid truck kilometres would be eligible for the rebate. These assumptions imply the DAFGS has increased the rigid truck freight task by approximately 1.8 per cent above the level it would have been prior to the tax changes.

Together then, these results imply the DAFGS has increased the total road freight task by 4.25 per cent above what it would otherwise have been had the DAFGS not been introduced. Rigid and articulated trucks undertook 17.5 per cent and 78.7 per cent respectively of the total tonne-kilometre road freight task in 2000–01.

Based on these assumptions, the BTRE estimates that in the absence of the reduction in the cost of diesel fuel to operators in the DAFGS, CO_2-e emissions from commercial vehicles would have been about 200 000 tonnes less in 2000–01. By 2010 and 2020, the BTRE estimates that the DAFGS would have increased annual emissions by approximately 250 000 tonnes and 300 000 tonnes (see table 4.21), respectively. The increase in emissions may have been marginally higher if alternative fuels had been excluded from the DAFGS. These estimates also ignore any reduction in rail freight emissions arising from substitution of freight from rail to road as a result of the DAFGS.

TABLE 4.21 ESTIMATED IMPACT OF DAFGS ON COMMERCIAL VEHICLE CO_2 EQUIVALENT EMISSIONS

(Gigagrams)

Year	*Absence of DAFGS*	*Base case*	*Emissions difference*
2000	20761.9	20761.9	..
2001	21122.1	21329.4	–207.3
2002	21588.8	21798.3	–209.5
2003	22171.3	22386.0	–214.7
2004	22771.6	22991.7	–220.1
2005	23175.1	23398.6	–223.5
2006	23672.9	23901.5	–228.6
2007	24212.2	24445.3	–233.1
2008	24772.4	25010.2	–237.8
2009	25340.7	25583.2	–242.5
2010	25905.5	26152.8	–247.3
2011	26514.6	26767.6	–253.0
2012	27120.7	27378.7	–258.0
2013	27727.3	27990.5	–263.2
2014	28341.1	28609.5	–268.4
2015	28942.0	29216.1	–274.1
2016	29537.4	29816.5	–279.1
2017	30111.8	30395.8	–284.0
2018	30673.6	30961.8	–288.2
2019	31166.6	31459.0	–292.4
2020	31578.0	31874.0	–296.0

.. not applicable
Source: BTRE estimates.

‘WITH MEASURES’ PROJECTIONS OF CO_2 EQUIVALENT EMISSIONS

Table 4.22 presents the resulting ‘With Measures’ projections (i.e. the base case plus the measures scenarios) using the emission reductions estimated in the above sections. If the Government emission abatement measures (currently in train for the transport sector) manage to reach their full proposed potential, then the values in table 4.22 comprise the likely alterations to the base case emission projections (set out in table 1.3).

The base case projections have total transport emissions growing by 2 per cent per annum between 2000 and 2010. The ‘With Measures’ scenario assumptions reduce this forecast growth to 1.76 per cent per annum.

The ‘base case with measures’ scenario has 2.3 per cent less total transport emissions in 2010 than the base case (composed of a 2.28 per cent reduction if the NAFC targets within the ESMVI can be met, and a further 0.05 per cent from the Alternative Fuels programs).

The base case emission result for 2010 would be 0.3 per cent lower in the absence of the fuel price reductions following the introduction of the DAFGS.

TABLE 4.22 'WITH MEASURES' EMISSION PROJECTIONS BY TYPE OF TRANSPORT, FOR ENERGY END-USE BY AUSTRALIAN DOMESTIC CIVIL TRANSPORT 1990–2020

(Gigagrams of direct CO_2 equivalent)

Year	Cars	Road	Air	Rail (non-electric)	Coastal shipping	Other (minor)	Total
1990	34220	17321	2565	1741	1939	1890	59676
1991	34351	16982	3142	1727	1811	1885	59897
1992	34847	16810	3393	1673	1742	1890	60357
1993	35600	17607	3553	1641	1684	1896	61980
1994	36148	17722	3707	1769	1664	1911	62921
1995	37496	18329	4274	1708	1866	1926	65600
1996	38355	19018	4636	1672	1770	1942	67393
1997	38607	19203	4840	1806	1811	1957	68223
1998	39170	20268	4846	1743	1614	1972	69612
1999	40009	20537	4781	1717	1475	1982	70502
2000	40696	20762	4996	1782	1505	1980	71720
2001	41476	21328	5280	1840	1442	1989	73355
2002	43113	21796	5541	1875	1429	1998	75752
2003	43901	22383	5789	1911	1417	2007	77409
2004	44451	22988	6050	1948	1406	2016	78859
2005	44966	23395	6313	1986	1396	2033	80090
2006	45234	23898	6584	2025	1388	2050	81178
2007	45587	24441	6868	2064	1380	2067	82407
2008	45756	25006	7164	2104	1373	2084	83486
2009	45833	25579	7471	2145	1367	2100	84495
2010	45801	26149	7792	2186	1363	2117	85408
2011	45787	26764	8130	2229	1359	2131	86400
2012	45746	27375	8485	2272	1356	2146	87379
2013	45672	27987	8856	2316	1353	2160	88344
2014	45585	28606	9245	2361	1352	2175	89323
2015	45463	29212	9650	2407	1351	2189	90274
2016	45338	29813	10073	2454	1351	2203	91233
2017	45216	30392	10513	2502	1352	2217	92191
2018	45065	30958	10968	2551	1354	2231	93125
2019	44897	31455	11437	2600	1356	2244	93990
2020	44711	31870	11922	2651	1359	2258	94772

Notes: 'Air' is total domestic aviation (i.e. including general aviation).
'Other (minor)' includes buses, motorcycles, small marine pleasure craft, ferries and unregistered off-road motor vehicles.

Source: BTRE estimates.

chapter 5

IMPACT OF ALTERNATIVE TRANSPORT MEASURES ON TRANSPORT EMISSIONS

SUMMARY

As part of this and previous studies, the Bureau has estimated the likely change in future emission levels due to the implementation of a range of possible transport policy scenarios. These scenarios will typically relate to hypothetical courses of action, and not be indicative of any particular policy options currently under government consideration. Rather, they are purely intended to augment any current research programs investigating the efficiency of emission reduction measures – particularly those looking into possible *'no regrets'* (i.e. no net cost to society) or *low cost* emission abatement options for the transport sector.

Of the various policy scenarios investigated to date, the most significant scope for abatement appears to be offered by traffic congestion reductions through *optimal road pricing* (ORP).

Emission abatement strategies will generally tend to involve:

- increased take-up of technological innovation (e.g. promotion of greater sales of efficient hybrid-fuel motor vehicles);
- improvements to infrastructure or transport services (e.g. construction of high capacity roads, to smooth traffic flows, or enhanced public transport systems);
- transport demand management (in particular, encouraging travellers to change inefficient commuter behaviour through pricing mechanisms or education campaigns);

or a combination of these various elements.

The use of Intelligent Transport Systems (ITS) to apply optimal road user charges (i.e. charges that vary, to be higher in more congested areas) across metropolitan road networks offers a particularly effective combination of transport demand management (TDM) and advanced technology use.

The estimated emission reductions for a (nationwide) urban road pricing scenario (along with the estimated social costs associated with such a policy) are presented in this chapter. Table 5.1 summarises the key findings of the Bureau's modelling of congestion pricing scenarios – with optimal road pricing having the potential for significant reductions in CO_2-e emissions from road transport. The BTRE estimates that close to 6800 gigagrams (i.e. 6.8 million tonnes) of CO_2-e emissions from urban traffic could be abated annually by 2010 (under the assumed charge levels of the scenario being levied across the eight State and Territory capitals).

TABLE 5.1 ESTIMATED ABATEMENT COST AND REDUCTION IN EMISSIONS FOR ORP SCENARIO

Policy instrument	*Abatement strategy*	*Average abatement cost ($/t)*	*CO_2-e abated in 2010 (Gg)*
Optimal road pricing (ORP)	Use Intelligent Transport Systems to charge road users appropriately for the costs resulting from their travel decisions.	–1300	6766

Note: For this scenario, ORP charges are levied across the eight Australian State and Territory capitals.
Source: BTRE estimates, BTCE 1996b.

Note that there are considerable unknowns in this type of analysis and the results should only be taken as indicative of possible benefits. For example, elasticity values for responses to many of the price changes involved in such policy setting are, at best, only poorly quantified. Abatement cost estimates have been computed on the basis of net national economic cost to Australian residents.

Note also that a previous Bureau publication – BTCE Report 94, *Transport and Greenhouse: Costs and options for reducing emissions* — gives a detailed presentation of the cost elements and likely emission benefits of not only ORP, but also a wide range of possible abatement measures (e.g. accelerated penetration of fuel saving technology in new motor vehicles, increased urban parking charges, alternative fuel use, road surface improvement, freight mode switching, encouraging more urban public transit use, accelerating turnover of transport fleets through increased vehicle scrappage).

CONGESTION REDUCTIONS THROUGH OPTIMAL ROAD PRICING

Policy instrument: Use Intelligent Transport Systems (ITS) to charge road users appropriately for the costs resulting from their travel decisions.

Road systems in Australian cities are becoming progressively more crowded and urban traffic congestion becoming an increasingly important problem. Large proportions of Australian urban car trips occur during morning and evening peak times. Significant portions of the road networks of major

Australian cities (particularly Sydney) increasingly experience heavy traffic volumes throughout much of the day. Consequently, approximately half of total urban vehicle kilometres travelled (VKT) are currently performed under congested traffic conditions (BTCE 1996b: p. 312). That is, the travel is typically done on roads with either heavy congestion (involving average traffic speeds of less than a third of that possible on those roads under free-flow traffic conditions) or interrupted flow (where traffic is moving at around half that of free-flow or unimpeded speeds).

Congestion, as an economic externality, imposes significant costs on society. Road users incur higher private costs when joining a congested traffic stream, through increased vehicle-operating costs and trip travel times. In addition, road users do not typically take account of the fact that their decisions to travel serve to increase congestion, and therefore impose additional delays and costs on other road users. Depending on how close the traffic volume is to a road's designed traffic capacity, increases in overall delays can rise sharply as traffic increases.

Rough (order of magnitude) social costs due to urban traffic congestion are presented in BTE (1999b). The Bureau estimates a total cost of approximately 12.8 billion dollars per year due to traffic congestion in major Australian cities (with Sydney currently experiencing costs of around 6.0 billion dollars per annum, Melbourne 2.7, Brisbane 2.6, Adelaide 0.8, Perth 0.6 and Canberra 0.05). If nothing is done, the total cost of Australian urban congestion could rise to about 29.7 billion dollars per year by 2015 (BTE 1999b: table 1).

Fuel consumption per vehicle (e.g. litres per 100 kilometres) under congested traffic conditions is approximately twice that of the vehicles' fuel use under free-flow conditions. Therefore, congestion has the potential to double the output of greenhouse gas emissions from a stream of vehicle traffic. Emission rates of noxious pollutants (e.g. carbon monoxide, volatile organic compounds and particulates) also tend to be approximately twice as high under congested conditions.

BTRE estimates, based on the Bureau's modelling of urban network congestion (detailed in BTCE 1996a and BTCE 1996b: ch. 18), suggest that as much as 40 per cent of the fuel used by road vehicles in Australia's major cities is the result of interruptions to the traffic flow.

As well as being practically impossible for urban traffic to flow completely free from interruption and delay, it would be extremely expensive (and economically inefficient) to attempt to remove urban congestion entirely. However, congestion levels can be efficiently reduced (and social amenity improved) by a variety of measures. Since congestion is typically such a diverse problem, varying significantly both spatially and temporally, the most effective policies aimed at reducing it will tend to be those that can target particular city areas or particular times of travel. Besides the construction of new infrastructure to handle higher traffic volumes, examples of options aimed at encouraging people to avoid congested areas include parking surcharges, freeway tolls, cordon charges for entering the CBD, and continuous electronic road pricing.

ITS applications, such as electronic toll collection technologies and traffic monitoring systems, offer technically achievable ways of determining appropriate road user costs and charging motorists in real time.

For example, BTCE (1996a) estimated that levying optimal road user charges within the major Australian cities could reduce peak hour travel by the order of 20 per cent, while reducing overall travel time by close to 40 per cent, and total traffic fuel consumption by close to 30 per cent. ('Optimal' here refers to the charges being structured to vary between different parts of the city according to requirements, so that they would be higher in the more congested areas and lower in less congested areas.)

Such optimal congestion charges could significantly reduce greenhouse gas emissions from road vehicle use within major Australian cities (by a combination of reducing overall travel and by spreading the remaining travel more evenly across networks). The BTRE estimates that optimal road congestion charges within the eight State and Territory capitals (i.e. Sydney, Melbourne, Brisbane, Adelaide, Perth, Hobart, Darwin and Canberra) could reduce Australian CO_2-e emissions by around 6.8 million tonnes per annum by 2010 (see table 5.2). The annual emission reduction from the optimal charges (applied to the eight capital cities) could grow to nearly 7 million tonnes of CO_2-e by 2020.

The cumulative emission reductions estimated for this optimal road pricing (ORP) scenario total 31.6 million tonnes of CO_2-e (37.9 million tonnes FFC) by 2010, and around 100.5 million tonnes (120.5 million tonnes FFC) by 2020 (versus the 'base case plus measures' projected emissions for the metropolitan car fleet).

Estimates of the average and marginal costs of implementing congestion charges are detailed in BTCE Report 94 (1996b: ch. 18) — which, along with BTCE Report 92 (1996a), still form part of the state-of-the-art in this field, as few national studies dealing with the costs and benefits of optimal road pricing have been conducted since.

The marginal social costs derived in BTCE (1996a) for ORP (taking infrastructure costs, welfare effects, congestion reductions and externality benefits into account) range over –$1807 per tonne abated (for Melbourne) to –$380 per tonne (for Perth). That is, the BTRE expects this measure to yield net economic benefits. The results of BTCE (1996b) imply that the average cost (over a 20-year time frame) of ORP applied across Australian metropolitan travel is of the order of –$1300 per tonne of CO_2-e abated (i.e. a substantial social benefit).

TABLE 5.2 CHANGE IN CO_2 EQUIVALENT EMISSIONS BETWEEN BAU METROPOLITAN ESTIMATES AND THE SCENARIO FOR OPTIMAL CONGESTION CHARGES

(gigagrams)

Year	*Base case plus measures*	*ORP policy scenario*	*Emission reduction*
2000	25389	25389	..
2001	26018	26018	..
2002	27183	27183	..
2003	27822	27509	313
2004	28314	27199	1115
2005	28789	26522	2267
2006	29107	25505	3602
2007	29483	24508	4975
2008	29741	23719	6023
2009	29941	23373	6568
2010	30071	23305	6766
2011	30213	23415	6798
2012	30336	23510	6826
2013	30437	23589	6848
2014	30530	23661	6869
2015	30600	23715	6885
2016	30667	23767	6900
2017	30735	23820	6915
2018	30784	23857	6926
2019	30820	23885	6934
2020	30843	23904	6940

.. not applicable
Note: Emission estimates refer to car travel within the 8 Australian capital cities.
Source: BTRE estimates.

OTHER TDM MEASURES

Some measures, such as ORP, appear likely to be quite effective even if implemented independently of any other abatement policies. Yet often, emission abatement will tend to be most successful when a combination of interacting measures are implemented together. As an example, consider a policy instrument that encourages car manufacturers to progressively reduce the average fuel consumption of their new vehicles over the coming years. The effectiveness of such a measure will be aided by any other policy instruments that serves to:

- encourage higher new vehicle sales to improve the fleet penetration rate of the new technology (e.g. through vehicle price reductions, especially if targeted at fuel-efficient models, or through incentives to scrap more older vehicles)
- improve the efficiency of the remaining portion of the fleet (e.g. mandatory inspection and maintenance campaigns, or tightening of emissions standards for in-service vehicles).

Optimal road pricing belongs to a set of measures that attempts to make individuals face more accurate price signals in their travel behaviour – prompting them to make more efficient transport decisions. Since the costs imposed on society by transport will typically depend on the volume and composition of its traffic flows, charges levied on road users will tend to be more efficient the more accurately they vary to reflect the time, location, amount and method of travel. As well as electronic road pricing, an important option for improving such price signals is 'variablisation' – that is, increasing the variable proportion of motoring costs and reducing the fixed proportion.

Vehicle registration and insurance comprise significant proportions of total motoring costs in Australia, but as fixed costs do not provide any disincentive to excessive car use. Charging insurance and registration fees on a variable basis – so as to be proportional to the amount of car travel performed – will not only more accurately reflect road user costs (for registration purposes) and accident exposure levels (for insurance purposes), but will encourage reductions in vehicle kilometres and subsequent greenhouse emission levels.

Global Positioning Systems (GPS) and other related advanced technologies even allow the variation of such 'vehicle use pricing' by the area of travel, and could be readily combined with a system levying optimal congestion charges. (An added advantage of GPS-based insurance schemes is improved vehicle recovery rates following car thefts.)

A range of policy strategies can be naturally allied with the introduction of major pricing mechanisms such as ORP or variablisation, with the aim of achieving the best possible reduction in emissions at the least social cost. For example, synergies between measures could be obtained by combining the introduction of city-wide electronic road pricing with strategies to:

- improve the efficiency or cost of the public transit system
- improve access for non-motorised transport
- restructure parking charges to further discourage car travel to congested areas
- encourage the replacement of urban car trips with public transport or non-motorised travel through information provision and education campaigns targeting transport options.

Strategies to improve transport demand management by educating the public about their travel options (such as the 'TravelSmart' program) can result in very cost-effective emission abatement – but the overall success of such campaigns will vary from centre to centre and will depend crucially on a variety of demographic factors (such as average trip distances required by the targeted population, amount of spare capacity on the public transport system, and the adequacy of local infrastructure to handle greater non-motorised trip levels).

'TravelSmart' is the name given to a set of transport awareness initiatives run by the Western Australian Department of Environmental Protection and Department of Planning and Infrastructure.

TravelSmart is a community-based program that encourages people to use alternatives to travelling in their private car, especially as a single occupant driver. It provides information, motivation and skills to help people choose alternatives to driving for personal travel. This is done through a program called 'Individualised Marketing' that reaches households through schools, businesses and local government. TravelSmart also collaborates with organisations or community groups involved with environmental, health, cycling and transport access issues.

The rest of this section will discuss the sorts of issues that should be considered when assessing the feasibility of introducing location-specific policy options such as Individualised Marketing – options which could serve as useful adjuncts to a complete TDM package of measures, but will need to be assessed separately for each target community considered. Nationwide 'average abatement costs' will typically not be very meaningful when derived for such area-specific measures, so this section will use Individualised Marketing as an example (following the experience of TravelSmart in South Perth) for examining the cost elements that could be involved in a detailed implementation analysis for a given city.

Some initial applications of individualised marketing programs (such as the South Perth Pilot Project in 1997) have achieved reductions in overall car travel of between 10 and 17 per cent through a combination of increased walking, cycling, public transit use and car pooling. These changes in travel behaviour were found to be maintained reasonably well when measured one or two years later. For example, over a small, random sample for the pilot project in South Perth in 1997, TDM via individualised marketing achieved a 10 per cent reduction in car trips (with a 14 per cent reduction in overall car VKT across participants), a 16 per cent increase in walking, a 21 per cent increase in public transit use, and a 91 per cent increase in cycling (Ker & James 1999). Recent large-scale application of the program across South Perth (over 15 300 households) has apparently achieved similar levels of success (Litman 2001a).

If an Individualised Marketing campaign was introduced to other Australian metropolitan areas, it is hard to know whether similar VKT reductions would be obtained as for South Perth. For such a scenario, any VKT reduction occurring during times of heavy traffic congestion would be particularly beneficial, since heavily congested driving has around twice the average fuel consumption of free-flow conditions.

As well as the direct costs of program implementation, the assessment of the costs and benefits (of any policy measures aimed at reducing urban VKT) should also consider the likely changes in transport externality levels and in consumer surplus. A range of externality unit cost estimates and transport elasticities that can be used in such calculations are presented in BTCE (1995a), Luk & Thoresen (1996), Litman (2001b), Bray & Tisato (1998), and BTRE (2002b).

The upfront costs for the South Perth Pilot Project were around $40 per person. Annualising this cost over 10 years (the assessment period typically chosen for the pilot projects) gives an estimated basic implementation cost of about $4 per year per person for Individualised Marketing. It is probable that for widespread application of the measure, extra spending would be required each year for marketing maintenance or follow-up programs (to ensure a reasonable durability for the travel changes). Depending on the particular neighbourhood, even further spending could be required for improvements to cycling/walking access and public transit capacity (to service commuter mode changes). Benefits would include savings in vehicle operating costs (with a likely non-fuel cost rate of around 9 cents per kilometre, for utilisation related depreciation and maintenance, such as tyre replacement and vehicle servicing), fuel use (at around 40 cents per litre), air pollution costs (indicative rate of 1 cent per kilometre), congestion costs (possible average rate of 15 cents per kilometre), road accident costs (indicative average rate of 10 cents per kilometre), roadway costs (in the order of 2 cents per kilometre for utilisation related expenditure such road maintenance and traffic control) and other externality costs (possibly in the order of 0.2 cents per kilometre for traffic noise and water pollution from road run-off).

Average travel times would be expected to increase slightly. This time increase should probably not be costed at the 'value of time' usually included in cost-benefit analyses of vehicle use, with perhaps a nominal value of $1 per hour being suitable. Literature figures for the 'value of time' are often given to be of the order of $10 per hour. However, such values are not likely to be valid in these circumstances since many travellers freely choose to switch to slower modes as a result of the individualised marketing programs. Therefore, it is likely that the individuals involved either did not value the time they gave away (by the greater travel duration) at such high levels, or that there are uncaptured benefits balancing the extra time costs (e.g. many people could be finding that, once they have experienced them, they actually prefer the less stressful conditions of non-motorised modes or public transit). The extra costs involved in more cycling are probably more than balanced by the benefit to society of improved health from greater exercise levels.

If the VKT reductions experienced by the South Perth program are maintained over time, this application of Individualised Marketing will have generated a reasonable level of emission abatement at relatively low overall cost (in fact, using the above unit cost estimates implies that the program is likely to have been a 'no regrets' measure, involving net social gains).

While these estimated gains appear encouraging, there are a number of factors that should be kept in mind before generalising these results more widely. In particular, increased travel time could be a significant issue for some users. For example:

- Problems with mode switching may emerge if working times are inflexible.
- Sufficient capacity in public transport services and reasonable levels of infrastructure for non-motorised commuting have to exist (to carry the trips generated by the TDM mode shifts).
- Even for transport users wishing to switch modes, there will remain many trips still heavily favouring the use of a private vehicle (e.g. transporting small children or bulky loads).

Another possible problem with generalising from such studies is the issue of whether the VKT reductions seen by the pilot projects will be representative of *total network* travel changes, rather than simply those of the targeted individuals. As well as the VKT reductions (quoted for the study population) possibly not being obtained across all areas upon city-wide application of the measure, the estimated reduction may also not incorporate allowance for subsequent increases in general car travel due to reduced congestion levels on the network (from the TDM measure) attracting an *'induced traffic'* effect. The abatement success of such TDM marketing measures would be reduced if such effects generated significant volumes of extra car travel.

To date, the support for personalised travel programs has relied heavily on the generally favourable results of the South Perth trials. Yet there are various factors that raise doubts as to the extent it is valid to extrapolate these results across the wider community. Firstly, the lack of a control group means that it is difficult to determine whether the increase in public transport patronage that followed the introduction of personalised travel planning in South Perth could be attributed to it or to other factors, such as a general improvement in bus services.

In fact, the use of a control group is rare in such pilot assessment studies. A trip reduction pilot program in Denver used a pilot group and a control group to isolate the impact of the training (in trip reduction strategies) from any external factors. The study found no change in solo driving that could be definitely attributed to the program (Higgins 1995, p. 37).

A second issue with many such programs concerns the relatively large drop out rate often exhibited by personalised travel planning. While there may be significant reductions in car use for people that complete the program, the success of the program should be assessed in terms of the total population of the targeted area rather that just those completing the program. Such programs typically have highly variable retention rates.

In an objective review of the effectiveness of personalised travel planning, the UK Department of Transport and Local Government and the Regions (DTLR) concluded:

"… it is apparent that while there is evidence to suggest that this type of approach can be very effective in changing travel behaviour, there is, as yet, no conclusive pattern emerging as to when and where it is most useful. This highlights the complexity of processes leading to travel behaviour change, and our only partial understanding of those processes" (DTLR 2002).

The DTLR considered personalised travel planning programs to work best where there was a gap between the perception of public transport services and reality:

"For public transport, where services and travel quality is much higher than is perceived, personalised approaches can have very large effects, but where such a gap does not exist the travel behaviour effects could be negligible" (DTLR 2002).

DTLR (2002) concluded that more trials need to be conducted before a full evaluation of the effectiveness of personalised journey planning techniques can be made, especially in terms of their ability to encourage lasting mode shifts.

Hence, while it is constructive that trials of TDM measures such as individualised marketing are being performed in Australia, it would be simplistic to conclude that the scale of the mode shifts so far experienced can be duplicated everywhere. Also, some technological developments (many making use of a variety of Intelligent Transport Systems) could reduce the case for individualised marketing and make other TDM measures more effective. For example, an increasing number of cities have established web sites where individuals can nominate their trip requirements (e.g. origin and destination), and the site then presents a range of travel options for different modes or a combination of modes. A range of information is often provided, including public transport details, travel times and travel costs associated with the various options.

Examples of such systems include:

- CityPlanner <www.travelinfosystems.com>, which allows travellers in the United Kingdom to check the availability of services and door-to-door journey times for different travel modes. It even suggests alternative ways to travel using all the available services (based on journey planner software that includes timetables for buses, the National Rail network and the London Underground).

- Transperth's Journey Planner, <www.transperth.wa.gov.au/generalcontent.aspx?documentinstanceid=311>.

- The SNCF (Société Nationale des Chemins de fer Français) site for "Travelling in the Paris Region: Timetables and routes", <idf.sncf.fr/GB/default.htm>.

Of course, as for other abatement strategies, TDM marketing measures and traveller information systems will tend to be more effective if they are allied with other, related measures such as integrated transport and land-use planning (including provision for non-motorised travel), parking policies, public transit improvements and road pricing.

A range of other ITS technologies could lead to reductions in transport emissions: including more widespread application of advanced traffic light coordination (to smooth traffic flows), public transport priority systems, incident management systems, and freight-distribution management systems; yet do not offer the same scale of abatement as optimal road pricing.

While electronic road pricing set-up costs could be relatively small, yet offer significant emission and economic benefits, a critical issue is how to achieve sufficient community support to enable ORP to become politically and socially acceptable.

appendix

1

CARMOD MAJOR INPUT ASSUMPTIONS

PASSENGER VEHICLES: RESULTS USING BTRE CARMOD

CARMOD is a model of the dynamics of the Australian car fleet. The model incorporates age-specific characteristics (based on the year of manufacture of the vehicle), and calculates vehicle utilisation for each vintage over time, allowing for vehicle ageing and scrappage.

Estimating fuel consumption forms the main segment of the model framework. The model decomposes annual fleet fuel consumption into four components:

$$\underset{(litres)}{\text{Fuel consumption}} = \underset{(cars\ per\ \text{'}000\ persons)}{\frac{\text{Vehicles}}{\text{Population}}} \times \underset{(\text{'}000\ persons)}{\text{Population}} \times \underset{(km\ per\ car)}{\text{VKT}} \times \underset{(litres\ per\ km)}{\frac{\text{Average Fuel Intensity}}{100}}$$

Note: VKT is vehicle kilometres travelled per vehicle (per annum), and the factor of 100 is included because average fuel intensity is usually quoted in terms of litres consumed per 100 kilometres travelled (i.e. L/l00 km).

Once the model has estimated fuel consumption and total vehicle kilometres travelled for each vintage, emissions of CO_2, methane (CH_4), nitrous oxide (N_2O), other oxides of nitrogen (NO_x), carbon monoxide (CO), and non-methane volatile organic compounds (NMVOCs, both exhaust and evaporative) are calculated using vintage-specific emission rates. (Emission levels for particulate matter (PM) and sulphur oxides (SO_x) can also be roughly estimated by the model.)

To partially represent the effect from the emissions of several different gases, emissions of the directly radiative greenhouse gases (CO_2, CH_4 and N_2O) are also expressed in terms of a common unit—CO_2 equivalent emissions. The calculation of CO_2 equivalent emissions uses scale factors known as Global Warming Potentials (GWPs), which basically compare the radiative effect of an emitted gas over a specified period (commonly 100 years) with that of an equivalent mass of CO_2. Due to the difficulty in quantifying such a global average value for gases that only reside in the atmosphere for a relatively short time (such as CO, NO_x and NMVOCs), the indirect greenhouse gases do not currently have GWPs assigned to them, even though their greenhouse contributions can be substantial (as well as often being noxious air pollutants). The current CO_2 equivalent approach thus underestimates the total radiative effect of anthropogenic emissions.

The newly estimated version of CARMOD has been revised to take into account the surge in vehicle ownership experienced over the past five years. CARMOD is now based on a function that relates total private vehicle travel to real income growth. Car ownership rates are then derived from a base trend in annual vehicle travel per person and estimates of annual VKT per car.

Previous versions of CARMOD based total vehicle numbers on the product of population and vehicle ownership. Vehicle ownership was assumed to follow a simple logistic function over time. For Australia, the estimated car ownership saturation rate implied by pre-1995 data was around 0.52 vehicles per person. More recently, however, vehicle ownership has drifted off the trend logistic function. It appears GDP growth and decreases in real vehicle prices have stimulated higher car ownership levels those than originally implied by the historical data.

In fact, current car ownership is now actually above the old saturation estimate of around 0.52 vehicles per person. Refitting the logistic curve (including the data for recent years), implies that the trend saturation level for the Australian passenger vehicle fleet has shifted upwards to at least 0.54 cars per person, and could possibly be even significantly higher. Since there are only a few data points for the new trend (i.e. since the divergence from the originally estimated logistic curve), statistics using the original (logistic curve) methodology do not allow reasonable convergence to an updated estimate of the trend in cars per person over time. It was seen necessary to develop an alternative structural equation on which to base the modelling. As a result, a new projection method—of relating the trend in per capita vehicle travel to the trend in per capita GDP—was pursued for this study.

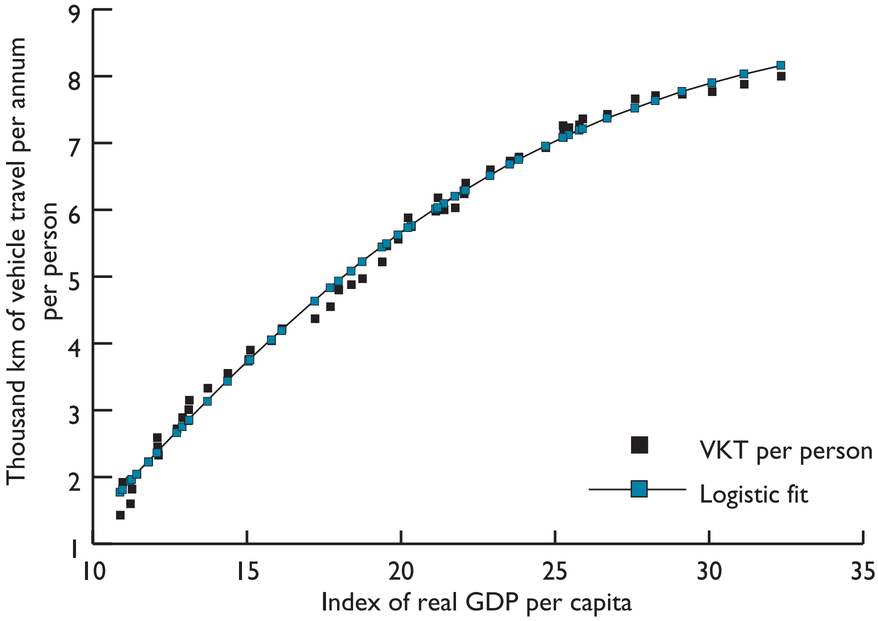
Though growth in vehicle ownership will tend to be related partly to increasing income levels, the Australian car market has also seen significant reductions in vehicle prices over recent years. Reduction in tariffs on imported motor vehicles and, more recently, the replacement of a 22 per cent wholesale tax on motor vehicles by the GST has seen vehicle prices fall significantly. Between June 1995 and June 2000, the CPI index of motor vehicle purchase costs has fallen, in nominal terms, by 3.4 per cent per annum. Over the same period, the total CPI index increased by 2.2 per cent per annum.

Revised CARMOD: base case assumptions

Car ownership

As mentioned above, passenger vehicle travel per person was modelled as a saturating curve of real Australian GDP per person. Weibull, Gompertz and Logistic curves were fit to the data—and all gave similar formulations (i.e. similar fits to the data and similar forecast levels over the next 20 years). The fit for the simplest of the derived forms (the logistic function), for data covering the second half of the twentieth century, is displayed in figure I.1 below.

FIGURE I.1 PER CAPITA TREND IN ANNUAL PASSENGER VEHICLE TRAVEL VERSUS REAL GDP



Sources: BTRE estimates, ABS (2001a).

The per capita VKT functions all asymptote to about 9000 kilometres per person (for the total Australian population. The specification of the logistic function plotted in figure I.1 is given by:

VKT per person = –6.8 + 15.8 / (1 + EXP(–(GDP per person – 9.6)/8))

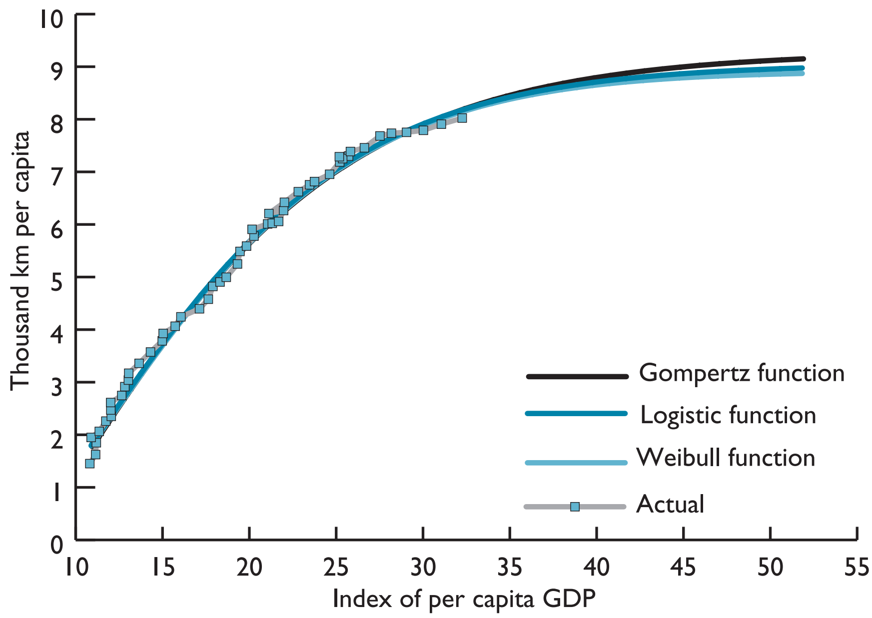
using real Australian GDP (thousand dollars per capita) in 1999 prices.

The AGO specified GDP forecasts (to 2020) can then be used to derive trend curves into the future for the various equations. The three best fitting formulations (i.e. Weibull, Gompertz and Logistic) are plotted for the GDP forecasts in figure I.2. For this study, the logistic curve values were chosen as the underlying trend for projecting VKT per person to 2020.

Projections of average car utilisation (thousand kilometres per annum) were then estimated using the trend in annual GDP change (with an elasticity of 0.12), the trend in household ownership of vehicles (with an elasticity of –0.4), and projected changes in the proportion of the population of working age—as a proxy for a variety of demographic factors that tend to reduce average VKT as the average age of the population increases—assumed elasticity of 0.75).

Where possible, elasticities were estimated using regression analyses on BTRE long-term data sets for Australian vehicle characteristics. Where data limitations prevented such data fitting, assumed elasticities were based on literature values—especially those given in the Bureau's *Transport Elasticities Database* (2002b) and in NELA (2000), quoting Pickrell (1995).

FIGURE I.2 FORECAST TREND IN PASSENGER VEHICLE TRAVEL VERSUS REAL GDP



Source: BTRE estimates.

The result of the various input assumptions (GDP trend as specified by AGO, cars per household assumed to continue current trends and increase from about 1.4 to about 1.5 by 2020, and ABS projections of the proportion of the population between the ages of 15 and 64 falling from about 67 per cent to about 65 per cent by 2020), are estimates of average VKT per car that remain fairly steady over the forecast period.

This estimated base trend in VKT per car was then combined with the estimated base trend in VKT per person (from the logistic formulation) to give a base trend for cars per person to 2020. This base trend was then modified for changes in vehicle prices over time (with an elasticity of –0.1), to derive the final base case estimates for Australian car ownership (given in table I.1).

Average VKT per car estimates for each projection year were then adjusted for projected fuel price changes (using an elasticity of –0.1) to give the final estimates for base case vehicle utilisation. These values (which are roughly constant at a level of about 15 850 kilometres per vehicle per annum from 2010 onwards), along with the final base case projections of VKT per person, are also given in table I.1. Though the estimation process is dependent on the chosen elasticity values, the final utilisation trends derived by this formulation are not highly sensitive to variations in those elasticity values. For example, making the above relationship, between average VKT and the various underlying factors, doubly elastic would result in an estimated final trend only slightly higher than the current base case, at about 16 200 kilometres per vehicle per annum. Whereas making the relationship half as elastic gives an average VKT trend centred on about 15 700 kilometres.

Australian population projections and urban versus non-urban splitting factors.

Total population projections are as specified by the AGO (and to 2020 follow a similar trend to Series III of current ABS long-term population projections).

TABLE I.1 BASE CASE VKT AND VEHICLE OWNERSHIP ASSUMPTIONS

Financial year	*VKT/person ('000 km)*	*Vehicle ownership (cars per person)*	*Average VKT per car ('000 km)*
2000	8.001	0.5152	15.530
2001	8.059	0.5235	15.395
2002	8.317	0.5277	15.760
2003	8.416	0.5325	15.802
2004	8.487	0.5367	15.812
2005	8.552	0.5406	15.819
2006	8.592	0.5438	15.800
2007	8.641	0.5469	15.799
2008	8.694	0.5496	15.819
2009	8.741	0.5519	15.839
2010	8.782	0.5541	15.849
2011	8.818	0.5561	15.858
2012	8.850	0.5581	15.858
2013	8.876	0.5598	15.855
2014	8.899	0.5613	15.854
2015	8.918	0.5626	15.852
2016	8.934	0.5636	15.850
2017	8.947	0.5645	15.849
2018	8.958	0.5653	15.847
2019	8.967	0.5659	15.846
2020	8.975	0.5664	15.844

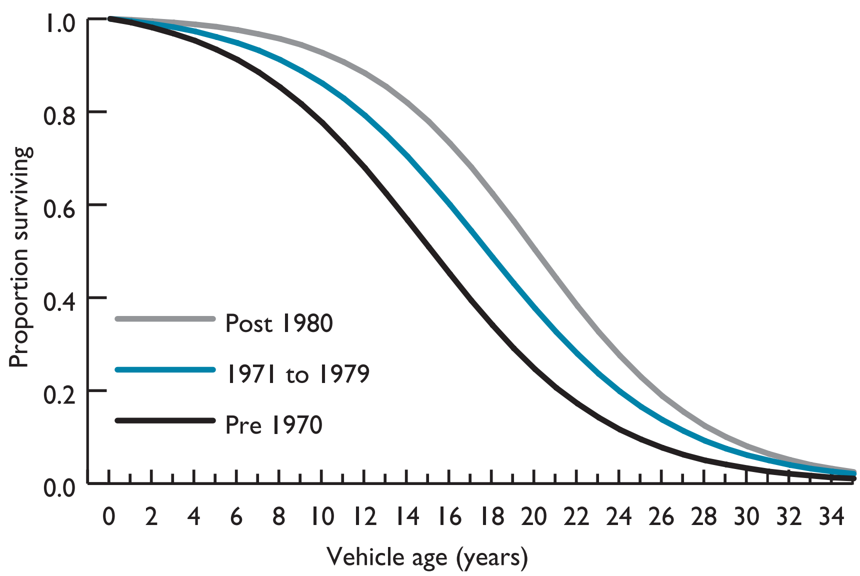
Source: BTRE estimates.

ABS long-term projections (Series II and Series III) have the proportion of the population in capital cities increasing from about 64 per cent in 2000 to about 65 per cent and 66 per cent respectively by 2020. Based on these trends, the CARMOD input assumption regarding the urban versus non-urban population split has been changed (from a constant 70/30 split) to an input of the urban population share increasing slightly to be about 71.5 per cent by 2020.

Vehicle scrappage rates

The vehicle scrappage curves in CARMOD were checked against results from the latest ABS vehicle census data and, across grouped vehicle cadres, no statistically significant differences in vehicle survival trends were apparent. The base curves used in the model are plotted below.

FIGURE 1.3 CURRENT CARMOD VINTAGE SURVIVAL CURVES



Sources: ABS (2000b), BTRE estimates.

Fuel efficiency

Future rate of fuel use (L/100 km) assumptions for passenger vehicles are given in table 1.2 for both NAFC and 'on-road' values. National Average Fuel Consumption (NAFC) is a sales-weighted average of new passenger cars, which currently does not include all 4WD passenger vehicles.

TABLE I.2 CURRENT CARMOD BASE CASE SCENARIO FOR FUEL INTENSITY

(L/100 km)

Year	*NAFC*	*Base case intensity— adjusted for 'on-road' fuel consumption, and for inclusion of 4WDs*
2000	8.34	10.25
2005	7.91	9.79
2010	7.42	9.02
2015	7.00	8.44
2020	6.70	8.01

Note: 'on road' values given here are not adjusted for future traffic congestion effects.
Sources: BTRE estimates, AGO (pers. comm. 1 May 2001).

Deterioration rates in vehicle fuel consumption and emissions

Currently, CARMOD assumes no deterioration in fuel consumption during a vehicle's first two years, with 1 per cent deterioration (in L/100 km) per annum thereafter for each vehicle cadre (until reaching a plateau for each vintage of 10 per cent worse than when new).

For emissions, CARMOD assumes some deterioration in emissions performance for different vintage vehicles (as outlined in table I.3 below).

TABLE I.3 EMISSION DETERIORATION RATES FOR CARS

(g/km/annum)

	Pre-1986	*Post-1986*	*Post-1997*
CO	1.2	1.0	0.5
HC	0.07	0.06	0.03
NO_x	0.05	0.05	0.05

Sources: BTRE estimates, FORS National In-Service Vehicle Emissions Study (1996).

Emission factors

Average emission factors derived from CARMOD results will differ slightly from current NGGI emission rates, due to inclusions in CARMOD for the differences between on-road driving (particularly in urban areas) and cycle test values, and to the emission methodology in CARMOD being substantially more detailed than the NGGI default processes. Only N_2O emissions have a significantly different rate between CARMOD and the current NGGI methodology—all other emission outputs would have similar totals and, apart from N_2O, estimated CO_2 equivalent emissions would not be affected at all (since AGO have requested only direct CO_2-e be reported, and the effects of indirect greenhouse gases are not included in any totals).

CARMOD, however, uses a substantially lower rate for N_2O emissions from three-way catalyst petrol vehicles than the NGGI. This is because the Bureau regards the default value used in the NGGI to be overestimated. The CARMOD value is based on data collated for BTCE Report 88 (1995a) and on rates used by the United States Environmental Protection Agency—e.g. Table D-12 of <http://yosemite.epa.gov/OAR/globalwarming.nsf /uniquekeylookup/shsu5bnglk/$file/annex-d.pdf>

Sensitivity of the results to this issue is addressed in Chapter 2 of the report.

TABLE I.4 CARMOD PETROL VEHICLE AVERAGE EMISSION FACTORS (REPRESENTATIVE VALUES)

(g/km)

Vintage	*CH_4*	*N_2O*	*NO_x*	*CO*	*NMVOCs exhaust*	*NMVOCs evaporative*
1970s	0.210	0.0041	2.16	37.82	3.33	2.87
1985	0.150	0.0041	1.71	28.92	2.38	2.40
1989	0.100	0.0375	1.21	7.82	0.50	1.23
1990s	0.060	0.0375	0.69	4.50	0.32	1.23
2015	0.044	0.0375	0.43	1.76	0.22	1.00
2020	0.044	0.0375	0.43	1.76	0.22	1.00

Sources: BTRE estimates, FORS National In-Service Vehicle Emissions Study (1996), MAQS Air Emissions Inventory (EPANSW 1995), NGGIC (1996), Air Emissions Inventory Port Phillip Bay Control Region (EPAV 1991).

Global Warming Potentials

GWP values are as specified by AGO (and are based on previously published IPCC rates).

TABLE I.5 GWP VALUES USED IN BASE CASE

	CO_2	CH_4	N_2O	CO	NMVOC	NO_x
Urban	1	21	310	na	na	na
Non-urban	1	21	310	na	na	na

na not available (due to difficulty in quantifying global radiative effect of relatively short-lived gaseous species that are not well-mixed in the atmosphere).
Source: AGO (pers. comm. 1 May 2001) based on IPCC (1996).

Other assumptions

Traffic congestion

Current BTRE assumptions (roughly based on work for Bureau information sheets on congestion) have urban traffic congestion increasing the rate of fuel consumption by urban vehicles by 17 per cent by 2020. Sensitivity analysis on this factor appears in Chapter 2.

Vehicle size distribution

CARMOD currently assumes a roughly constant size distribution of the vehicle fleet. In particular, it is assumed that the passenger vehicle fleet will continue to include a similar share of 4WD vehicles in the future.

Alternative fuels market penetration rates

Based on current growth trends, and likely levels of annual registrations for new motor vehicles, CARMOD currently has base case assumed values of LPG accounting for 7 per cent fuel consumption by cars, diesel for 4 per cent and NG for 1.5 per cent by 2020.

Base case emission projections: passenger cars

Table I.6 lists the base case CO_2 equivalent emissions from passenger cars (for direct greenhouse gases), from 1990 to 2020. End-use and full fuel-cycle estimates are presented.

Under the revised BTRE base case, CO_2 equivalent emissions from Australian passenger vehicles are projected to increase by around 28 per cent between 1998 and 2020.

Table I.7 lists the projected base case emissions by gas type.

Base case projections for major characteristics of the Australian car fleet are given in table I.8.

TABLE I.6 PROJECTED BASE CASE CO_2 EQUIVALENT EMISSIONS FROM PASSENGER CARS

(Gigagrams)

Financial year	CO_2	Direct CO_2 equivalent (CO_2, CH_4, N_2O) End-use	Direct CO_2 equivalent (CO_2, CH_4, N_2O) Full fuel cycle
1990	33275	34220	41064
1991	33339	34351	41221
1992	33764	34847	41816
1993	34438	35600	42720
1994	34909	36148	43378
1995	36155	37496	44995
1996	36926	38355	46026
1997	37124	38607	46328
1998	37619	39170	47004
1999	38379	40009	48011
2000	38998	40696	48835
2001	39729	41491	49789
2002	41327	43187	51824
2003	42150	44070	52884
2004	42778	44748	53698
2005	43415	45431	54517
2006	43858	45910	55092
2007	44360	46523	55828
2008	44815	46999	56399
2009	45223	47426	56911
2010	45570	47792	57350
2011	45951	48189	57827
2012	46287	48540	58248
2013	46574	48843	58612
2014	46832	49116	58939
2015	47042	49342	59210
2016	47231	49547	59456
2017	47412	49742	59690
2018	47553	49898	59878
2019	47661	50021	60025
2020	47735	50110	60132

Source: BTRE estimates.

TABLE I.7 PROJECTED BASE CASE NON-CO_2 EMISSIONS (END-USE) FOR PASSENGER VEHICLES

(Gigagrams)

Financial year	CO	NO_x	CH_4	N_2O	NMVOCs Exhaust	NMVOCs Evaporative	NMVOCs Total
1990	3152	210	17.59	1.86	257.8	268.7	526.5
1991	3146	212	17.44	2.09	246.2	257.3	503.4
1992	3136	216	17.47	2.31	241.8	243.6	485.5
1993	3125	217	17.44	2.57	238.0	241.1	479.1
1994	3083	218	17.28	2.83	231.7	237.0	468.7
1995	3098	223	17.43	3.15	230.0	238.2	468.1
1996	3040	225	17.26	3.44	223.3	235.2	458.6
1997	2957	222	16.68	3.65	215.4	227.0	442.4
1998	2826	219	16.34	3.90	205.5	222.9	428.3
1999	2672	214	15.91	4.18	194.5	218.8	413.3
2000	2527	210	15.48	4.43	184.1	214.6	398.7
2001	2395	208	15.12	4.66	174.9	211.3	386.2
2002	2321	210	14.84	4.99	169.7	212.6	382.4
2003	2222	209	14.60	5.20	163.2	210.9	374.1
2004	2126	208	14.34	5.38	156.9	209.1	366.1
2005	2032	206	14.08	5.55	151.0	207.6	358.7
2006	1946	203	13.79	5.68	145.8	205.9	351.7
2007	1892	201	13.64	6.05	142.8	201.4	344.2
2008	1834	198	13.49	6.13	139.7	199.6	339.3
2009	1789	197	13.38	6.20	137.5	199.2	336.7
2010	1754	195	13.30	6.27	136.1	199.6	335.6
2011	1716	195	13.23	6.32	134.6	199.9	334.5
2012	1675	194	13.18	6.37	133.0	200.4	333.4
2013	1641	194	13.29	6.42	131.9	200.9	332.8
2014	1613	195	13.43	6.46	131.1	201.4	332.5
2015	1591	195	13.61	6.50	130.6	201.9	332.6
2016	1566	194	13.71	6.54	130.1	202.3	332.5
2017	1540	192	13.82	6.58	129.7	202.8	332.5
2018	1516	191	13.94	6.62	129.3	203.2	332.5
2019	1504	191	14.17	6.65	129.3	203.2	332.6
2020	1490	190	14.39	6.69	129.2	203.6	332.9

Source: BTRE estimates.

TABLE I.8 CARMOD PROJECTED PARAMETERS (BASE CASE) FOR AUSTRALIAN CAR FLEET, 1990–2020

Financial Year	*Vehicles (thousand)*	*VKT (billion km)*	*Energy use (PJ)*	*Passenger kilometres (billion)*	*Fuel intensity (L/100 km)*	*New vehicles (thousand)*
1990	7797	124.2	510.2	198.1	12.0	492.2
1991	8012	124.9	511.5	198.9	12.0	440.8
1992	8143	126.9	518.2	201.5	11.93	437.0
1993	8280	130.1	528.5	205.9	11.88	449.8
1994	8404	132.6	535.8	209.1	11.81	476.0
1995	8628	138.2	555.2	217.1	11.74	528.4
1996	8882	142.0	567.5	222.4	11.68	531.3
1997	9101	143.3	570.8	223.7	11.64	550.9
1998	9419	146.0	578.4	226.8	11.58	654.8
1999	9690	149.7	590.1	231.7	11.52	672.7
2000	9837	152.8	599.6	235.4	11.48	596.0
2001	10121	155.8	610.9	239.4	11.46	654.4
2002	10293	162.2	635.4	248.4	11.45	642.5
2003	10477	165.6	648.1	253.1	11.45	637.4
2004	10650	168.4	657.8	256.9	11.42	633.2
2005	10819	171.1	667.6	260.8	11.41	675.5
2006	10971	173.3	674.5	263.9	11.38	662.7
2007	11123	175.7	682.3	267.3	11.35	663.4
2008	11266	178.2	689.4	270.8	11.31	661.3
2009	11401	180.6	695.7	274.1	11.27	651.7
2010	11537	182.9	701.2	277.3	11.21	659.0
2011	11656	184.8	707.2	280.0	11.19	645.5
2012	11776	186.7	712.5	282.6	11.16	657.9
2013	11891	188.5	717.2	285.0	11.12	651.5
2014	12002	190.3	721.4	287.4	11.09	643.8
2015	12108	191.9	724.9	289.6	11.04	650.2
2016	12206	193.5	728.0	291.9	11.00	654.1
2017	12301	195.0	730.9	294.1	10.96	662.8
2018	12392	196.4	733.3	296.3	10.92	671.5
2019	12481	197.8	735.2	298.4	10.87	679.3
2020	12567	199.1	736.5	300.4	10.82	689.3

Note: 'Fuel intensity' refers to the average rate of on-road fuel consumption across the entire car fleet, where values have been adjusted to allow for the inclusion of 4WD passenger vehicles and the effects of urban traffic congestion.

Sources: BTRE estimates, ABS (2000a).

appendix 2

TRUCKMOD MAJOR INPUT ASSUMPTIONS

MODIFICATIONS TO BTRE TRUCKMOD

The base case commercial vehicle emission projections were estimated using TRUCKMOD.

TRUCKMOD is a model of Australian commercial vehicle travel and fuel use. The model tracks vehicle use for three separate classes of commercial vehicle—light commercial vehicles (LCVs), rigid trucks and articulated trucks—by age of vehicle. For the analysis of this report, the model output produced estimates of 'actual' VKT, fuel use and emissions for 1970–71 to 1997–98, and projections to 2019–20. A description of TRUCKMOD is given in BTCE (1995b).

TRUCKMOD has been upgraded and redeveloped for the current project—there have been some minor structural changes to the model and many of the base case assumptions have been revised in the light of more recent data.

The major structural changes to TRUCKMOD are:

- re-estimation of the age-based vehicle attrition functions using recent Motor Vehicle Census data (ABS 2000b). The vehicle attrition function now controls the relative mix of vehicles (by age) leaving the commercial fleet. The overall number of commercial vehicles leaving the fleet is controlled through a variable aggregate attrition function.
- inclusion of a variable aggregate attrition function. This feature recognises that vehicle attrition will vary over time, and allows the user to control the aggregate rate of vehicle attrition. The inclusion of this feature means that it is now possible for the model to incorporate the latest vehicle sales data, by adjusting the aggregate attrition rate.

New premises in the model formulation for this project are:

- The aggregate freight task model has been revised. Over the period 2000–2020, the aggregate road freight task is forecast to grow at 4.0 per cent per annum. This is based on assumed average GDP growth of 3.0 per cent per annum and real road freight rates declining by 0.5 per cent per annum. In BTCE (1995b), real freight rates were assumed to decline by approximately 0.75 per cent per annum between 1992–93 and 2014–15.

However, more recent evidence, such as TransEco (2001 and earlier issues) and ABS (2001e), shows that the reduction in real freight rates has been slower for much of the 1990s than over the previous two decades. Therefore, the BTRE has assumed a slightly slower reduction in real road freight rates (0.5 per cent per annum) for the current base case than previously assumed in BTCE (1995b).

- the split of the freight task between LCVs, rigid trucks and articulated trucks has been revised, with LCVs and rigid trucks share of the task now slightly less than in the original version of TRUCKMOD.
- the average load carried by articulated trucks has been assumed to grow at a rate consistent with the growth in average loads between 1971 and 1999. For articulated trucks, average loads are assumed to grow by approximately 1.6 per cent per annum.
- the assumed improvements in average fuel efficiencies of new commercial vehicles have been revised downwards from previous versions.

MAJOR ASSUMPTIONS IN BASE CASE EMISSION PROJECTIONS

Aggregate freight task

In TRUCKMOD, the aggregate freight task is a function of GDP growth and real freight rates. The relationship is based on the following econometric model of road freight movements estimated by the BTRE:

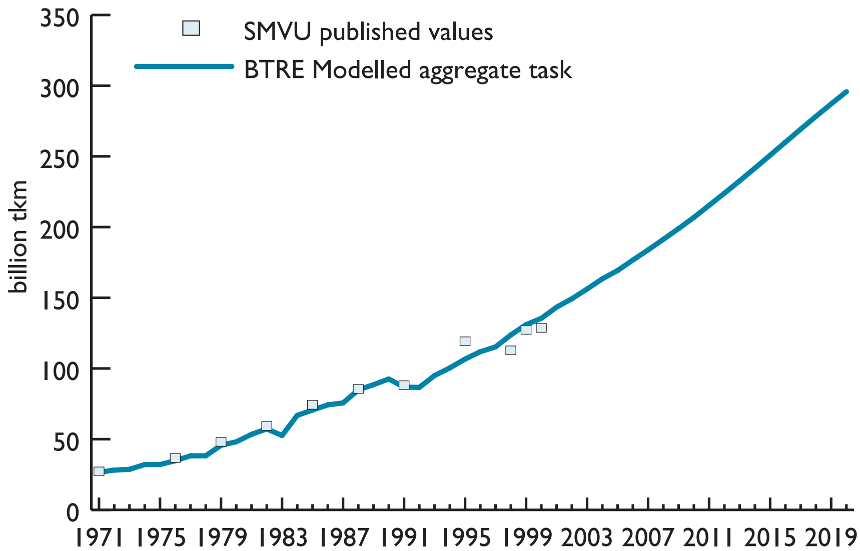
$$\ln \text{Freight}_t = 0.30 + 1.167 \ln \Delta\text{GDP} - 0.898 \ln \text{Road Freight Rate} + 0.017\ \Delta\text{GDP}$$

for tonne-kilometres of freight in the year t, with ΔGDP the annual percentage change in real GDP.

Note: All variables in the model are expressed in real terms.

BTRE has used the Australian Greenhouse Office (AGO) GDP growth path assumptions, from 2000 to 2020, for the base case commercial vehicle emissions projections—see Appendix VI, table VI.3. The GDP assumptions made by the AGO imply average annual economic growth of 3.04 per cent per annum between 2000 and 2020. Over the same period, the BTRE has assumed a decline in real road freight rates of 0.5 per cent per annum (based on historical rates). These assumptions imply average growth in road freight activity of 3.96 per cent per annum between 2000 and 2020 (figure II.1).

FIGURE II.1 PROJECTED GROWTH IN ROAD FREIGHT TASK



Sources: ABS (2000a and earlier issues), BTRE estimates.

Share of freight by vehicle type

TRUCKMOD assumes that the share of freight carried by articulated trucks will continue to increase, mainly at the expense of rigid trucks. The articulated truck freight task, as a share of the aggregate freight task, is projected to increase from 76 per cent in 1995 to 86 per cent by 2020. Based on extrapolation of historic trends (using the logistic substitution method), the share of the freight task carried by rigid trucks is projected to decline from 19.8 per cent to 11.2 per cent and LCVs from 4.2 per cent to 3.4 per cent (figure II.2).

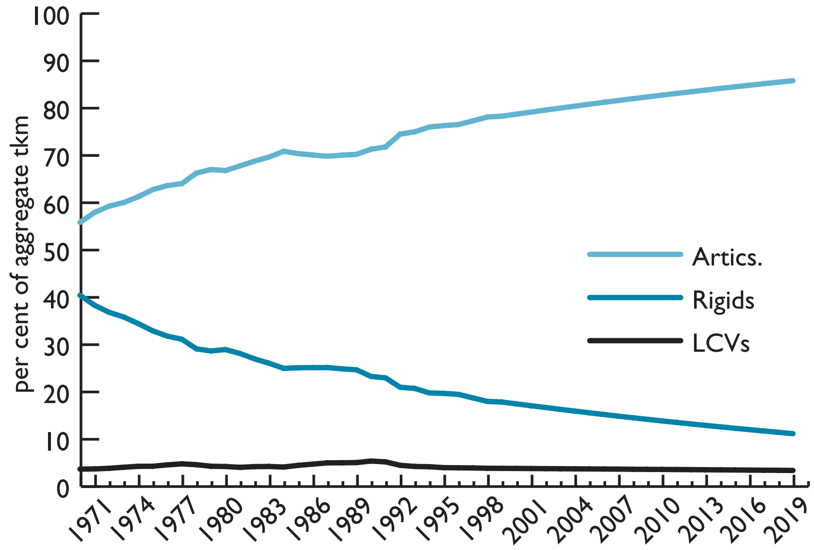
Average load and average VKT

In TRUCKMOD, average load and average VKT are critical determinants of the required vehicle stock and hence total VKT. Like much of the other source data within TRUCKMOD, estimates of average load and average VKT are sourced from the *Survey of Motor Vehicle Use* (SMVU) (ABS 2000a and earlier issues). Since 1991, the SMVU estimates of average load and average VKT have exhibited large variation from survey to survey, which appears to be partly attributable to reductions in the sample size of the SMVU. The inter-survey variation present in the recent releases of the SMVU tends to obscure any changes to trends.

For the base case, it is assumed within TRUCKMOD that trend growth in average loads and average VKT continue pre-1991 trends. Therefore, for the base case, the average load carried by articulated trucks is assumed to increase between 1995 and 2020 by 1.64 per cent per annum (from about 17.6 tonnes to 26.6 tonnes), rigid trucks 1 per cent per annum (from 3.4 tonnes to 4.4

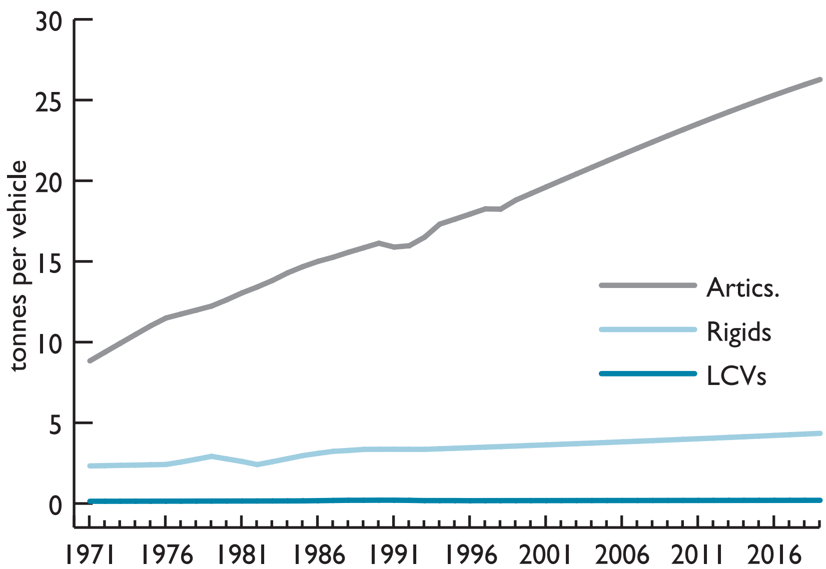
tonnes) and LCVs 0.5 per cent per annum (from 0.18 tonnes to 0.2 tonnes)—see figure II.3. Average VKT by LCVs and rigid trucks are assumed to remain constant at 16 600 kilometres and 18 500 kilometres respectively, from 1995 to 2020. Average VKT by articulated trucks is assumed to increase by 1 per cent per annum, from 84 000 kilometres in 1995 to 107 000 kilometres in 2020 (figure II.4).

FIGURE II.2 ASSUMED FREIGHT TASK SPLIT



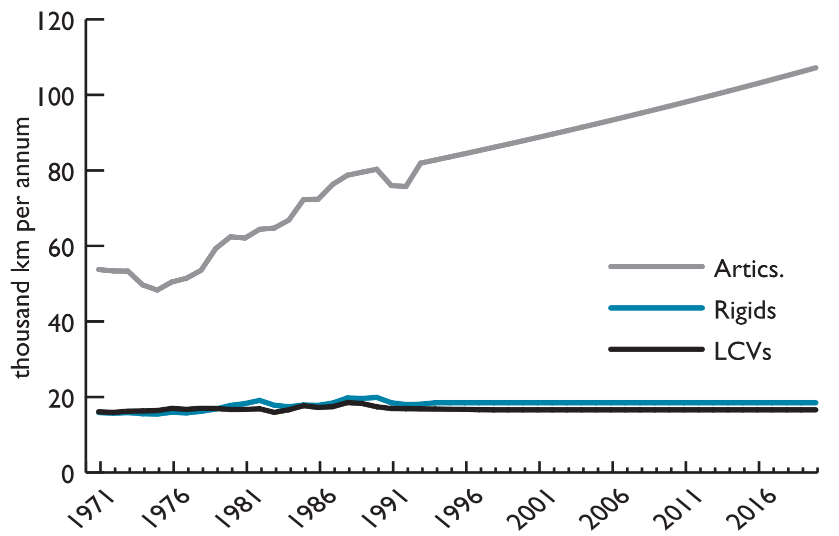
Sources: ABS (2000a and earlier issues), BTRE estimates.

FIGURE II.3 PROJECTED AVERAGE LOAD



Sources: ABS (2000a and earlier issues), BTRE estimates.

FIGURE 11.4 AVERAGE VKT PROJECTIONS



Sources: ABS (2000a and earlier issues), BTRE estimates.

Implied vehicle stock levels

The base case freight task, average load and average VKT assumptions imply growth in the stock of commercial vehicles of 2.85 per cent per annum for LCVs, 0.7 per cent per annum for rigid trucks and 1.85 per cent per annum for articulated trucks.

New vehicle fuel efficiencies

In TRUCKMOD, total fuel consumption is the product of vehicle cohort (age) based VKT and average fuel efficiency. For the base case, average vehicle fuel efficiency of each cohort is assumed to remain constant over time—an implicit assumption of no deterioration in vehicle fuel efficiency. While TRUCKMOD has the capability to incorporate age-related fuel efficiency deterioration, there is little evidence available about the presence or scale of any deterioration. TRUCKMOD therefore does not include any deterioration factors for vehicle fuel efficiency in the base case.

For the base case, new vehicle fuel efficiency for LCVs and rigid trucks are assumed to increase by 0.25 per cent and 0.1 per cent per annum respectively from 1995 to 2020. For articulated trucks it is assumed there is no improvement in on-road average fuel efficiency (litres per vehicle kilometre, averaged over the fleet)—all improvement in the technical fuel efficiency of vehicles is assumed to be offset by increasing vehicle loads.

These trends appear to be consistent with the available evidence. There are no historical data currently available that give average fuel efficiencies for fleets of new commercial vehicles. The SMVU provides estimates of 'in-service' fleet fuel efficiency for commercial vehicles—data that contain indications of some improvements in LCV fuel efficiency over time. However, the data also show recent trends of worsening on-road fuel efficiency for rigid and articulated trucks, partly attributable to increasing vehicle size and mass.

Fuel type split

Base case assumptions about the fuel type split were derived from historical share trends. Diesel is assumed to be practically the only source of motive power for articulated trucks to 2020. For rigid trucks, diesel is assumed to be the primary fuel, with its share increasing to 95 per cent in 2020. For LCVs, petrol and ADO use were assumed to be almost evenly split by 2020, around 40 per cent each, with LPG, LNG and CNG accounting for the remaining 20 per cent.

Fleet average vehicle attrition rates

Fleet average vehicle attrition rates play a major role in the take-up rate of new technology. The BTRE has assumed that the aggregate rate of vehicle attrition is approximately equal to recent historical data. Over the period 1971–1991 average attrition rates were up to 6 per cent for commercial vehicles. Since 1991, however, average commercial vehicle attrition rates have been somewhat lower, around 3 per cent for LCVs, 2.5 per cent for rigid trucks and 3.75 per cent for articulated trucks. In the base case projections the average rate of vehicle attrition, between 2000 and 2020, is assumed equal to post-1991 observed attrition rates.

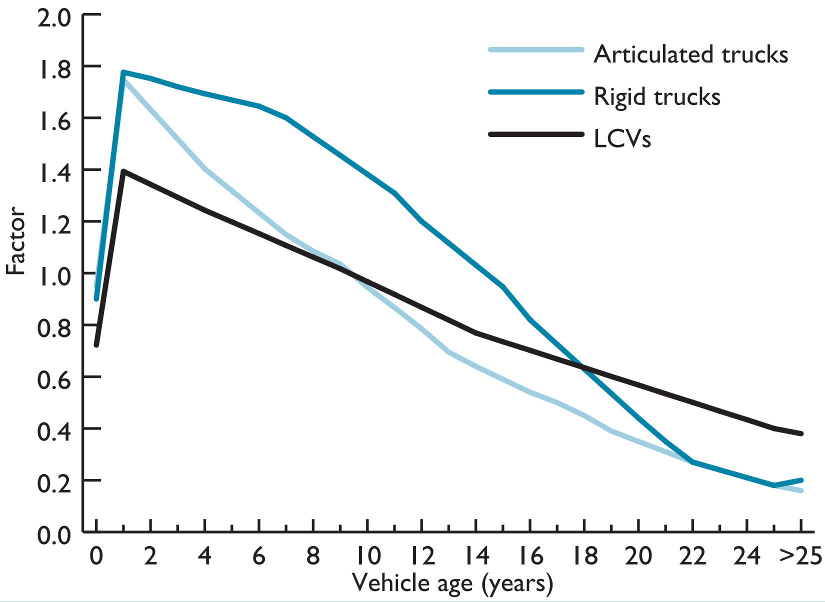
Age-based vehicle attrition functions

The age-based vehicle attrition functions have been revised in TRUCKMOD, based on more recent analysis, using a larger data set, undertaken by the BTRE. The age based vehicle attrition functions control the relative rate of exit of different aged vehicles.

Average vehicle VKT by vehicle age

TRUCKMOD computes total VKT by each age cohort of commercial vehicles. The age-based VKT estimates are computed from the fleet average VKT scaled by an age specific VKT scale factor (derived from an analysis of the 1991 and 1995 SMVU commercial vehicle data). The age specific VKT scale factors for each commercial vehicle class are illustrated in figure II.5. (An adjustment factor is included in TRUCKMOD to ensure that average VKT computed from the age-based sum of VKT matches the exogenously calculated fleet average VKT.)

FIGURE II.5 AGE-BASED VKT SCALE FACTORS



Notes: Since new vehicles are bought throughout the year, the average utilisation across the new vehicle fleet for any particular year is approximately half a year's VKT.
Sources: ABS (2000a and earlier issues), BTRE estimates.

Deterioration of vehicle emissions performance

For the base case, TRUCKMOD assumes no deterioration in emissions performance over the life of the vehicle. There is scope within TRUCKMOD to allow for deteriorating vehicle emissions performance over the life of the vehicle, but there is no clear evidence of deterioration in emissions performance. This assumption is consistent with NEPC (2000: p. vii), which found no statistically significant evidence of a relationship between vehicle age and emission performance.

Emission factors and GWPs

The emission factors used in the base case are as per BTCE (1995a), supplemented by the latest results from the NEPC (2000) test results for diesel vehicles. All CO_2 equivalent emissions are based on 100-year global warming potential factors (supplied by the AGO, using previously published IPCC values).

The NEPC (2000) diesel vehicle emission test results are based on a four-segment composite urban drive-cycle test. A total of 80 vehicles were tested in the study, selected from six separate vehicle classes. Each vehicle class, therefore, comprised only a relatively small number of vehicles.

Drive-cycle test results often require some adjustments to correct for differences between test and normal driving conditions. For the base case projections, the NEPC results have been included in TRUCKMOD without any on-road adjustment.

At present TRUCKMOD uses an average emissions factor, for each gas type, applied to all vehicle cohorts. Some simplifying assumptions were necessary to translate the NEPC (2000) results to emission factors for use within TRUCKMOD. NEPC (2000) presents results for three separate vehicle cohorts: vehicles manufactured between 1980–1989, vehicles manufactured between 1990–1995 and vehicles manufactured since 1996. The emission factors differ, sometimes significantly, between vehicle cohorts. There is no clear age related trend in vehicle emissions. With the exception of particulate matter emissions, the BTRE has assumed the median cohort (i.e. the vehicles manufactured between 1990–1995) NEPC emission factors in TRUCKMOD (factors listed in the table II.1). Particulate matter emission rates are based on vehicles manufactured since 1996.

TABLE II.1 AVERAGE TEST-CYCLE EMISSIONS FACTORS

(grams per kilometre)

Vehicle type	*CO*	*HC*	*NO_x*	*PM10*
LCVs	3.28	0.11	1.04	0.318
Rigid trucks	3.80	0.76	5.16	0.314
Articulated trucks	5.23	0.48	15.36	0.687

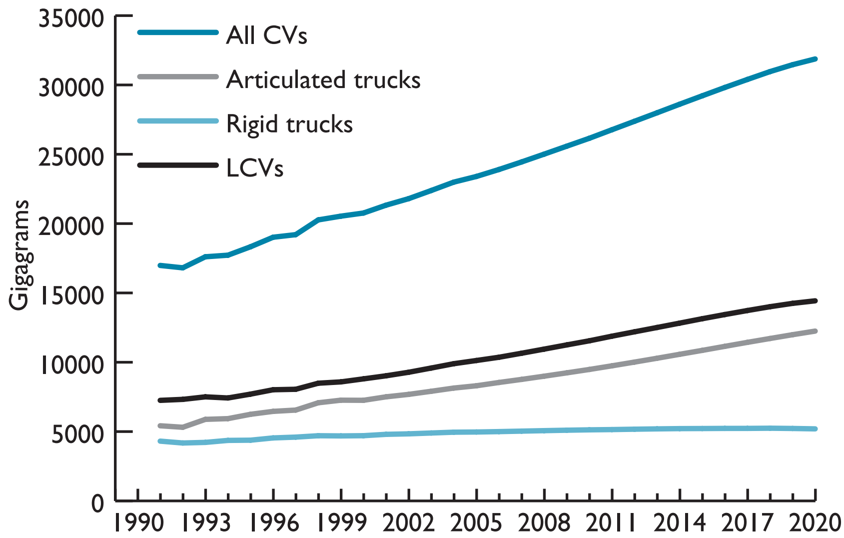
Sources: NEPC (2000), BTRE estimates.

Estimates of particulate emissions from commercial vehicles are a new feature in TRUCKMOD. The BTRE has not yet incorporated the improvements in particulate emissions expected from the planned introduction of new fuels (especially diesel reformulation) and for new technology. Also, particulates are not included in the National Greenhouse Gas Inventory. Accordingly, particulate emission estimates produced by TRUCKMOD have not been included in the base case emissions results.

BASE CASE EMISSION PROJECTIONS: COMMERCIAL VEHICLES

The BTRE base case implies average growth in commercial vehicle CO_2 equivalent emissions of 2.2 per cent per annum from 2000 to 2020, (20 762 Gg to 31 874 Gg). CO_2 equivalent emissions from articulated trucks and LCVs are projected to grow most strongly, 2.7 per cent and 2.4 per cent respectively.

FIGURE II.6 COMMERCIAL VEHICLE BASE CASE CO_2 EQUIVALENT EMISSIONS, 1990–2020



Source: BTRE estimates.

Tables II.2 and II.3 list the base case emission projections for end-use and full fuel cycle CO_2 emissions, end-use CO_2 equivalent emissions and non-CO_2 gaseous emissions (see also figure II.6). Tables II.4, II.5 and II.6 list the base case projections of the number of vehicles, total VKT and total tonne–kilometres by type of commercial vehicle from 1990 to 2020.

TABLE II.2 PROJECTED BASE CASE CO_2 AND CO_2 EQUIVALENT EMISSIONS—ALL COMMERCIAL VEHICLES

(Gigagrams)

Year ending June	CO_2 End-use	CO_2 Full fuel cycle	Direct CO_2 equivalent (CO_2, CH_4, N_2O) End-use
1991	16775.7	19736.4	16981.7
1992	16604.4	19536.9	16810.4
1993	17392.9	20463.9	17606.6
1994	17508.2	20599.4	17722.0
1995	18106.9	21306.0	18329.2
1996	18786.6	22104.3	19017.5
1997	18969.7	22317.7	19202.6
1998	20021.7	23553.4	20267.5
1999	20287.9	23870.2	20537.0
2000	20509.4	24127.2	20761.9
2001	21069.7	24785.1	21329.4
2002	21532.5	25329.3	21798.3
2003	22112.2	26210.1	22386.0
2004	22710.3	26919.3	22991.7
2005	23112.2	27396.0	23398.6
2006	23608.3	28315.9	23901.5
2007	24145.5	28961.9	24445.3
2008	24703.8	29633.4	25010.2
2009	25269.6	30315.5	25583.2
2010	25832.5	30992.9	26152.8
2011	26440.1	31724.0	26767.6
2012	27044.8	32450.9	27378.7
2013	27649.7	33179.4	27990.5
2014	28261.9	33917.0	28609.5
2015	28861.1	34640.7	29216.1
2016	29455.1	35356.9	29816.5
2017	30028.5	36048.7	30395.8
2018	30589.5	36724.7	30961.8
2019	31082.0	37319.9	31459.0
2020	31495.5	37818.7	31874.0

Source: BTRE estimates.

TABLE II.3 PROJECTED BASE CASE NON-CO_2 EMISSIONS — ALL COMMERCIAL VEHICLES

(Gigagrams, end-use)

Year ending June	CH_4	N_2O	NO_x	*CO*	*NMVOCs*
1991	3.73	0.41	123.6	771.5	71.2
1992	3.72	0.41	122.9	770.9	71.0
1993	3.81	0.43	131.4	791.8	73.7
1994	3.80	0.43	133.4	802.2	74.5
1995	3.92	0.45	139.8	828.0	77.2
1996	4.06	0.47	145.3	859.8	80.1
1997	4.08	0.48	147.3	867.4	80.9
1998	4.27	0.50	156.7	903.6	84.8
1999	4.29	0.51	160.6	913.9	86.1
2000	4.34	0.52	161.1	920.5	86.7
2001	4.43	0.54	166.5	940.9	88.9
2002	4.50	0.55	170.4	956.2	90.6
2003	4.60	0.57	175.2	977.5	92.8
2004	4.70	0.59	180.2	997.1	95.0
2005	4.74	0.60	183.5	1007.0	96.2
2006	4.81	0.62	188.1	1022.8	98.0
2007	4.88	0.64	192.5	1036.9	99.7
2008	4.94	0.65	197.0	1050.9	101.4
2009	5.01	0.67	201.6	1066.3	103.2
2010	5.07	0.69	206.2	1078.9	104.9
2011	5.13	0.71	211.3	1092.9	106.6
2012	5.17	0.73	216.1	1103.7	108.2
2013	5.22	0.75	221.0	1114.9	109.8
2014	5.26	0.76	226.0	1125.3	111.3
2015	5.31	0.79	231.2	1137.2	113.0
2016	5.34	0.80	236.1	1144.7	114.3
2017	5.35	0.82	240.8	1150.1	115.5
2018	5.35	0.84	245.1	1151.3	116.3
2019	5.34	0.85	249.2	1151.6	117.0
2020	5.25	0.87	252.7	1142.2	116.9

Source: BTRE estimates.

TABLE II.4 PROJECTED NUMBER OF COMMERCIAL VEHICLES

('000 vehicles)

Year	*LCVs*	*Rigid trucks*	*Articulated trucks*
1990	1314.9	328.9	51.8
1991	1354.3	331.0	52.1
1992	1380.9	329.6	51.4
1993	1417.9	328.6	52.4
1994	1417.9	332.7	52.6
1995	1494.0	334.0	55.2
1996	1554.1	345.0	56.5
1997	1567.7	348.5	56.9
1998	1658.9	356.1	61.0
1999	1715.2	358.5	62.8
2000	1756.8	364.5	63.1
2001	1826.4	372.9	64.8
2002	1882.9	375.9	65.8
2003	1949.4	380.5	67.2
2004	2017.9	385.2	68.6
2005	2068.5	386.1	69.4
2006	2135.6	389.8	70.7
2007	2198.3	392.4	71.9
2008	2262.8	395.0	73.1
2009	2327.3	397.2	74.4
2010	2392.6	399.3	75.6
2011	2463.4	402.0	77.1
2012	2532.5	404.2	78.4
2013	2601.6	406.0	79.8
2014	2671.2	407.7	81.2
2015	2740.4	409.0	82.6
2016	2807.9	409.7	84.0
2017	2872.9	410.0	85.3
2018	2934.5	409.5	86.6
2019	2991.6	408.2	87.7
2020	3045.2	406.3	88.7

Sources: ABS (2000a and earlier issues), BTRE estimates.

TABLE II.5 PROJECTED VEHICLE KILOMETRES TRAVELLED BY COMMERCIAL VEHICLES

(million kilometres)

Year	*LCVs*	*Rigid trucks*	*Articulated trucks*
1991	22947.3	6117.4	3961.6
1992	23337.1	5933.3	3893.0
1993	23906.5	5947.0	4291.0
1994	23849.8	6149.0	4351.3
1995	25039.6	6171.8	4610.5
1996	25984.6	6375.2	4771.6
1997	26086.3	6440.9	4847.1
1998	27538.5	6581.4	5256.6
1999	28472.4	6625.6	5463.0
2000	29162.2	6736.6	5539.7
2001	30318.0	6890.6	5751.1
2002	31256.6	6946.6	5899.9
2003	32359.3	7032.5	6081.0
2004	33497.2	7118.6	6270.1
2005	34336.9	7135.6	6405.2
2006	35450.8	7203.9	6593.6
2007	36492.5	7251.5	6770.8
2008	37563.2	7299.0	6955.9
2009	38632.8	7340.6	7143.7
2010	39717.6	7379.7	7337.4
2011	40892.0	7429.7	7551.1
2012	42039.2	7469.1	7763.4
2013	43187.4	7503.2	7979.9
2014	44342.7	7533.4	8202.1
2015	45491.0	7557.4	8427.6
2016	46611.7	7572.2	8653.1
2017	47690.6	7575.9	8876.1
2018	48712.5	7567.0	9094.1
2019	49661.4	7543.6	9304.3
2020	50549.6	7508.5	9509.3

Sources: ABS (2000a and earlier issues), BTRE estimates.

TABLE II.6 PROJECTED TONNE–KILOMETRES BY COMMERCIAL VEHICLES

(billion tonne–kilometres)

Year	*LCVs*	*Rigid trucks*	*Articulated trucks*
1990	4.69	22.86	65.02
1991	4.68	20.23	61.94
1992	4.52	19.90	62.19
1993	4.28	19.95	70.78
1994	4.27	20.83	75.29
1995	4.48	21.12	81.05
1996	4.47	22.03	85.33
1997	4.58	22.48	88.22
1998	4.88	23.19	95.63
1999	5.07	23.58	102.35
2000	5.21	24.21	106.04
2001	5.49	25.04	112.81
2002	5.68	25.50	118.13
2003	5.91	26.07	124.21
2004	6.15	26.65	130.59
2005	6.34	26.98	135.96
2006	6.58	27.52	142.57
2007	6.80	27.97	149.06
2008	7.04	28.44	155.84
2009	7.28	28.89	162.79
2010	7.52	29.33	169.98
2011	7.78	29.82	177.75
2012	8.04	30.28	185.60
2013	8.30	30.73	193.66
2014	8.56	31.16	201.95
2015	8.83	31.57	210.43
2016	9.09	31.95	218.99
2017	9.35	32.28	227.57
2018	9.59	32.57	236.09
2019	9.83	32.79	244.46
2020	10.06	32.97	252.73

Sources: ABS (2000a and earlier issues), BTRE estimates.

appendix 3

AVIATION PROJECTIONS

After road transport, aviation is currently the second largest modal source of greenhouse gas emissions in the Australian transport sector. Air transport accounts for around 14 per cent of total transport carbon dioxide equivalent (CO_2-e) emissions from Australian fuel use. Of this share of total emissions, bunker fuel use (international aviation) accounts for 66 per cent and domestic aviation accounts for 34 per cent.

As yet, there is no international agreement on how to attribute emissions from international air transport to individual countries. The models developed by the BTRE make projections about emissions resulting from fuel uplifted in Australia, but they do not necessarily imply attribution of these emissions entirely to Australia. Around 42 per cent of the fuel required for international air passenger movement to and from Australia is uplifted in Australia (derived from figures contained in Apelbaum 2001: p. 11)

Separate models are estimated below for domestic and international air travel. The domestic aviation industry is essentially split into two groups, depending on the type of fuel used. Aviation gasoline (Avgas) is used primarily by the general aviation market and aviation turbine fuel (Avtur) is used primarily by scheduled airline services. The general aviation market (consisting of commuter and charter services, private and training flights, and aerial agricultural work) is relatively small compared to the domestic airline market, accounting for less than 5 per cent of domestic aviation fuel use (DISR 2001). International aviation uses only Avtur.

AIRCRAFT EMISSIONS

Emissions from aircraft depend on engine technology and the type and amount of fuel consumed. The main aircraft emissions are carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x) and non-methane volatile organic compounds (NMVOCs) which essentially consist of hydrocarbon (HC) species. Small amounts of methane (CH_4) and nitrous oxide (N_2O) are also emitted.

Each combination of aircraft type and engine model will have its own specific emissions profile (Alamdari & Brewer 1994: p. 149). Carbon monoxide emissions are essentially proportional to the amount of fuel burned. The rate at which the non-CO_2 gases such as CO, HC and NO_x are emitted varies according to the stage of an aircraft's operations, as shown in table III.1. Of the non-CO_2 gases, an aircraft will emit mainly NO_x while cruising. An aircraft idling emits mainly HC. Take-offs use the most engine power and emit a large amount of NO_x.

TABLE III.1 AVERAGE AIRCRAFT EMISSION RATES

Stage of aircraft operation	*Average time spent in stage (%)*	*Average engine power (% of maximum load)*	*Emissions per unit of fuel burnt* CO	HC (g/kg)	NOx
Idle	5	5	5	20	5
Take-off	1	100	0	0	40
Cruise	92	60	0	0	20
Approach	2	30	5	2	10

Sources: Alamdari & Brewer (1994), BTCE (1995a).

Of the non-CO_2 gases from aircraft, nitrogen oxides have the highest overall emission rate and are the most difficult to control. Increasing fuel efficiency can reduce emission levels of CO_2, CO and HC. According to which engine technology is employed, however, emission levels of NO_x may increase (Alamdari & Brewer 1994: p. 151).

The effects of nitrogen oxides (and other gaseous emissions) depend on the altitude at which they are emitted. Nitrogen oxides contribute to two major environmental problems: ozone formation in the troposphere (the lower atmosphere) leading to global warming, and stratospheric (above 15 kilometres altitude) ozone depletion (Alamdari & Brewer 1994: p. 150).

Aircraft emission levels can be estimated as the product of consumption of a particular aviation fuel and a conversion factor which converts fuel consumed into the quantity emitted of any particular gas. Aviation turbine fuel and aviation gasoline have different emission factors (table III.2) for each of the greenhouse gases, due to the different compositions of the two fuel types. Averaging over the composition of the domestic and international airline fleets (by main engine type) and over the times spent in their various operating modes gives slightly differing emission factors for domestic and international avtur use. For example, international fights spend a greater proportion of total flight time cruising than do domestic flights.

TABLE III.2 AVERAGE AVIATION EMISSION CONVERSION FACTORS

(grams per megajoule of fuel)

Gas	*Avgas*	*Domestic Avtur*	*International Avtur*
CO_2	68.0	67.8	67.8
NO_x	0.076	0.27	0.26
CH_4	0.057	0.0011	0.0004
NMVOCs	0.513	0.01	0.004
CO	22.8	0.079	0.05
N_2O	0.0009	0.002	0.002

Source: BTCE (1995a: Appendix 5).

For forecasting purposes, the average emission factors shown in table III.2 are assumed to remain constant over the period 1999–2000 to 2019–2020 (essentially due to the lack of any data to the contrary).

DOMESTIC AVIATION

Domestic aviation currently accounts for about 34 per cent of total greenhouse gas emissions (in CO_2 equivalent terms) from the Australian civil aviation industry. If recent trends continue, air travel will become more affordable. Increased demand for travel, in turn, will lead to higher fuel use and thus higher emissions.

Demand for domestic air services depends on both the number of passengers and the amount of freight to be carried on the network. As the volume of passengers and freight increase, it can be expected that more fuel will be consumed due to greater loads and the need for more aircraft.

Over the last 10 years domestic aircraft passenger numbers have grown steadily, albeit at a slower rate in the latter half of the decade. Between 1990 and 2000, aircraft passengers increased by 150 per cent.

In terms of tonnes carried, air freight is only a very small component of the total freight task within Australia, although the share is substantially higher in terms of the value of the goods carried (BTCE 1991: p. 13). Due to the short transit times offered by aircraft compared to road and rail, air transport attracts mainly perishable, non-bulk goods. Scheduled airline services carried approximately 98 per cent of total domestic air freight in 1997–98 (Apelbaum 2001).

Tonnes of air freight carried have remained fairly constant for the past 10 years, rising by only 9 per cent between 1988 and 1998 (AVSTATS 2001). Since 1989, however, the reporting of air freight statistics to the relevant authorities has not been consistent and statistics are unavailable for some airlines. Since air freight is carried almost completely on regular scheduled passenger services, it has not been included in the analysis as a determinant of the overall demand for aircraft fuel.

BTRE model specification

Due to the long-term nature of the projections (from 1999–2000 to 2019–2020), the specification of the BTRE model is focused on simplicity while incorporating the major determinants affecting domestic avtur consumption.

The aim of the modelling process is to project total greenhouse gas emission levels from domestic civil aviation fuel (avtur) consumption. This includes fuel used on trunk and regional routes. Military fuel use is not included as it would require different explanatory variables to those for trunk and regional passenger services. The BTRE estimates that approximately 20 per cent of current domestic Avtur sales are to the military, but there is no time series available.

Fuel consumption is modelled as the product of the domestic (trunk and regional) aviation task level (measured by the number of seat–kilometres) and the average fuel intensity of the aircraft fleet (measured in litres consumed per seat–kilometre), which takes into account changes in technology. As the fuel efficiency of the aircraft fleet improves, the amount of fuel required to undertake the same task will decline. If the domestic task increases faster than the improvement in fuel efficiency, fuel consumption will be expected to increase.

The task level, measured in seat–kilometres travelled, can be derived by dividing the passenger–kilometres travelled by the passenger load factor. The passenger load factor measures the proportion of seats which are filled by passengers. For example, if the load factor was 100 per cent, then all aircraft seats would be filled and seat–kilometres would be equal to passenger–kilometres. With a load factor of 50 per cent, however, seat–kilometres are twice the magnitude of passenger–kilometres.

As seat–kilometres increase, more fuel is consumed because more aircraft are required to undertake the task. An increase in seat–kilometres may result from an increase in passengers travelling under the same load factor or from the same number of passengers travelling under a reduced load factor. Since aircraft operators tend to schedule service frequencies to maintain high load factors, forecasting seat–kilometres essentially relies on forecasting passenger–kilometres travelled. Passenger numbers are modelled and then multiplied by an average distance travelled to derive passenger–kilometres.

Passenger numbers have been split into two segments: Australian resident passengers flying on the domestic network (APASS) and foreign passengers flying on the domestic network (FPASS). The variables which affect the number of Australian residents are likely to differ from the variables affecting foreigners travelling on the domestic network.

The major variables which were found to affect the number of Australians travelling on the domestic air network were the level of income (depicted by the real gross non-farm product) and the price of airfares (depicted by an index of average real airfares for a medium distance journey).

To determine the number of foreign travellers on the domestic air network, it has been assumed that 75 per cent of the total number of foreign international passengers arriving in Australia will make a journey on the domestic air network on trunk routes. The proportion of 0.75 is an estimate made by the Bureau (see BTCE 1995: p. 67) utilising of the International Visitors Survey from the Bureau of Tourism Research (BTR). Results of these traveller surveys, reported for example in International Tourism Forecasts (BTR 1992), help determine the average number of domestic air passenger movements generated by each short-term foreign arrival (which means that person stays in Australia for less than 12 months).

Domestic consumption of avtur is estimated on the basis of the following set of equations.

Fuel consumption is derived by multiplying seat–kilometres travelled by the average aircraft fleet fuel intensity,

$$FC = SKM \times \text{fuel intensity} \qquad \text{(III.1)}$$

where FC is total domestic aviation turbine fuel consumption (measured in million litres), SKM is the total number of seat–kilometres flown on domestic flights (measured in million seat–kilometres) and fuel intensity refers to an average domestic aircraft fleet fuel intensity (measured in litres of fuel consumed per seat–kilometre flown).

Seat–kilometres are derived by dividing passenger–kilometres flown by the passenger load factor:

$$SKM = DPASSKM / LF \qquad \text{(III.2)}$$

where SKM is the total of domestic seat-kilometres flown (measured in million seat-kilometres), DPASSKM is the total number of domestic revenue passenger-kilometres flown (millions) and LF is the average passenger load factor (expressed as a proportion of aircraft passenger capacity).

Total domestic passenger-kilometres are the sum of kilometres flown by both Australian residents and by foreigners on the domestic air network:

$$DPASSKM = APASSKM + FPASSKM \qquad \text{(III.3)}$$

where DPASSKM is the total number of passenger-kilometres flown on the domestic network (millions), APASSKM is the number of Australian resident passenger-kilometres flown on the domestic network (millions) and FPASSKM is the number of passenger-kilometres travelled by foreigners on the Australian domestic network (millions).

Passenger-kilometres flown by residents on the domestic network are derived by multiplying resident passenger numbers on trunk routes by an average trunk route distance and resident passenger numbers on regional routes by an average regional route distance:

$$APASSKM = (TPASS \times TAVKM) + (RPASS \times RAVKM) \qquad \text{(III.4)}$$

where APASSKM is the number of Australian resident passenger-kilometres flown on the domestic network (millions), TPASS is the number of Australian resident passengers travelling on the domestic trunk network (millions) and TAVKM is an average distance flown on trunk routes (kilometres), RPASS is the number of Australian resident passengers travelling on the domestic regional network (millions) and RAVKM is an average distance flown on regional routes (kilometres). Australian residents flying on the domestic network are modelled as a function of real gross non-farm product, real (medium distance) airfares, and dummy variables for the pilots' dispute in 1989-90, the World Expo held in Brisbane in 1988 and a definitional change for passenger numbers from September 1993 onwards. The model is estimated using quarterly data and the Cochrane-Orcutt procedure. See table III.3 for a summary of the regression statistics and diagnostic results.

TABLE III.3 RESULTS OF THE BTRE DOMESTIC AVIATION MODEL

Dependent variable	*Diagnostics*	*Independant variables*	*Coefficient*	*Standard error*
ln APASS	Adj. R^2 = 0.995	Constant	5.70	0.36
	Period = 1981Q1 to 2000Q4	ln RGNF	1.03	0.03
	EM: CORC	ln RMEDF	–0.50	0.03
		EXDUM	0.08	0.02
		AIRDUM	–0.70	0.02
		DEFDUM	0.13	0.01

Notes: 1. Adj R^2 refers to the adjusted R^2 statistic.
2. Period refers to the estimation period, where Q denotes quarterly data.
3. EM refers to the estimation method used, where CORC denotes Cochrane–Orcutt estimation.

Source: BTRE estimates.

That is,

$$\ln APASS = 5.70 + 1.03 \ln RGNF - 0.50 \ln RMEDF + 0.07\ EXDUM - 0.70\ AIRDUM + 0.13\ DEFDUM \qquad (III.5)$$

where APASS is the number of Australian passengers travelling on the domestic network (measured in millions), RGNF is real gross non-farm product, RMEDF is an index of real medium distance airfares, EXDUM is a dummy variable in the September quarter of 1988 for the World Expo held in Brisbane, AIRDUM is a dummy variable for the pilots' dispute in 1989–90, and DEFDUM is a dummy variable for a definitional change from September 1993 onwards that counts passengers by aggregating total traffic on board each flight stage, instead of counting traffic once per flight number.

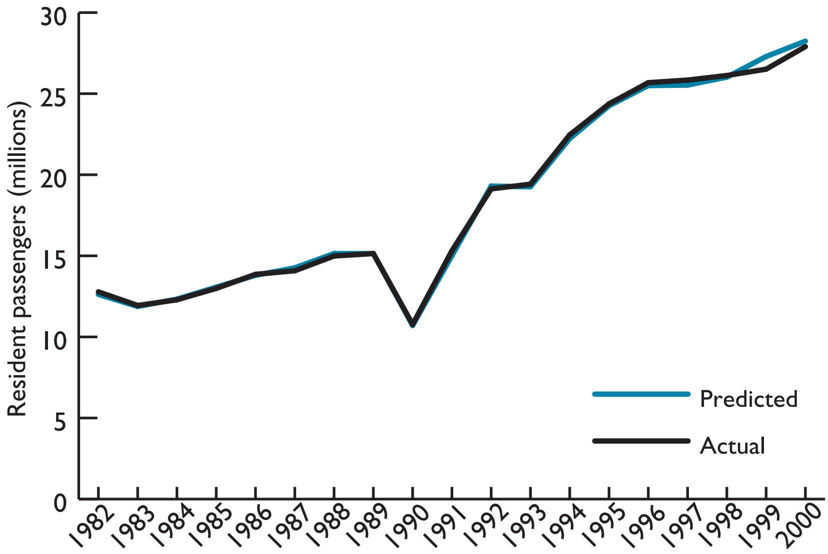
Passenger–kilometres flown by foreigners on the domestic network were estimated by multiplying total short-term foreign international arrivals by the average distance flown on trunk routes (the BTRE assumes the majority of foreigners travel on trunk routes) and 0.75 (the BTRE estimate of the proportion of foreign arrivals that undertake a domestic trip by air):

$$FPASSKM = INPASS \times 0.75 \times TAVKM \qquad (III.6)$$

where FPASSKM is the number of passenger–kilometres travelled by foreigners on the Australian domestic air network (millions), INPASS is the total number of short-term foreign arrivals in Australia (millions) and TAVKM is the average distance flown on trunk routes (kilometres).

Data collected for each of the variables in equations III.1 to III.6 are detailed in Table III.13.

FIGURE III.1 ACTUAL AND PREDICTED LEVELS OF AUSTRALIAN RESIDENTS TRAVELLING ON THE DOMESTIC NETWORK



Sources: BTRE Indicators Database, AVSTATS Database (2001), BTRE estimates.

Figure III.1 graphs the historical actual and predicted levels of APASS using the BTRE model specification (using annual summation of quarterly data). The model assumes constant elasticities. Originally it was expected that income, airfares and the real petrol price index (a proxy for competition by road transport) would all influence the number of Australian residents travelling on the domestic air network. However, the real petrol price index was removed from the final model because it was highly correlated to real airfares and did not offer any different information with which to model passenger numbers. The coefficient on RGNF of 1.03 (shown in table III.3) suggests that passenger numbers are quite responsive to changes in national income levels. As expected, airfares have a negative impact on passenger numbers.

Fuel intensity. Historical data on fuel consumption and seat–kilometres travelled permit the use of equation III.1 to obtain a series on the fuel intensity of the domestic aircraft fleet. The fuel intensity series is derived by dividing fuel consumption by seat–kilometres to obtain litres per seat–kilometre. Table III.4 provides the time series for the period 1981–82 to 1999–2000.

Average kilometres. Average kilometres is derived separately for trunk and regional routes. Total trunk revenue passenger–kilometres flown (TPASSKM) is divided by the total number of trunk passengers (TPASS), giving average kilometres flown on trunk routes (TAVKM). Similarly, total regional revenue passenger–kilometres flown (RPASSKM) is divided by the total number of regional passengers (RPASS), giving average kilometres on regional routes (RAVKM). Revenue kilometres refer to the number of kilometres travelled with fee-paying passengers. They do not include kilometres flown for the re-positioning of aircraft. Average kilometres flown have been increasing steadily from approximately 810 kilometres for trunk routes and 210 kilometres for regional routes in 1982, to approximately 1160 kilometres for trunk routes and 390 kilometres for regional routes in 2000.

TABLE III.4 DERIVED FUEL INTENSITY SERIES FOR THE DOMESTIC AIRLINE FLEET

Year ending June	(1) Domestic aviation fuel consumption (million litres)	(2) Seat–kilometres (million)	(3) Fuel Intensity (3) = (1) / (2) (L/skm)
1982	964.5	14933	0.065
1983	934.9	14248	0.066
1984	930.7	13966	0.067
1985	954.6	14733	0.065
1986	1026.7	16110	0.064
1987	1066.9	17334	0.062
1988	1142.3	18322	0.062
1989	1125.5	18821	0.060
1990	899.4	14847	0.061
1991	1150.2	21748	0.053
1992	1255.6	25703	0.049
1993	1313.6	26294	0.050
1994	1377.7	32154	0.043
1995	1601.1	36768	0.044
1996	1748.9	39761	0.044
1997	1826.6	41423	0.044
1998	1617.8	41077	0.039
1999	1666.5	41467	0.040
2000	1997.3	42953	0.046

Sources: BTCE (1995a, p. 232–233), DISR (2001), AvStats (2001), BTRE estimates.

Australian passengers. The number of Australian passengers travelling on the domestic air network is calculated by subtracting the estimated foreign passenger component from statistics on total domestic passengers. Between 1982 and 1989 Australian passenger numbers increased from 13.1 million to 15.2 million—an increase of approximately 16 per cent. Growth was stifled in 1989–90 by the pilots' dispute, and Australian resident passenger numbers fell to 10.7 million (a fall of 30 per cent in one year). Since the pilots' dispute, passenger numbers have grown strongly, increasing to 27.88 million in 2000, an increase of 83 per cent since 1990–91 (the first financial year after the pilot strike).

Foreign passengers. The number of foreign visitors travelling on the Australian domestic air network was estimated to be 75 per cent of the total number of short-term foreign arrivals. Numbers of foreign passengers have been increasing strongly since 1982, with only a small decline due to the pilots' dispute in 1989–90 and again for the Asian crisis in 1998. Numbers grew from 0.72 million in 1982 to approximately 1.6 million in 1990 and 3.5 million in 2000. In other words, more than double as many foreign passengers flew on domestic routes in 2000 than they did a decade before. The pilots' dispute led to a fall in foreign passengers in 1990 of only 3 per cent from 1989 levels and the Asian crisis led to only 0.5 per cent decline in 1998 from 1997 levels, with growth appearing to have resumed after that.

Real gross non-farm product. The seasonally adjusted real gross non-farm product is an income variable and uses 1999 as the base year. It has been increasing every year since 1982, with the exception of the 1982-83 financial year.

Real airfares. The price level was represented by an index (base 1997) of average real air fares on medium distance air routes. Real domestic airfares declined between 1984 and 1992 due mostly to airline deregulation and the introduction of Compass in 1992. Since the departure of Compass that same year, real airfares have risen but are still well below pre-deregulation levels. It is expected that if real airfares increase, fewer people will be able to afford to travel, which will cause a negative impact on Australian passenger numbers.

EXDUM. This is a dummy variable which reflects the World Expo held in Brisbane in the third quarter of 1989. It is set to 1 in that quarter and zero everywhere else.

AIRDUM. This is a dummy variable which reflects the year of the pilots' dispute. It is equal to 0 for all years except those of the pilots' dispute: from the second quarter of 1989 to the third quarter of 1990. AIRDUM is equal to 0.2 in quarters one and two of 1989, 0.8 in quarter three of1989, 1 in quarter four of 1989, 0.4 in quarter one of 1990, 0.3 in quarter two of 1990, 0.2 in the period quarter three 1990 to quarter one 1991, 0.1 in quarter two of 1991 and 0 elsewhere. Different coefficients are used to account for the degree of the effect in a particular quarter.

DEFDUM. This is a dummy variable to account for a definitional change from September 1993 onwards that counts passengers by aggregating total traffic on board each flight stage, instead of counting traffic once per flight number. It is set at 0.33 for the September quarter of 1993 (as it was in effect for one month of this quarter only), and at 1 after the third quarter of 1993.

Foreign arrivals. Foreign arrivals are the total number of short-term foreign arrivals in Australia (INPASS). The modelling of foreign arrivals is detailed below, especially in equation III.13. Foreign arrivals have shown strong growth since 1982, increasing by 390 per cent by 2000. Since 1990, foreign arrivals have grown by 117 per cent.

Assumptions

For the purposes of projecting domestic aviation turbine fuel consumption to the year 2019–20, it is necessary to make a number of assumptions about the independent variables. Table III.5 roughly summarises the assumptions regarding future growth in the underlying variables.

It was assumed that the real gross non-farm product (RGNF) would increase by an average of 3 per cent per annum to the year 2019–20. The exact annual growth rate projections for income are an average of GTEM, G-Cubed and

Monash projections, provided by the AGO (pers. comm. 2001)—see Appendix VI, table VI.3.

TABLE III.5 DOMESTIC AVIATION PROJECTION ASSUMPTIONS

(per cent growth per annum)

Variable	*2000–2020*
Real gross non-farm product (RGNF)	+3.0
Real airfares (RMEDF)	–1.3
Average kilometres travelled (AVKM)	+1.5
Passenger load factor (LF)	0.0

Source: BTRE estimates

Real airfares (RMEDF) are assumed to decline by 1.3 per cent per annum to the year 2019–20. The decline in real airfares will most likely be due to increased competition in the domestic aviation market.

The passenger load factor (LF) is assumed to remain constant at the 1999–2000 figure of 75 per cent. Since 1985, load factors have varied very little from a 70–75 per cent figure. The assumed value of 75 per cent is slightly higher than the average load factor over the past 15 years, as airline operators are expected to try and increase current load factors as a means of cutting costs to remain competitive. This is already the case for regional airlines which have shown steady increases in load factors since 1990–91. A number of scenarios outlined in the next section ('Projection results and scenarios') alter the assumption made about passenger load factors.

Average kilometres travelled per passenger on trunk routes (TAVKM) and regional routes (RAVKM) are assumed to increase by 1.5 per cent per annum. This is consistent with historical data and assumes that developments in aircraft and fuels will allow planes to fly longer distances.

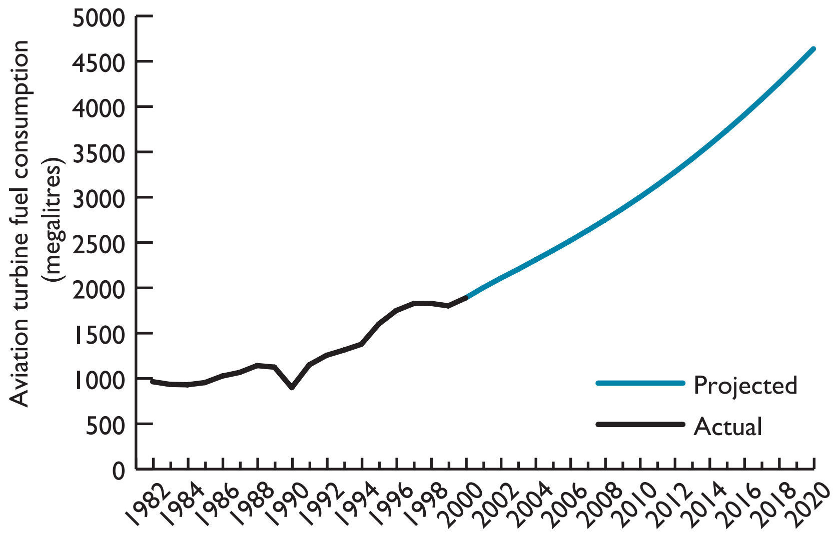
BTCE (1992) calculated the likely improvements to the domestic aircraft fleet fuel efficiency under a number of scenarios. Likely improvements will depend upon when the fleet is replaced. Between 1988 and 2005 the BTCE (1992: p. 44) estimated improvements in fuel efficiency to be 33 per cent if aircraft are replaced after 15 years; 22 per cent if replaced after 20 years; and 14 per cent if replaced after 25 years. Using these figures and extending them to the year 2020, the improvements in fuel efficiency between 2000 and 2020 would reach 43 per cent for a fleet replaced after 15 years; 28 per cent after 20 years; and 18 per cent after 25 years. The BTCE also reported in 1995 that Qantas (pers. comm. 1994) suggested that a fuel efficiency improvement of 40 per cent in 20 years appeared unlikely. Therefore, it is assumed that by 2020 the fuel efficiency of the domestic aircraft fleet will improve by 28 per cent in the base case scenario.

Table III.13 details the actual and projected levels for each model variable for each year to 2019–20.

Projection results and scenarios

Using the BTRE model and the assumptions in table III.5, domestic avtur consumption from civil aviation is projected to increase from 1992 million litres in 1999–2000 to 3102 million litres in the year 2009–10 and to 4741 million litres in 2019–20. Figure III.2 shows the projected levels of domestic civil aviation turbine fuel consumption.

FIGURE III.2 ACTUAL AND PROJECTED LEVELS OF DOMESTIC AVIATION TURBINE FUEL PROJECTION



Sources: DISR (2001), BTRE estimates.

On the basis of the assumptions in table III.5, it is projected that Australian residents travelling on the domestic network will increase from 27.88 million in 1999–2000 to 42.06 million in 2009–10 and to 59.67 million in 2019–20. The total number of seat–kilometres travelled on the domestic air network (including Australian and foreign passengers) will increase from 42.95 billion in 1999–2000 to 80.37 billion in 2009–10 and to 146.5 billion in the year 2019–20.

Tables III.6 and III.7 detail how changing the assumptions on fuel efficiency and load factors affects projected levels of fuel consumption and seat–kilometres travelled. As fuel efficiency improves, total fuel consumption levels (and proportionally, emissions) fall. As load factors are increased, fuel consumption declines.

TABLE III.6 SCENARIOS FOR DOMESTIC AVTUR CONSUMPTION

(million litres)

Fuel efficiency improvement by 2019–20 (per cent over 1999–2000)	*Load factor in 2019–20* 0.7	0.75	0.8
10	6211	5797	5435
	(34%)	(25%)	(17%)
18	5659	5282	4952
	(22%)	(14%)	(7%)
28	4968	4638	4348
	(7%)	(..)	(–6%)
30	4831	4509	4227
	(4%)	(–3%)	(–9%)

.. not applicable
Notes: Base case scenario is a load factor of 0.75 and fuel efficiency improvement of 28 per cent.
Figures in parentheses refer to percentage change from base case estimate.
Source: BTRE estimates.

TABLE III.7 SCENARIOS FOR DOMESTIC SEAT–KILOMETRES IN 2019–20

Load factor in 2019–20	*Seat-kilometres (million skm)*	*Change from base case (%)*
0.70	156 960	7.1
0.75	146 496	..
0.80	137 340	–6.3

.. not applicable
Note: Base case assumption is load factor of 0.75.
Source: BTRE estimates.

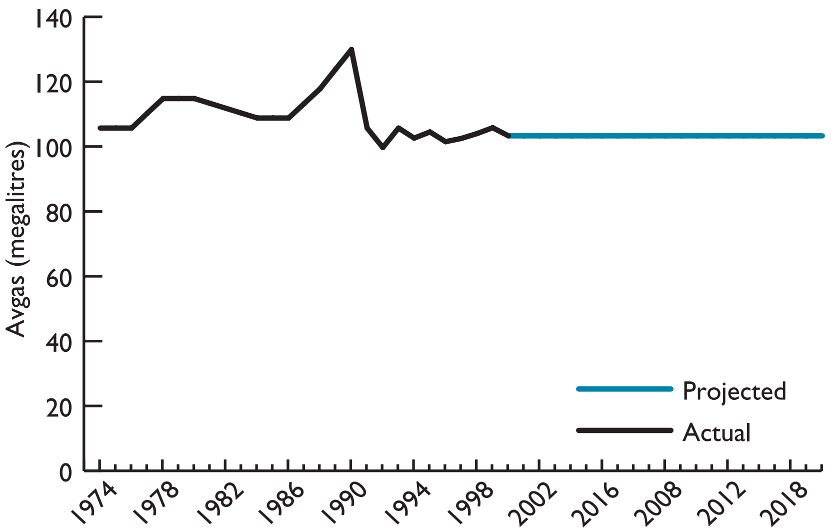
Aviation gasoline

Avtur is by far the major fuel consumed in the domestic aviation market. However aviation gasoline (Avgas) is also used, mainly in the general aviation market. The level of fuel consumption by general aviation is only a very small component of total aviation fuel consumption and does not warrant an extensive econometric modelling procedure.

Avgas consumption has changed very little in the past 25 years and based on historical data it has been assumed to remain constant at the 1999–2000 figure of 103.3 megalitres per year (DISR 2001; BTCE 1995a: p. 234).

Figure III.3 illustrates the actual and projected Avgas consumption levels between 1973–74 and 2019–20. Table III.14 details the actual and projected levels of Avgas.

FIGURE III.3 AVIATION GASOLINE CONSUMPTION PROJECTIONS



Sources: DISR (2001), BTCE (1995a: p. 234).

Projected emissions from domestic aviation

Projected levels of greenhouse gas emissions can be calculated from the fuel consumption projections for domestic aviation.

Conversion of fuel consumption in litres to megajoules of energy is made by multiplying litres consumed and the relevant energy density conversion factor: for Avtur, the energy density is 36.8 megajoules per litre of fuel; for Avgas, 33.1 megajoules per litre of fuel.

Megajoules of fuel consumed are multiplied by the relevant emission conversion factors to obtain emission levels for each of the greenhouse gases.

Carbon dioxide equivalent emission levels for the total domestic aviation market (both major airlines and general aviation) are projected to increase by a total of 139 per cent between 1999–2000 and 2019–20. The increase in emissions is essentially due to the scheduled airline market, where carbon dioxide equivalent emissions seem set to increase by 146 per cent between 1999–2000 and 2019–20. The carbon dioxide equivalent emissions from the general aviation market is assumed to remain unchanged over the same period. This may turn out to be an overestimate if 'cleaner' aviation gasoline is developed. Nevertheless, the proportion of emissions from Avgas for the aviation sector is so small that even a 30 per cent reduction in emissions between 2000 and 2020 would give domestic (civil) aviation emissions in the year 2019–20 only 0.5 per cent less than the current projection. Tables III.16-17 contain projected levels of greenhouse gases from domestic aviation.

As mentioned earlier, increasing passenger load factors and/or improving fuel efficiency will lead to reduced fuel consumption and carbon dioxide equivalent emissions.

INTERNATIONAL AVIATION

International aviation currently accounts for around 66 per cent of total greenhouse gas emission levels from the civil aviation industry using fuel purchased in Australia.

The level of aviation turbine fuel (Avtur) uplifted in Australia will in part depend upon the projected level of international travel to and from Australia.

Foreign passenger arrivals in Australia have been growing strongly since 1982 as Australia has become a more popular tourist destination. Between 1990 and 2000 foreign arrivals increased by 117 per cent, and Australian passenger departures increased by 60 per cent.

BTRE model specification

Due to the long-term nature of the projections (from 1999–2000 to 2019–20), the BTRE model specification has been developed with the aim of achieving a simple formulation that incorporates all of the major determinants affecting international Avtur consumption.

Fuel consumption was modelled as the product of the international task to and from Australia (measured in seat–kilometres performed) and the fuel intensity of the international aircraft fleet arriving in and departing from Australia (measured in litres per seat–kilometre). If the fuel efficiency of the aircraft fleet improves, then fuel consumption will fall. Alternatively if the task (and thus seat–kilometres) declines, fuel consumption will also decline.

Seat–kilometres were derived by dividing international passenger–kilometres by the average passenger load factor (which is a measure of the percentage of the aircraft seats in use). As seat–kilometres increase, so will fuel consumption. Seat–kilometres may increase if load factors decline and/or passenger volumes increase.

Short-term international passenger–kilometres were derived by multiplying short-term passenger numbers by the average distance flown. Passenger numbers were split into two groups: short-term foreign arrivals and Australian resident departures. Total international passenger numbers were derived by doubling short-term foreign arrivals and Australian resident departures (to account for the return journey) and increasing the result by approximately 2 per cent to account for long-term or permanent movements (derived from data contained in ABS 2001c).

The major variables which were found to affect both foreign arrivals and Australian resident departures were income levels and relative prices in Australia compared to overseas countries (represented by the real trade weighted index of the exchange rate). Real airfares were not included as the trade-weighted index better captures the costs of the entire holiday package.

The level of freight carried by international aircraft was not found to be a significant variable when determining fuel consumption. While international air freight is carried on passenger flights if there is sufficient space available, tonnages are very small. Only 0.1 per cent of international freight is carried by air (BTRE Indicators Database). Most international trade is carried by ships.

Equations (III.7) to (III.13) outline the final BTRE model specification for international avtur fuel consumption. Table III.8 presents a summary of the regression results and diagnostic tests.

TABLE III.8 RESULTS OF THE INTERNATIONAL AVIATION MODEL

Dependent variable	*Diagnostics*	*Independent variables*	*Coefficient*	*Standard Error*
ln OUTPASS	Adj. R^2 = 0.99	Constant	–7.61	0.42
	Period: 1981Q1 to 2000Q2	ln RGNF	1.72	0.02
	EM: OLS	ln RTWI(–2)	0.18	0.04
		BIDUM	–0.07	0.02
		OLYDUM	–0.04	0.03
		DUM1	0.07	0.01
		DUM2	–0.07	0.02
ln INPASS	Adj. R^2 = 0.99	Constant	–16.86	0.85
	Period: 1981Q1 to 2000Q4	ln G7GDP	3.41	0.07
	EM: CORC	ln RTWI(–4)	–0.48	0.09
		BIDUM	0.10	0.03
		ASIADUM	0.01	0.00
		OLYDUM	0.03	0.06
		ERRDUM	–0.07	0.05

Notes:
1. Adj R^2 refers to the adjusted R2 statistic.
2. Period refers to the estimation period, where Q denotes quarterly data and A denotes annual data.
3. EM refers to the estimation method used, where OLS denotes Ordinary Least Squares estimation and CORC denotes Cochrane–Orcutt estimation.

Source: BTRE estimates.

Fuel uplifted in Australia is calculated by an identity linking it to total seat–kilometres times the average fleet fuel intensity times 0.42. The latter is an estimate of the proportion of total aviation fuel consumed by aircraft flying to and from Australia which is uplifted in Australia (derived from data contained in Apelbaum 2001).

$$AFC = SKM \times FI \times 0.42 \quad \text{(III.7)}$$

where AFC is international Avtur uplifted in Australia (measured in million litres), SKM is the total number of international seat–kilometres travelled by aircraft arriving in and departing from Australia (millions), and FI is the average aircraft fleet fuel intensity (measured in litres consumed per seat–kilometre travelled).

For the years prior to 1999–2000 a series for the average fleet fuel intensity can be calculated by dividing the total fuel consumed for Australia's international task by the total seat–kilometres travelled.

$$FI = TFC / SKM \quad \text{(III.8)}$$

where FI is the average aircraft fleet fuel intensity (measured in litres consumed per seat–kilometre travelled), TFC is the total fuel consumed by international aviation travelling to and from Australia (million litres) and SKM is the total number of international seat–kilometres travelled by aircraft arriving in and departing from Australia (millions).

Seat-kilometres travelled for Australia's international task were calculated by dividing total passenger-kilometres travelled by the average passenger load factor.

$$SKM = TIPKM / LF \quad \text{(III.9)}$$

where SKM is the total number of international seat-kilometres travelled by aircraft arriving in and departing from Australia (millions), TIPKM is the total number of passenger-kilometres travelled by short-term and long-term travellers arriving in and departing from Australia (millions) and LF is the passenger load factor (expressed as a proportion of total aircraft capacity).

The total number of international passenger-kilometres travelled to and from Australia is equal to the number of passenger-kilometres travelled by short-term travellers divided by α (an estimate of the proportion of the total number of passengers who are short-term travellers).

$$TIPKM = IPKM / \alpha \quad \text{(III.10)}$$

where TIPKM is the total number of international passenger–kilometres travelled to and from Australia by short-term and long-term travellers (millions) and IPKM is the total number of international passenger–kilometres travelled to and from Australia by short-term travellers (millions).

International passenger–kilometres travelled to and from Australia by short-term travellers were modelled by summing the number of short-term Australian resident departures and the short-term foreign arrivals multiplied by their respective average distances travelled. The identity was then multiplied by two to account for the return journey.

$$\text{IPKM} = \{ (\text{OUTPASS} \times \text{AVKMOUT}) + (\text{INPASS} \times \text{AVKMIN}) \} \times 2 \quad \text{(III.11)}$$

where IPKM is the total number of international passenger–kilometres travelled to and from Australia by short-term travellers (millions), OUTPASS is the total number of short-term Australian resident departures (millions), AVKMOUT is the average distance travelled by international passengers leaving Australia (kilometres), INPASS is the total number of short-term foreign arrivals in Australia (millions) and AVKMIN is the average distance travelled by international passengers arriving in Australia.

Short-term Australian resident departures were modelled as a function of real Australian non-farm gross domestic product, the real trade weighted index lagged four quarters between 1982Q1 (i.e. the first quarter of 1982) and 1988Q4 and two quarters between 1989Q1 and 2000Q2, and dummy variables for the Bicentennial year, the Olympic Games, and two 'error' dummy variables. The model uses quarterly data and was estimated by using Ordinary Least Squares estimation.

$$\begin{aligned} \ln \text{OUTPASS} = \; & -7.61 + 1.72 \ln \text{RGNF} + 0.18 \ln \text{RTWI}(-2) \\ & - 0.07\,\text{BIDUM} - 0.04\,\text{OLYDUM} + 0.07\,\text{DUM1} \\ & - 0.07\,\text{DUM2} \qquad \text{(III.12)} \end{aligned}$$

where OUTPASS is the seasonally adjusted number of short-term Australian resident departures (measured in millions), RGNF is real Australian real gross non-farm product, RTWI(–2) is the real trade-weighted index lagged four quarters to 1988Q4 and two quarters thereafter, BIDUM is a dummy variable for the bicentennial year (1988Q1 to 1988Q3), OLYDUM is a dummy variable for the Olympic Games (2000Q2 to 2000Q3), DUM1 is a dummy variable from 1991Q4 to 1993Q2 and DUM2 is a dummy variable from 1999Q2 to 2000Q1.

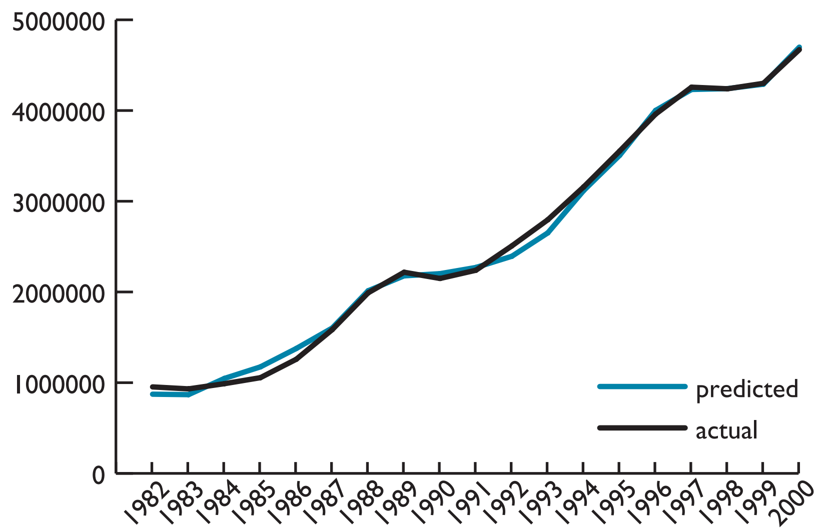
Short-term foreign arrivals in Australia were modelled as a function of overseas income levels as measured by the gross domestic product of seven major OECD economies, the real trade weighted index lagged four quarters, and dummy variables for the bicentennial celebrations (1988), the rise in Asian tourism in the 1990s, the Sydney Olympic Games (2000) and an error dummy for 2000 onwards. The model uses quarterly data and was estimated by Cochrane–Orcutt estimation.

$$\begin{aligned} \ln \text{INPASS} = \; & -16.86 + 3.41 \ln \text{G7GDP} - 0.48 \ln \text{RTWI}(-4) \\ & + 0.10\,\text{BIDUM} + 0.01\,\text{ASIADUM} + 0.03\,\text{OLYDUM} \\ & - 0.07\,\text{ERRDUM} \qquad \text{(III.13)} \end{aligned}$$

where INPASS is the total number of short-term foreign arrivals (millions), G7GDP is the sum of gross domestic products of seven major OECD economies (the United States, Japan, Germany, France, Italy the United Kingdom and Canada), RTWI(–4) is the real trade-weighted index lagged four quarters, BIDUM is a dummy variable for quarters 1, 2 and 3 in 1988, ASIADUM is a dummy variable for increased tourism from Asia (from 1993Q1 to 1997Q4), OLYDUM is a dummy variable for the Olympic Games in 2000Q2 and 2000Q3, and ERRDUM is an error dummy variable from 2000Q1 onwards.

Data collected for each of the variables outlined in equations III.7 to III.13 are detailed in Table III.18.

FIGURE III.4 ACTUAL AND PREDICTED LEVELS OF FOREIGN PASSENGER ARRIVALS



Sources: ABS (2001c); BTRE Indicators Database; AVSTATS (2001).

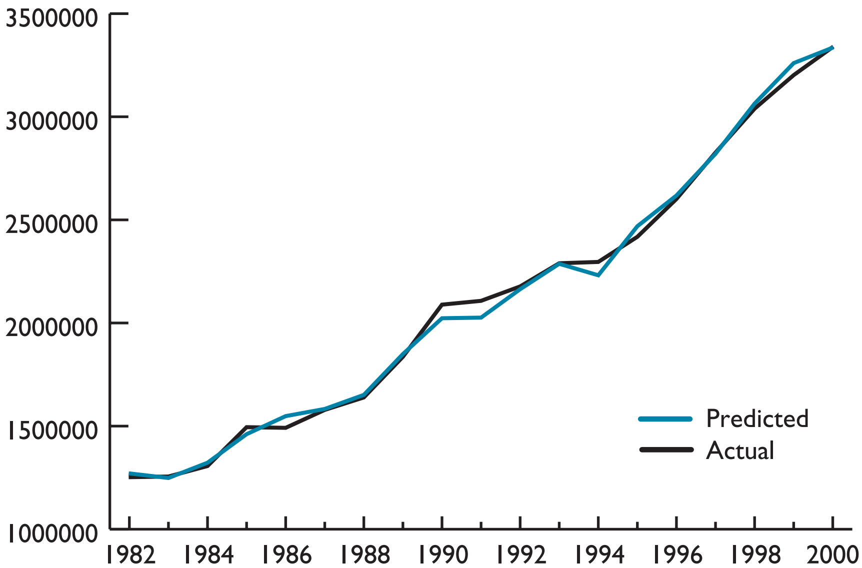
Quarterly figures were used to model foreign passenger arrivals (INPASS), estimated using the Cochrane–Orcutt procedure over the period 1981Q1 to 2000Q4. Figure III.4 illustrates the historical (actual) and predicted levels for INPASS (summed over quarters to give annual data).

The coefficient for G7GDP of 3.41 (shown in table III.8) suggests that overseas tourism to Australia is highly responsive to changes in income levels. Higher income levels in other countries should make international travel more affordable as well as a relatively greater increase in being able to afford long-haul travel in comparison to short-haul travel. This should result in a rise in foreign arrivals in Australia.

A lag was used for the real trade-weighted index (RTWI) to capture the long lead time presumably required by foreign tourists when planning to visit Australia (BTCE 1991b: p. 42). The negative coefficient (–0.48) suggests that, as travel to Australia becomes relatively more expensive, passenger numbers will decline.

Australian resident (short-term) departures (OUTPASS) were estimated by Ordinary Least Squares estimation using seasonally adjusted quarterly data over the period 1981Q1 to 2000Q2. Figure III.5 shows the historical (actual) and predicted levels for OUTPASS.

FIGURE III.5 ACTUAL AND PREDICTED LEVELS OF AUSTRALIAN RESIDENT (SHORT-TERM) DEPARTURES



Sources: ABS (2001c); BTRE Indicators Database; AVSTATS (2001).

The coefficient of 1.72 in table III.8 for the income variable (RGNF) suggests that, as Australian income levels increase, so will overseas travel as it becomes more affordable. The real trade-weighted index is a measure of the relative cost to Australian tourists to travel overseas and the small positive coefficient of 0.18 shows a fairly unresponsive effect.

A discussion of some of the variables used in the analysis follows.

Fuel intensity. It is difficult to derive a series for average fleet fuel intensity for international aircraft arriving in and departing from Australia, as data are readily available only for Qantas aircraft. However, a series was derived using historical data on fuel consumption and seat-kilometres travelled, in a manner similar to the derived domestic aviation fuel intensity series. Fuel intensity was derived by dividing the total fuel uplifted by the total seat–kilometres travelled (table III.9).

TABLE III.9 DERIVED FUEL INTENSITY SERIES FOR THE INTERNATIONAL AIRLINE FLEET

Year ending June	*(1) AFC (million litres)*	*(2) Seat kilometres (million)*	*(3) TFC (3) = (1) / 0.42 (million litres)*	*(4) Fuel Intensity (4) = (3) / (2) (L/skm)*
1982	1018.80	69810.19	2425.71	0.03475
1983	991.80	71133.30	2361.43	0.03320
1984	989.50	70321.14	2355.95	0.03350
1985	1114.20	73987.38	2652.86	0.03586
1986	1136.40	77415.42	2705.71	0.03495
1987	1200.10	86844.83	2857.38	0.03290
1988	1357.30	96060.30	3231.67	0.03364
1989	1567.00	111428.53	3730.95	0.03348
1990	1711.60	118701.36	4075.24	0.03433
1991	1780.60	126338.44	4239.52	0.03356
1992	1889.08	132628.54	4497.81	0.03391
1993	2042.00	144273.06	4861.90	0.03370
1994	2101.10	149225.15	5002.61	0.03352
1995	2300.47	165600.55	5477.32	0.03308
1996	2478.92	180674.25	5902.19	0.03267
1997	2560.23	191657.88	6095.78	0.03181
1998	2840.72	201920.60	6763.62	0.03350
1999	2707.77	201128.49	6447.08	0.03205
2000	2526.19	217043.72	6014.75	0.02771

Note: AFC refers to total Avtur uplifted in Australia and TFC is total fuel consumed by aircraft arriving in and departing from Australia.
Sources: BTCE (1995a: p. 238–239), DISR (2001); AVSTATS (2001); BTRE estimates.

Average kilometres. Average kilometres travelled were split into outbound and inbound average kilometres. Ten regions were identified and data on passenger numbers travelling between Australia and the destination region were collated. The average distance flown was calculated by multiplying the proportion of total passengers to a particular region by the stage distance, and summing over all regions. Tables III.19 and III.20 detail the calculation and results.

The average number of kilometres travelled by inbound passengers declined between 1982 and 1998 and has been rising since, reflecting the fall in Asian tourists and the increasing proportion of non-Asian tourists. The average number of kilometres travelled by outbound passengers has changed little over the past 10 years, except for a decline in 1999, however this has largely been corrected in 2000. Between 1982 and 1998 the average distance travelled by inbound passengers fell by approximately 10 per cent, but have since risen to higher than 1990 levels. Average distances travelled by outbound passengers are now only 0.5 per cent less than the 1990 figures.

OUTPASS. The number of short-term Australian resident departures is a seasonally adjusted series. In 1990, passenger departures totalled approximately 2.1 million, increasing to approximately 3.3 million in 2000 (an increase of 60 per cent).

INPASS. The number of short-term foreign passenger arrivals in Australia grew from approximately 2.1 million in 1990, to approximately 4.7 million in 2000 (an increase of 117 per cent).

α. Alpha (α) is here an estimate of the number of international passengers who are short-term travellers. Between 1982 and 1993 the proportion of short-term travellers increased, but it has remained at a constant level since. In 1982, about 95 per cent of visits were classified as short-term (that is, for a period of less than 12 months); in 1986 it was 97 per cent; and in 1993 reached 98 per cent (BTCE 1995a: p. 88). In 2000, the proportion was also about 98 per cent (based on ABS 2001c). A trend growth rate was assumed for estimating values of the intervening years.

RGNF. The seasonally adjusted real gross non-farm product is an income variable and uses 1999 as the base year. It has been increasing every year since 1982, with the exception of the 1982–83 financial year.

G7GDP. The G7 gross domestic product is used as an overseas income variable. It is an index of the real gross domestic product for the group of seven major industrial countries of the OECD (Canada, France, Germany, Italy, Japan, the United Kingdom and the United States). It increased by approximately 61 per cent between 1982 and 2000. As overseas income levels increase, it is expected that the number of foreign passengers travelling to Australia will also increase.

RTWI. The real trade-weighted index of the Australian dollar is equal to the trade-weighted index multiplied by the Australian consumer price index (CPI), using 1990 as a base year, divided by the OECD CPI (using 1995 as a base year). It is expected that as the real trade-weighted index increases (that is, prices in Australia increase relative to overseas) there will be fewer foreign arrivals and more Australian departures.

Assumptions

For the purposes of projecting aviation turbine fuel uplifted in Australia by international aviation to the year 2020, it was necessary to make a number of assumptions about the independent variables. Table III.10 summarises the assumptions used.

TABLE III.10 INTERNATIONAL AVIATION PROJECTION ASSUMPTIONS

(per cent per annum)

Variable	*2000–2020*
Overseas income (G7GDP)	+2.5
Real trade weighted index (RTWI)	+0.0
Real gross non-farm product (RGNF)	+3.0
Proportion of short-term passengers (α)	+0.0
Average inbound distance (AVKMIN)	+1.5
Average outbound distance (AVKMOUT)	+1.5
Passenger load factor (LF)	+0.0

Source: BTRE Estimates

Overseas income levels (G7GDP) were assumed to increase by 2.5 per cent per annum to the year 2020 (BTRE estimates). The real trade-weighted index (RTWI) was assumed to remain unchanged until 2020. It was assumed that the real Australian gross non-farm product (RGNF) will increase by an average of 3 per cent per annum to the year 2019–20. The exact annual growth rate projections are an average of GTEM, G-Cubed and Monash projections (AGO 2001, pers. comm.)—see Appendix VI, table VI.3.

In the absence of alternative information, the load factor was assumed to remain constant at the year 2000 level of 69.3 per cent. As this was an arbitrary assumption, the following section considers a number of scenarios, including changes to the passenger load factor assumption.

The average number of kilometres travelled by an international passenger was also assumed to remain constant at the year 2000 level: approximately 9372 kilometres for foreign arrivals and approximately 8973 kilometres for Australian resident departures.

It was assumed that long-term and permanent movements will account for 2 per cent of total international passenger numbers. In 2000, 98 per cent of total international passengers travelling to and from Australia were short-term travellers (derived from data contained in ABS 2001c).

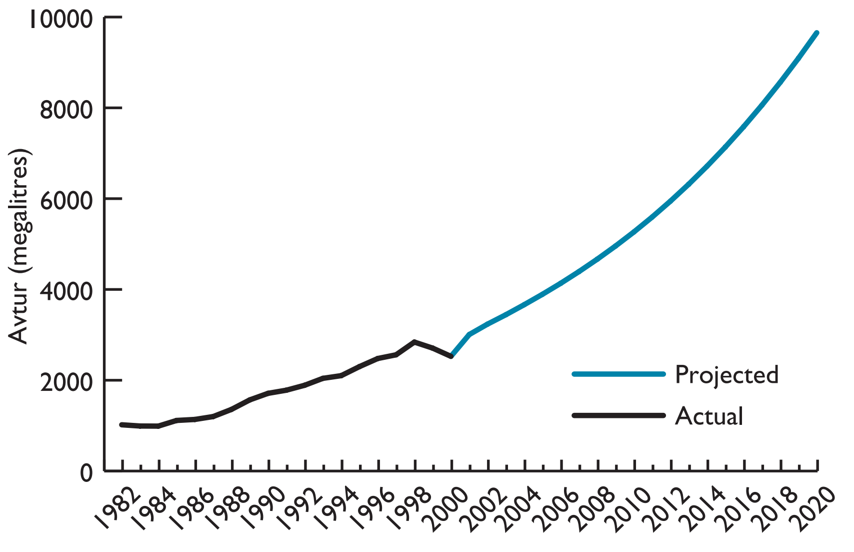
As for domestic aviation, BTCE (1992) calculated the likely improvements to the international aircraft fleet fuel efficiency under a number of scenarios. Between 1988 and 2005, the BTCE (1992: p. 44) estimated improvements in fuel efficiency to be 28 per cent if aircraft are replaced after 15 years; 17 per cent if replaced after 20 years; and 16 per cent if replaced after 25 years. Extending these results to the year 2020, the improvements in fuel efficiency between 2000 and 2020 could reach 36 per cent for a fleet replaced after 15 years; 22 per cent after 20 years; and 21 per cent after 25 years. The BTCE reported in 1995 that Qantas (pers. comm. 1994, in BTCE 1995) suggests that a fuel efficiency improvement of 40 per cent in 20 years is unlikely. It is assumed that by 2020 the fuel efficiency of the international aircraft fleet will improve by 22 per cent in the base case scenario.

A base case projection of fuel consumption (for Avtur uplifted in Australia) can be calculated on the basis of these assumptions. Table III.18 gives the projected levels of each of the variables to the year 2019–20.

Projection results and scenarios

Using the BTRE models and the assumptions made about the independent variables detailed above, Avtur consumption by international aviation was projected to increase from 2526 megalitres in 1999–2000 to 4936 megalitres in 2009–10 and to 9052 megalitres in 2019–20. Figure III.6 graphs the actual and projected levels of international Avtur uplifted in Australia.

FIGURE III.6 ACTUAL AND PROJECTED LEVELS OF INTERNATIONAL AVIATION TURBINE FUEL UPLIFTED IN AUSTRALIA



Sources: DISR (2001), BTCE (1995a); BTRE Estimates.

Using the assumptions in table III.10, foreign arrivals are projected to increase from 4.67 million in 1999–2000 to 11.39 million in 2009–10 and to 26.41 million in 2019–20. Similarly, Australian departures are projected to increase from 3.34 million in 1999–2000 to 6.21 million in 2009–10 and to 10 million in 2019–20. In seat–kilometres travelled, this adds up to an overall increase of approximately 360 per cent between 1999–2000 and 2019–20.

Tables III.11 and III.12 demonstrate the effect of changing the assumptions (about fuel efficiency improvements and load factors) on fuel consumption by international aviation. As fuel efficiency improves and/or the load factor increases, fuel consumption will fall.

TABLE III.11 SCENARIOS FOR INTERNATIONAL AVIATION TURBINE FUEL UPLIFTED IN AUSTRALIA

(million litres)

Fuel efficiency improvement by 2019–20 (per cent over 1999–2000)	*Load factor in 2019–20*		
	0.65	*0.69*	*0.75*
15	10521	9864	9117
22	9654	9052	8367
30	8664	8123	7509
36	7922	7427	6865

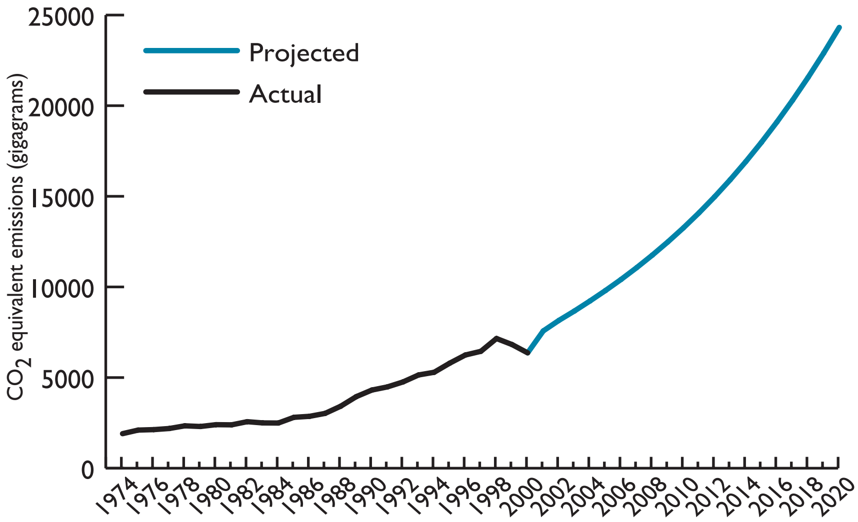
Note: Base case scenario is a load factor of 0.69 and fuel efficiency improvement of 22 per cent.
Source: BTRE estimates.

TABLE III.12 SCENARIOS FOR INTERNATIONAL SEAT–KILOMETRES IN 2019–20

Load factor in 2019–20	*Seat–kilometre task (million skm)*
0.65	1 063 428
0.69	997 037
0.75	921 638

Note: Base case assumption load factor is 0.69.
Source: BTRE estimates.

FIGURE III.7 CARBON DIOXIDE EQUIVALENT EMISSIONS FROM INTERNATIONAL AIRCRAFT UPLIFTING FUEL IN AUSTRALIA



Sources: DISR (2001), BTCE (1995a); BTRE estimates.

Projected emissions from international aviation

Projected levels of greenhouse gas emissions can be calculated from the projections of international avtur use.

Fuel consumption data were converted from megalitres consumed to megajoules of energy consumed through multiplying by the relevant energy density conversion factor. For Avtur, the energy density is 36.8 megajoules per litre (Bush et al. 1993: p. 52). Megajoules consumed were multiplied by the relevant emissions conversion factor (outlined in table III.2) to obtain emission levels for each of the relevant gases.

Carbon dioxide equivalent emission levels for international aircraft using fuel uplifted from Australia are projected to increase by a total of approximately 258 per cent between 1999–2000 and 2019–20. Table III.21 reports the projected levels of each of the greenhouse gases.

Figure III.7 graphs carbon dioxide equivalent emission levels for international aviation fuel uplifted in Australia.

CONCLUDING REMARKS

The BTRE model specifications are fairly simple yet incorporate the major determinants of fuel use by domestic and international aviation.

The BTRE projects that fuel consumption and thus greenhouse gas emissions will increase considerably by the year 2019–20.

Following the BTRE model specification and related assumptions, Avtur use by civil aviation is projected to increase from a total of 4415 megalitres in 1999–2000, to 8264 megalitres in the year 2009–10 and to 14 292 megalitres in the year 2019–20.

Aviation gasoline use has been projected to remain constant to 2019–20 at the 1999–2000 level of 103.3 megalitres.

The total civil aviation sector is projected to increase greenhouse gas emissions between 1999–2000 and 2019–20 by approximately 219 per cent. Table III.22 details greenhouse gas emission estimates from the civil aviation sector.

It should be noted that it was necessary to derive a number of variables used in the analysis (for example, fuel intensity), due to lack of directly published data. The values of these variables may therefore not be very accurate, and may be useful only as an indication of likely trends over time.

For making projections, the BTRE models also rely heavily on the assumptions made. Higher incomes, for example, lead to increased demand for travel, resulting in higher fuel consumption. Increased load factors and larger aircraft, however, will partially counteract the increase in fuel consumption, as fewer aircraft will be needed to undertake the task. The models also directly couple growth in passenger movements (and in aviation emissions) with income growth, and do not include any constraints on this growth. If, in the future, there are radical technological changes or demand behaviour for the aviation sector undergoes structural change (e.g. air travel reaches a saturation level in its mode share for Australian non-urban journeys; the aviation industry is affected by major changes in consumer confidence, habits or mode-preference; telecommuting replaces a significant share of business travel), then future growth in aviation emissions would probably not be maintained at the levels forecast here.

The BTRE models are designed primarily for long-term projections and therefore do not include all variables that may be relevant in the short-term. Due to the long-term nature of the projections, the BTRE models were derived on an aggregated basis and do not consider specific origin-destination pairs. For example, tourism growth to and from Asian countries has not been modelled separately. For these reasons, the BTRE models should be used only for long-term projections and on an aggregated level, rather than for specific origin-destination pairs.

TABLE III.13 DOMESTIC AVIATION PROJECTIONS

Year	DPASS (million)	RPASS (million)	FPASS (million)	APASS (million)	TPASS (million)	DAVKM (km)	RAVKM (km)	DPASSKM (million)	RPASSKM (million)	FPASSKM (million)	APASSKM (million)	TPASSKM (million)
1982	12.60	1.22	0.72	13.10	13.81	810.51	210.07	10210.03	255.57	579.56	9886.04	10465.60
1983	11.42	1.24	0.70	11.97	12.66	799.84	208.63	9135.32	259.33	558.91	8835.74	9394.65
1984	11.71	1.22	0.74	12.19	12.93	811.51	207.50	9506.06	252.56	601.94	9156.68	9758.62
1985	12.53	1.24	0.79	12.98	13.77	825.55	209.79	10345.15	259.52	653.22	9951.45	10604.67
1986	13.44	1.36	0.94	13.85	14.80	840.63	213.03	11300.06	288.92	793.32	10795.65	11588.98
1987	13.83	1.43	1.19	14.08	15.27	871.38	222.44	12053.63	319.06	1035.53	11337.15	12372.68
1988	14.96	1.51	1.49	14.99	16.48	887.15	234.73	13275.97	355.26	1324.40	12306.82	13631.23
1989	15.13	1.68	1.66	15.15	16.81	908.12	240.49	13742.74	403.89	1510.18	12636.45	14146.63
1990	10.40	1.91	1.61	10.70	12.31	961.09	276.22	9997.17	527.32	1548.89	8975.59	10524.49
1991	14.75	2.20	1.68	15.27	16.95	983.92	293.21	14516.06	644.04	1652.62	13507.48	15160.10
1992	18.49	2.52	1.88	19.13	21.01	1031.98	296.35	19081.51	747.05	1941.08	17887.48	19828.56
1993	18.58	2.90	2.10	19.38	21.48	1022.52	294.08	18995.97	852.21	2144.07	17704.11	19848.18
1994	21.46	3.33	2.37	22.42	24.79	1066.21	295.19	22878.96	982.98	2526.04	21335.91	23861.94
1995	23.42	3.61	2.67	24.37	27.03	1080.35	312.21	25304.29	1126.83	2879.27	23551.85	26431.12
1996	24.68	3.97	2.97	25.68	28.65	1099.51	321.58	27138.44	1275.51	3265.95	25148.01	28413.96
1997	24.60	4.44	3.19	25.85	29.04	1131.87	337.71	27844.71	1499.41	3614.11	25730.01	29344.12
1998	24.49	4.81	3.18	26.13	29.31	1140.31	372.30	27927.87	1792.07	3626.02	26093.92	29719.95
1999	24.81	4.93	3.22	26.51	29.74	1149.49	380.11	28518.44	1872.34	3707.03	26683.75	30390.78
2000	25.93	5.45	3.50	27.88	31.38	1160.83	388.18	30096.68	2117.28	4066.95	28147.01	32213.96
2001	27.51	5.80	3.96	29.35	33.31	1178.24	394.01	32418.02	2283.61	4662.01	30039.63	34701.64
2002	28.98	6.11	4.36	30.73	35.09	1195.92	399.92	34661.38	2441.64	5210.27	31892.76	37103.02
2003	30.39	6.40	4.74	32.05	36.79	1213.86	405.91	36883.76	2598.19	5752.55	33729.40	39481.95
2004	31.86	6.71	5.15	33.42	38.57	1232.07	412.00	39256.47	2765.33	6351.27	35670.53	42021.80

Continued...

TABLE III.13 DOMESTIC AVIATION PROJECTIONS *(Continued)*

Year	DPASS (million)	RPASS (million)	FPASS (million)	APASS (million)	TPASS (million)	DAVKM (km)	RAVKM (km)	DPASSKM (million)	RPASSKM (million)	FPASSKM (million)	APASSKM (million)	TPASSKM (million)
2005	33.36	7.03	5.61	34.78	40.38	1250.55	418.18	41713.84	2938.43	7012.31	37639.96	44652.27
2006	34.90	7.35	6.10	36.15	42.25	1269.30	424.46	44299.53	3120.58	7742.15	39677.96	47420.11
2007	36.52	7.69	6.63	37.58	44.21	1288.34	430.82	47047.28	3314.14	8547.95	41813.47	50361.42
2008	38.20	8.05	7.22	39.03	46.25	1307.67	437.28	49957.13	3519.11	9437.62	44038.63	53476.25
2009	39.96	8.42	7.85	40.53	48.38	1327.28	443.84	53041.21	3736.37	10419.88	46357.70	56777.57
2010	41.80	8.81	8.54	42.06	50.60	1347.19	450.50	56311.77	3966.75	11504.38	48774.15	60278.52
2011	43.74	9.21	9.29	43.66	52.95	1367.40	457.26	59804.44	4212.78	12701.75	51315.48	64017.22
2012	45.77	9.64	10.10	45.31	55.42	1387.91	464.12	63529.96	4475.22	14023.74	53981.44	68005.18
2013	47.91	10.09	10.99	47.01	58.00	1408.73	471.08	67489.92	4754.17	15483.32	56760.77	72244.09
2014	50.14	10.56	11.96	48.75	60.71	1429.86	478.15	71698.35	5050.62	17094.82	59654.16	76748.98
2015	52.48	11.06	13.00	50.53	63.54	1451.31	485.32	76168.60	5365.52	18874.05	62660.07	81534.12
2016	54.92	11.57	14.15	52.35	66.49	1473.08	492.60	80908.25	5699.39	20838.45	65769.19	86607.64
2017	57.47	12.11	15.39	54.18	69.57	1495.18	499.99	85921.75	6052.56	23007.31	68967.01	91974.31
2018	60.10	12.66	16.74	56.03	72.76	1517.60	507.49	91212.39	6425.25	25401.90	72235.74	97637.64
2019	62.83	13.24	18.21	57.86	76.07	1540.37	515.10	96782.21	6817.60	28045.72	75554.09	103599.81
2020	65.65	13.83	19.81	59.67	79.48	1563.47	522.83	102641.75	7230.36	30964.70	78907.41	109872.11

Continued...

TABLE III.13 DOMESTIC AVIATION PROJECTIONS *(Continued)*

Year	SKM (million)	LF (%)	RGNF ($m)	RMEDF	FI (L/skm)	FC Domestic civil aviation Avtur (ML)	FC Total domestic Avtur (ML)
1982	14933.23	70.1	81552	118.74	0.0646	964.5	1205.65
1983	14247.86	65.9	80053	129.71	0.0656	934.9	1168.65
1984	13966.23	69.9	85632	131.46	0.0666	930.7	1163.32
1985	14733.10	72.0	90338	127.53	0.0648	954.6	1193.22
1986	16109.85	71.9	92375	124.81	0.0637	1026.7	1283.38
1987	17333.77	71.4	96573	123.66	0.0615	1066.9	1333.58
1988	18321.84	74.4	101256	123.08	0.0623	1142.3	1427.82
1989	18821.36	75.2	106166	121.10	0.0598	1125.5	1406.88
1990	14846.97	70.9	108305	126.96	0.0606	899.4	1124.31
1991	21748.11	69.7	107204	111.61	0.0529	1150.2	1437.69
1992	25703.40	77.1	109118	103.59	0.0488	1255.6	1569.45
1993	26293.80	75.5	113063	97.12	0.0500	1313.6	1642.06
1994	32154.35	74.2	119169	97.89	0.0428	1377.7	1722.14
1995	36767.51	71.9	124360	94.76	0.0435	1601.1	2001.33
1996	39761.39	71.5	128457	91.41	0.0440	1748.9	2186.10
1997	41423.35	70.8	133455	99.85	0.0441	1826.6	2283.27
1998	41076.58	72.4	140314	101.66	0.0445	1828.5	2285.62
1999	41466.83	73.3	146821	101.85	0.0434	1801.4	2251.71
2000	42952.84	75.0	153540	111.98	0.0440	1888.6	2360.72
2001	46268.85	75.0	159248	108.19	0.0433	2001.23	2501.54
2002	49470.70	75.0	164821	106.79	0.0425	2104.86	2631.08

Continued...

TABLE III.13 DOMESTIC AVIATION PROJECTIONS *(Continued)*

Year	*SKM (million)*	*LF (%)*	*RGNF ($m)*	*RMEDF*	*FI (L/skm)*	*FC Domestic civil aviation Avtur (ML)*	*FC Total domestic Avtur (ML)*
2003	52642.60	75.0	170590	105.40	0.0419	2203.33	2754.16
2004	56029.07	75.0	176561	104.03	0.0412	2306.86	2883.58
2005	59536.36	75.0	182140	102.68	0.0405	2411.33	3014.17
2006	63226.81	75.0	187987	101.34	0.0398	2519.09	3148.86
2007	67148.56	75.0	193890	100.02	0.0392	2631.75	3289.69
2008	71301.66	75.0	199900	98.72	0.0386	2749.00	3436.25
2009	75703.43	75.0	205997	97.44	0.0379	2871.16	3588.95
2010	80371.36	75.0	212198	96.17	0.0373	2998.54	3748.17
2011	85356.30	75.0	218649	94.92	0.0367	3132.64	3915.80
2012	90673.58	75.0	225230	93.69	0.0361	3273.57	4091.97
2013	96325.46	75.0	231919	92.47	0.0355	3420.97	4276.21
2014	102331.97	75.0	238714	91.27	0.0349	3575.08	4468.85
2015	108712.16	75.0	245589	90.08	0.0344	3736.11	4670.14
2016	115476.85	75.0	252490	88.91	0.0338	3903.94	4879.92
2017	122632.42	75.0	259358	87.76	0.0333	4078.31	5097.88
2018	130183.52	75.0	266127	86.61	0.0327	4258.90	5323.62
2019	138133.08	75.0	272727	85.49	0.0322	4445.35	5556.68
2020	146496.15	75.0	279136	84.38	0.0317	4637.68	5797.10

Sources: BTRE estimates; ABS (2001c); BTRE Indicators Database; DISR (2001); AVSTATS (2001); BTCE (1995a).

TABLE III.14 AVIATION GASOLINE FUEL CONSUMPTION PROJECTIONS

Year	Fuel Consumption (million litres)
1974	105.74
1975	105.74
1976	105.74
1977	110.27
1978	114.80
1979	114.80
1980	114.80
1981	113.29
1982	111.78
1983	110.27
1984	108.76
1985	108.76
1986	108.76
1987	113.29
1988	117.82
1989	123.87
1990	129.91
1991	105.74
1992	99.70
1993	105.74
1994	102.60
1995	104.50
1996	101.50
1997	102.54
1998	104.00
1999	105.80
2000	103.30
2001	103.30
2002	103.30
2003	103.30
2004	103.30
2005	103.30
2006	103.30
2007	103.30
2008	103.30
2009	103.30
2010	103.30
2011	103.30
2012	103.30
2013	103.30
2014	103.30
2015	103.30
2016	103.30
2017	103.30
2018	103.30
2019	103.30
2020	103.30

Sources: BTRE estimates; DISR (2001); BTCE (1995a); Bush et al. (1993: p. 112)

TABLE III.15 DOMESTIC AVIATION TURBINE FUEL— PROJECTED GREENHOUSE GAS EMISSIONS

Year	FC (ML)	FC (PJ)	CO_2 (Gg)	NO_X (Gg)	CH_4 (Gg)	NMVOC (Gg)	CO (Gg)	N_2O (Gg)	Total CO_2 equivalent (Gg)
1974	715.89	26.34	1786.2	7.113	0.029	0.263	2.081	0.053	1803.7
1975	790.34	29.08	1971.9	7.853	0.032	0.291	2.298	0.058	1991.3
1976	799.64	29.43	1995.1	7.945	0.032	0.294	2.325	0.059	2014.8
1977	822.99	30.29	2053.4	8.177	0.033	0.303	2.393	0.061	2073.6
1978	878.83	32.34	2192.7	8.732	0.036	0.323	2.555	0.065	2214.3
1979	864.90	31.83	2158.0	8.594	0.035	0.318	2.514	0.064	2179.2
1980	902.32	33.21	2251.3	8.965	0.037	0.332	2.623	0.066	2273.3
1981	899.08	33.09	2243.2	8.933	0.036	0.331	2.614	0.066	2265.2
1982	964.52	35.49	2406.5	9.583	0.039	0.355	2.804	0.071	2430.1
1983	934.92	34.41	2332.7	9.289	0.038	0.344	2.718	0.069	2355.5
1984	930.66	34.25	2322.0	9.247	0.038	0.342	2.706	0.068	2344.7
1985	954.58	35.13	2381.7	9.485	0.039	0.351	2.775	0.070	2405.0
1986	1026.70	37.78	2561.7	10.201	0.042	0.378	2.985	0.076	2586.7
1987	1066.86	39.26	2661.9	10.600	0.043	0.393	3.102	0.079	2687.9
1988	1142.26	42.04	2850.0	11.349	0.046	0.420	3.321	0.084	2877.8
1989	1125.50	41.42	2808.2	11.183	0.046	0.414	3.272	0.083	2835.6
1990	899.45	33.10	2244.2	8.937	0.036	0.331	2.615	0.066	2266.1
1991	1150.15	42.33	2869.7	11.428	0.047	0.423	3.344	0.085	2897.7
1992	1255.56	46.20	3132.7	12.475	0.051	0.462	3.650	0.092	3163.3
1993	1313.65	48.34	3277.6	13.052	0.053	0.483	3.819	0.097	3309.7
1994	1377.71	50.70	3437.5	13.689	0.056	0.507	4.005	0.101	3471.1
1995	1601.06	58.92	3994.7	15.908	0.065	0.589	4.655	0.118	4033.8
1996	1748.88	64.36	4363.5	17.377	0.071	0.644	5.084	0.129	4406.2
1997	1826.62	67.22	4557.5	18.149	0.074	0.672	5.310	0.134	4602.1
1998	1828.49	67.29	4562.2	18.168	0.074	0.673	5.316	0.135	4606.8
1999	1801.37	66.29	4494.5	17.898	0.073	0.663	5.237	0.133	4538.4
2000	1888.57	69.50	4712.1	18.765	0.076	0.695	5.490	0.139	4758.2

Continued...

TABLE III.15 DOMESTIC AVIATION TURBINE FUEL—PROJECTED GREENHOUSE GAS EMISSIONS
(Continued)

Year	FC (ML)	FC (PJ)	CO_2 (Gg)	NO_X (Gg)	CH_4 (Gg)	NMVOC (Gg)	CO (Gg)	N_2O (Gg)	Total CO_2 equivalent (Gg)
2001	2001.23	73.65	4993.2	19.884	0.081	0.736	5.818	0.147	5042.0
2002	2104.86	77.46	5251.7	20.914	0.085	0.775	6.119	0.155	5303.1
2003	2203.33	81.08	5497.4	21.892	0.089	0.811	6.406	0.162	5551.2
2004	2306.86	84.89	5755.7	22.921	0.093	0.849	6.707	0.170	5812.0
2005	2411.33	88.74	6016.4	23.959	0.098	0.887	7.010	0.177	6075.2
2006	2519.09	92.70	6285.2	25.030	0.102	0.927	7.323	0.185	6346.7
2007	2631.75	96.85	6566.3	26.149	0.107	0.968	7.651	0.194	6630.5
2008	2749.00	101.16	6858.9	27.314	0.111	1.012	7.992	0.202	6925.9
2009	2871.16	105.66	7163.7	28.528	0.116	1.057	8.347	0.211	7233.7
2010	2998.54	110.35	7481.5	29.793	0.121	1.103	8.717	0.221	7554.6
2011	3132.64	115.28	7816.1	31.126	0.127	1.153	9.107	0.231	7892.5
2012	3273.57	120.47	8167.7	32.526	0.133	1.205	9.517	0.241	8247.6
2013	3420.97	125.89	8535.5	33.991	0.138	1.259	9.945	0.252	8618.9
2014	3575.08	131.56	8920.0	35.522	0.145	1.316	10.393	0.263	9007.2
2015	3736.11	137.49	9321.7	37.122	0.151	1.375	10.862	0.275	9412.9
2016	3903.94	143.66	9740.5	38.790	0.158	1.437	11.350	0.287	9835.7
2017	4078.31	150.08	10175.5	40.522	0.165	1.501	11.856	0.300	10275.1
2018	4258.90	156.73	10626.1	42.316	0.172	1.567	12.381	0.313	10730.0
2019	4445.35	163.59	11091.3	44.169	0.180	1.636	12.924	0.327	11199.8
2020	4637.68	170.67	11571.2	46.080	0.188	1.707	13.483	0.341	11684.4

Sources: BTRE estimates; BTCE (1995a).

TABLE III.16 DOMESTIC AVIATION GASOLINE— PROJECTED GREENHOUSE GAS EMISSIONS

Year	FC (ML)	FC (PJ)	CO_2 (Gg)	NO_X (Gg)	CH_4 (Gg)	NMVOC (Gg)	CO (Gg)	N_2O (Gg)	Total CO_2 equivalent (Gg)
1974	105.74	3.50	238.0	0.266	0.199	1.795	79.80	0.003	243.9
1975	105.74	3.50	238.0	0.266	0.199	1.795	79.80	0.003	243.9
1976	105.74	3.50	238.0	0.266	0.199	1.795	79.80	0.003	243.9
1977	110.27	3.65	248.2	0.277	0.208	1.872	83.22	0.003	254.3
1978	114.80	3.80	258.4	0.289	0.217	1.949	86.64	0.003	264.8
1979	114.80	3.80	258.4	0.289	0.217	1.949	86.64	0.003	264.8
1980	114.80	3.80	258.4	0.289	0.217	1.949	86.64	0.003	264.0
1981	113.29	3.75	255.0	0.285	0.214	1.924	85.50	0.003	260.6
1982	111.78	3.70	251.6	0.281	0.211	1.898	84.36	0.003	257.1
1983	110.27	3.65	248.2	0.277	0.208	1.872	83.22	0.003	253.6
1984	108.76	3.60	244.8	0.274	0.205	1.847	82.08	0.003	250.1
1985	108.76	3.60	244.8	0.274	0.205	1.847	82.08	0.003	250.1
1986	108.76	3.60	244.8	0.274	0.205	1.847	82.08	0.003	250.1
1987	113.29	3.75	255.0	0.285	0.214	1.924	85.50	0.003	260.6
1988	117.82	3.90	265.2	0.296	0.222	2.001	88.92	0.004	271.0
1989	123.87	4.10	278.8	0.312	0.234	2.103	93.48	0.004	284.9
1990	129.91	4.30	292.4	0.327	0.245	2.206	98.04	0.004	298.8
1991	105.74	3.50	238.0	0.266	0.199	1.795	79.80	0.003	243.2
1992	99.70	3.30	224.4	0.251	0.188	1.693	75.24	0.003	229.3
1993	105.74	3.50	238.0	0.266	0.199	1.795	79.80	0.003	243.2
1994	102.60	3.40	230.9	0.258	0.194	1.742	77.43	0.003	236.0
1995	104.50	3.46	235.2	0.263	0.197	1.774	78.86	0.003	240.3
1996	101.50	3.36	228.5	0.255	0.192	1.724	76.60	0.003	233.4
1997	102.54	3.39	230.8	0.258	0.193	1.741	77.38	0.003	235.8
1998	104.00	3.44	234.1	0.262	0.196	1.766	78.49	0.003	239.2
1999	105.80	3.50	238.1	0.266	0.200	1.797	79.85	0.003	243.3
2000	103.30	3.42	232.5	0.260	0.195	1.754	77.96	0.003	237.6
2001	103.30	3.42	232.5	0.260	0.195	1.754	77.96	0.003	237.6
2002	103.30	3.42	232.5	0.260	0.195	1.754	77.96	0.003	237.6
2003	103.30	3.42	232.5	0.260	0.195	1.754	77.96	0.003	237.6
2004	103.30	3.42	232.5	0.260	0.195	1.754	77.96	0.003	237.6
2005	103.30	3.42	232.5	0.260	0.195	1.754	77.96	0.003	237.6
2006	103.30	3.42	232.5	0.260	0.195	1.754	77.96	0.003	237.6
2007	103.30	3.42	232.5	0.260	0.195	1.754	77.96	0.003	237.6
2008	103.30	3.42	232.5	0.260	0.195	1.754	77.96	0.003	237.6
2009	103.30	3.42	232.5	0.260	0.195	1.754	77.96	0.003	237.6
2010	103.30	3.42	232.5	0.260	0.195	1.754	77.96	0.003	237.6

Continued...

TABLE III.16 DOMESTIC AVIATION GASOLINE— PROJECTED GREENHOUSE GAS EMISSIONS *(Continued)*

Year	FC (ML)	FC (PJ)	CO_2 (Gg)	NO_X (Gg)	CH_4 (Gg)	NMVOC (Gg)	CO (Gg)	N_2O (Gg)	Total CO_2 equivalent (Gg)
2011	103.30	3.42	232.5	0.260	0.195	1.754	77.96	0.003	237.6
2012	103.30	3.42	232.5	0.260	0.195	1.754	77.96	0.003	237.6
2013	103.30	3.42	232.5	0.260	0.195	1.754	77.96	0.003	237.6
2014	103.30	3.42	232.5	0.260	0.195	1.754	77.96	0.003	237.6
2015	103.30	3.42	232.5	0.260	0.195	1.754	77.96	0.003	237.6
2016	103.30	3.42	232.5	0.260	0.195	1.754	77.96	0.003	237.6
2017	103.30	3.42	232.5	0.260	0.195	1.754	77.96	0.003	237.6
2018	103.30	3.42	232.5	0.260	0.195	1.754	77.96	0.003	237.6
2019	103.30	3.42	232.5	0.260	0.195	1.754	77.96	0.003	237.6
2020	103.30	3.42	232.5	0.260	0.195	1.754	77.96	0.003	237.6

Sources: BTRE estimates; BTCE (1995a).

TABLE III.17 TOTAL DOMESTIC AVIATION EMISSION PROJECTIONS

Year	FC (ML)	FC (PJ)	CO_2 (Gg)	NO_X (Gg)	CH_4 (Gg)	NMVOC (Gg)	CO (Gg)	N_2O (Gg)	Total CO_2 equivalent (Gg)
1974	821.63	29.84	2024.2	7.38	0.23	2.06	81.88	0.06	2047.6
1975	896.08	32.58	2209.9	8.12	0.23	2.09	82.10	0.06	2235.2
1976	905.38	32.93	2233.1	8.21	0.23	2.09	82.12	0.06	2258.7
1977	933.26	33.94	2301.6	8.45	0.24	2.18	85.61	0.06	2327.9
1978	993.63	36.14	2451.1	9.02	0.25	2.27	89.19	0.07	2479.1
1979	979.70	35.63	2416.4	8.88	0.25	2.27	89.15	0.07	2444.0
1980	1017.12	37.01	2509.7	9.25	0.25	2.28	89.26	0.07	2537.4
1981	1012.37	36.84	2498.2	9.22	0.25	2.25	88.11	0.07	2525.7
1982	1076.30	39.19	2658.1	9.86	0.25	2.25	87.16	0.07	2687.1
1983	1045.19	38.05	2580.9	9.57	0.25	2.22	85.94	0.07	2609.1
1984	1039.42	37.85	2566.8	9.52	0.24	2.19	84.78	0.07	2594.9
1985	1063.34	38.73	2626.5	9.76	0.24	2.20	84.85	0.07	2655.1
1986	1135.46	41.38	2806.5	10.47	0.25	2.22	85.06	0.08	2836.9
1987	1180.15	43.01	2916.9	10.89	0.26	2.32	88.60	0.08	2948.5
1988	1260.08	45.93	3115.2	11.65	0.27	2.42	92.24	0.09	3148.8
1989	1249.37	45.52	3087.0	11.49	0.28	2.52	96.75	0.09	3120.5
1990	1029.36	37.40	2536.6	9.26	0.28	2.54	100.66	0.07	2564.9
1991	1255.89	45.83	3107.7	11.69	0.25	2.22	83.14	0.09	3140.9
1992	1355.26	49.50	3357.1	12.73	0.24	2.15	78.89	0.10	3392.6
1993	1419.39	51.84	3515.6	13.32	0.25	2.28	83.62	0.10	3552.9
1994	1480.31	54.10	3668.4	13.95	0.25	2.25	81.44	0.10	3707.0
1995	1705.56	62.38	4229.9	16.17	0.26	2.36	83.52	0.12	4274.1
1996	1850.38	67.72	4592.0	17.63	0.26	2.37	81.68	0.13	4639.6
1997	1929.16	70.61	4788.3	18.41	0.27	2.41	82.70	0.14	4837.9
1998	1932.49	70.73	4796.3	18.43	0.27	2.44	83.80	0.14	4846.0
1999	1907.17	69.79	4732.6	18.16	0.27	2.46	85.08	0.14	4781.8
2000	1991.87	72.92	4944.6	19.02	0.27	2.45	83.45	0.14	4995.7
2001	2104.53	77.06	5225.7	20.14	0.28	2.49	83.78	0.15	5279.6
2002	2208.16	80.88	5484.2	21.17	0.28	2.53	84.08	0.16	5540.7
2003	2306.63	84.50	5729.9	22.15	0.28	2.56	84.36	0.17	5788.7
2004	2410.16	88.31	5988.2	23.18	0.29	2.60	84.66	0.17	6049.6
2005	2514.63	92.16	6248.9	24.22	0.29	2.64	84.97	0.18	6312.8
2006	2622.39	96.12	6517.7	25.29	0.30	2.68	85.28	0.19	6584.3
2007	2735.05	100.27	6798.8	26.41	0.30	2.72	85.61	0.20	6868.1
2008	2852.30	104.58	7091.4	27.57	0.31	2.77	85.95	0.21	7163.5
2009	2974.46	109.08	7396.2	28.79	0.31	2.81	86.31	0.21	7471.3
2010	3101.84	113.77	7714.0	30.05	0.32	2.86	86.68	0.22	7792.2

Continued...

TABLE III.17 TOTAL DOMESTIC AVIATION EMISSION PROJECTIONS *(Continued)*

Year	FC (ML)	FC (PJ)	CO_2 (Gg)	NO_X (Gg)	CH_4 (Gg)	NMVOC (Gg)	CO (Gg)	N_2O (Gg)	Total CO_2 equivalent (Gg)
2011	3235.94	118.70	8048.6	31.39	0.32	2.91	87.07	0.23	8130.1
2012	3376.87	123.89	8400.2	32.79	0.33	2.96	87.48	0.24	8485.2
2013	3524.27	129.31	8768.0	34.25	0.33	3.01	87.90	0.25	8856.5
2014	3678.38	134.98	9152.5	35.78	0.34	3.07	88.35	0.27	9244.8
2015	3839.41	140.91	9554.3	37.38	0.35	3.13	88.82	0.28	9650.5
2016	4007.24	147.08	9973.0	39.05	0.35	3.19	89.31	0.29	10073.3
2017	4181.61	153.50	10408.1	40.78	0.36	3.25	89.81	0.30	10512.6
2018	4362.20	160.15	10858.6	42.58	0.37	3.32	90.34	0.32	10967.6
2019	4548.65	167.01	11323.8	44.43	0.37	3.39	90.88	0.33	11437.4
2020	4740.98	174.09	11803.7	46.34	0.38	3.46	91.44	0.34	11921.9

Sources: BTRE estimates; BTCE (1995a).

TABLE III.18 INTERNATIONAL AVIATION PROJECTIONS

Year	INPASS	OUTPASS	AVKMIN (km)	AVKMOUT (km)	IPKM (million)	LF (%)	Alpha	TIPKM (million)
1982	953400	1252300	9923.45	9398.99	42462.74	63.7	0.95	44469.09
1983	931700	1255500	9684.80	9188.62	41119.28	60.3	0.96	42893.38
1984	989000	1306400	9583.04	9219.18	43043.12	63.6	0.96	44724.24
1985	1055000	1494800	9564.04	9222.92	47752.97	66.8	0.97	49423.57
1986	1258300	1491600	9404.50	9107.86	50837.93	67.7	0.97	52410.24
1987	1584500	1578600	9384.32	8857.65	57704.30	68.4	0.97	59401.86
1988	1990500	1639000	9340.02	8869.68	66257.43	70.9	0.97	68106.75
1989	2217300	1836100	9524.83	9014.51	75341.91	69.4	0.97	77331.40
1990	2148800	2089000	9347.45	9068.73	78060.74	67.4	0.98	80004.72
1991	2239500	2107400	9398.25	9021.51	80118.65	64.9	0.98	81993.65
1992	2507900	2177200	9137.87	9042.80	85209.70	65.7	0.98	87076.16
1993	2795800	2289600	9042.61	9014.35	91841.17	65.0	0.98	93715.48
1994	3158900	2296000	9102.73	9009.44	98880.56	67.6	0.98	100898.53
1995	3553500	2417900	9096.78	9068.08	108502.19	66.9	0.98	110716.52
1996	3960500	2601300	8816.80	9047.79	116909.89	66.0	0.98	119295.81
1997	4257400	2826400	8833.51	9082.65	126557.94	67.4	0.98	129140.76
1998	4239800	3039100	9059.80	9069.61	131950.33	66.7	0.98	134643.20
1999	4299900	3201900	9219.88	8819.40	135766.76	68.9	0.98	138537.51
2000	4671300	3338200	9371.62	8973.08	147463.14	69.3	0.98	150472.59
2001	5275652	3733163	9371.62	8973.08	165878.71	65.0	0.98	169984.92
2002	5808942	4006484	9371.62	8973.08	180779.37	65.0	0.98	185254.43
2003	6318753	4251269	9371.62	8973.08	194727.81	65.0	0.98	199548.17
2004	6873307	4511009	9371.62	8973.08	209783.28	65.0	0.98	214976.32
2005	7476530	4769559	9371.62	8973.08	225729.62	65.0	0.98	231317.40
2006	8132694	5034985	9371.62	8973.08	242791.63	65.0	0.98	248801.77
2007	8846445	5312917	9371.62	8973.08	261157.45	65.0	0.98	267622.22
2008	9622837	5601404	9371.62	8973.08	280886.76	65.0	0.98	287839.92
2009	10467367	5900985	9371.62	8973.08	302092.33	65.0	0.98	309570.42
2010	11386017	6212046	9371.62	8973.08	324893.13	65.0	0.98	332935.64
2011	12385290	6539944	9371.62	8973.08	349507.26	65.0	0.98	358159.07
2012	13472262	6884259	9371.62	8973.08	376059.76	65.0	0.98	385368.86
2013	14654630	7242302	9371.62	8973.08	404646.66	65.0	0.98	414663.40
2014	15940767	7613865	9371.62	8973.08	435421.16	65.0	0.98	446199.70
2015	17339779	7998288	9371.62	8973.08	468542.09	65.0	0.98	480140.52
2016	18861573	8393315	9371.62	8973.08	504154.64	65.0	0.98	516634.63
2017	20516924	8795664	9371.62	8973.08	542401.89	65.0	0.98	555828.67
2018	22317554	9201445	9371.62	8973.08	583433.75	65.0	0.98	597876.24
2019	24276214	9606145	9371.62	8973.08	627408.15	65.0	0.98	642939.20
2020	26406771	10006737	9371.62	8973.08	674530.78	65.0	0.98	691228.32

Continued...

TABLE III.18 INTERNATIONAL AVIATION PROJECTIONS
(Continued)

Year	SKM (million)	AFC (ML)	TFC (ML)	FI (L/skm)	G7GDP ($billion)	RNFGDP ($billion)	RTWI (Index)
1982	69810.19	1018.80	2425.71	0.03475	38376	326.125	80.08
1983	71133.30	991.80	2361.43	0.03320	38568	321.203	75.79
1984	70321.14	989.50	2355.95	0.03350	40420	334.021	77.40
1985	73987.38	1114.20	2652.86	0.03586	41942	353.092	71.43
1986	77415.42	1136.40	2705.71	0.03495	43412	368.444	62.10
1987	86844.83	1200.10	2857.38	0.03290	44542	378.588	57.43
1988	96060.30	1357.30	3231.67	0.03364	46386	399.653	60.79
1989	111428.53	1567.00	3730.95	0.03348	48259	416.568	70.47
1990	118701.36	1711.60	4075.24	0.03433	49783	430.689	70.98
1991	126338.44	1780.60	4239.52	0.03356	50269	430.849	69.99
1992	132628.54	1889.08	4497.81	0.03391	50926	432.923	67.83
1993	144273.06	2042.00	4861.90	0.03370	51580	446.732	59.52
1994	149225.15	2101.10	5002.61	0.03352	52592	465.517	58.62
1995	165600.55	2300.47	5477.32	0.03308	54027	490.459	60.51
1996	180674.25	2478.92	5902.19	0.03267	55319	507.995	64.66
1997	191657.88	2560.23	6095.78	0.03181	57020	524.657	68.24
1998	201920.60	2840.72	6763.62	0.03350	58548	550.817	66.81
1999	201128.49	2707.77	6447.08	0.03205	59856	578.941	63.70
2000	217043.72	2526.19	6014.75	0.02771	61958	603.748	62.94
2001	261515.26	3006.22	7157.67	0.02737	64170	628.291	59.19
2002	285006.82	3235.82	7704.33	0.02703	65808	650.865	58.51
2003	306997.18	3442.45	8196.32	0.02670	67453	673.646	58.51
2004	330732.80	3662.82	8721.00	0.02637	69140	697.223	58.51
2005	355872.93	3892.58	9268.06	0.02604	70868	720.137	58.51
2006	382771.95	4135.12	9845.52	0.02572	72640	743.120	58.51
2007	411726.49	4393.00	10459.53	0.02540	74456	766.647	58.51
2008	442830.64	4666.54	11110.81	0.02509	76317	790.528	58.51
2009	476262.18	4956.88	11802.09	0.02478	78225	814.786	58.51
2010	512208.67	5265.19	12536.16	0.02447	80181	839.433	58.51
2011	551013.95	5594.15	13319.40	0.02417	82185	864.857	58.51
2012	592875.17	5944.83	14154.36	0.02387	84240	890.986	58.51
2013	637943.70	6317.76	15042.29	0.02358	86346	917.581	58.51
2014	686461.08	6714.31	15986.46	0.02329	88505	944.603	58.51
2015	738677.72	7135.85	16990.11	0.02300	90717	971.984	58.51
2016	794822.51	7583.42	18055.77	0.02272	92985	999.550	58.51
2017	855121.03	8058.00	19185.72	0.02244	95310	1027.073	58.51
2018	919809.60	8560.57	20382.30	0.02216	97693	1054.301	58.51
2019	989137.24	9092.14	21647.94	0.02189	100135	1080.959	58.51
2020	1063428.19	9654.33	22986.51	0.02162	102638	1106.886	58.51

Sources: BTRE estimates; ABS (2001c); BTRE Indicators Database; AVSTATS (2001); BTCE (1995a); DISR (2001); RBA (2001).

TABLE III.19 KILOMETRES FLOWN BY INBOUND INTERNATIONAL AVIATION PASSENGERS

Country	Distance (km)	Passenger numbers (by year) 1992	1993	1994	1995	1996	1997	1998	1999	2000
New Zealand	2200	459400	480600	487500	501800	612200	675800	695800	718800	773000
Malaysia	6300	52700	69800	87400	103500	122400	138500	124800	128100	146800
Japan	7800	602500	651700	690100	742200	813500	802300	797100	725800	705600
Indonesia	5500	39500	56300	88200	124200	146400	163300	120000	100500	85200
Other Asia	7500	333700	455200	613300	771500	934400	1021000	904300	867400	994200
Europe	17000	555900	594200	676500	747400	756200	835400	914100	983900	1131500
Africa	11000	18900	27600	41100	42200	46700	56200	58400	77800	72000
Pacific Islands	4000	88300	93300	102900	107100	110100	115700	118700	136200	135200
United States	12000	283200	270500	287200	295100	310400	321300	355700	393800	436900
Other	10000	102900	102000	111900	123400	145200	158000	171000	201700	226000
Passengers (million)		2.539	2.803	3.188	3.560	3.999	4.289	4.262	4.336	4.708
Total kilometres (billion)		23.201	25.348	29.020	32.388	35.263	37.891	38.612	39.977	44.125
AVKM		9137.9	9042.6	9102.7	9096.8	8816.8	8833.5	9059.8	9219.9	9371.6

Sources: BTRE estimates; ABS (2001c); BTRE (1995a).

TABLE III.20 KILOMETRES FLOWN BY OUTBOUND INTERNATIONAL AVIATION PASSENGERS

Country	Distance (km)	Passenger numbers (by year) 1992	1993	1994	1995	1996	1997	1998	1999	2000
New Zealand	2200	330000	345600	350900	361100	396900	409600	429100	477600	506500
Malaysia	6300	74100	81800	85500	85800	90800	101900	104200	111700	126400
Japan	7800	47300	47000	43900	42500	44800	50400	56600	61800	64400
Indonesia	5500	175400	197500	206200	213800	238300	279500	324000	349000	261900
Other Asia	7500	448300	488400	490400	549000	603800	647600	681000	737500	782600
Europe	17000	459700	485200	498500	530400	560100	611700	664100	648900	703200
Africa	11000	21800	27200	30000	35500	39700	54500	51100	50500	57700
Pacific Islands	4000	183800	187900	180100	172000	167300	175900	199300	219500	242400
United States	12000	322400	324300	291300	293800	328300	338100	346200	323900	373600
Other	10000	110800	114800	127300	139300	154400	167600	176600	208800	213800
Passengers (million)		2.176	2.302	2.306	2.425	2.626	2.839	3.034	3.191	3.335
Total kilometres (billion)		19.655	20.730	20.759	21.974	23.745	25.766	27.501	28.127	29.903
AVKM		9034.5	9006.5	9001.6	9060.6	9040.9	9076.3	9063.6	8813.9	8967.7

Sources: BTRE estimates; ABS (2001)c; BTRE Indicators Database; BTCE (1995a).

TABLE III.21 INTERNATIONAL AVIATION TURBINE FUEL—PROJECTED GREENHOUSE EMISSIONS

Year	AFC (ML)	AFC (PJ)	CO_2 (Gg)	NO_X (Gg)	CH_4 (Gg)	NMVOC (Gg)	CO (Gg)	N_2O (Gg)	Total CO_2 equivalent (Gg)
1974	756.2	27.83	1886.7	7.235	0.011	0.111	1.391	0.056	1904.8
1975	834.8	30.72	2082.9	7.988	0.012	0.123	1.536	0.061	2102.9
1976	844.7	31.08	2107.5	8.082	0.012	0.124	1.554	0.062	2127.6
1977	869.3	31.99	2169.0	8.318	0.013	0.128	1.6	0.064	2189.7
1978	928.3	34.16	2316.2	8.882	0.014	0.137	1.708	0.068	2338.3
1979	913.6	33.62	2279.4	8.741	0.013	0.134	1.681	0.067	2301.2
1980	953.1	35.07	2378.0	9.119	0.014	0.14	1.754	0.07	2400.8
1981	949.7	34.95	2369.5	9.087	0.014	0.14	1.747	0.07	2392.2
1982	1018.8	37.49	2541.9	9.748	0.015	0.15	1.875	0.075	2566.3
1983	991.8	36.50	2474.6	9.49	0.015	0.146	1.825	0.073	2498.2
1984	989.5	36.41	2468.8	9.468	0.015	0.146	1.821	0.073	2492.5
1985	1114.2	41.00	2780.0	10.661	0.016	0.164	2.05	0.082	2806.6
1986	1136.4	41.82	2835.4	10.873	0.017	0.167	2.091	0.084	2862.5
1987	1200.1	44.16	2994.3	11.483	0.018	0.177	2.208	0.088	3022.9
1988	1357.3	49.95	3386.5	12.987	0.02	0.2	2.497	0.1	3418.9
1989	1567.0	57.67	3909.7	14.993	0.023	0.231	2.883	0.115	3947.1
1990	1711.6	62.99	4270.5	16.377	0.025	0.252	3.149	0.126	4311.4
1991	1780.6	65.53	4442.7	17.037	0.026	0.262	3.276	0.131	4485.2
1992	1889.1	69.52	4713.3	18.075	0.028	0.278	3.476	0.139	4758.4
1993	2042.0	75.15	5094.9	19.538	0.03	0.301	3.757	0.15	5143.6
1994	2101.1	77.32	5242.3	20.103	0.031	0.309	3.866	0.155	5292.5
1995	2300.5	84.66	5739.8	22.011	0.034	0.339	4.233	0.169	5794.7
1996	2478.9	91.22	6185.0	23.718	0.036	0.365	4.561	0.182	6244.2
1997	2560.2	94.22	6387.9	24.496	0.038	0.377	4.711	0.188	6449.0
1998	2840.7	104.54	7087.7	27.18	0.042	0.418	5.227	0.209	7155.5
1999	2707.8	99.65	6756.0	25.908	0.04	0.399	4.982	0.199	6820.6
2000	2526.2	92.96	6303.0	24.171	0.037	0.372	4.648	0.186	6363.2

Continued...

TABLE III.21 INTERNATIONAL AVIATION TURBINE FUEL—PROJECTED GREENHOUSE EMISSIONS (*Continued*)

Year	AFC (ML)	AFC (PJ)	CO_2 (Gg)	NO_X (Gg)	CH_4 (Gg)	NMVOC (Gg)	CO (Gg)	N_2O (Gg)	Total CO_2 equivalent (Gg)
2001	3006.2	110.63	7500.6	28.764	0.044	0.443	5.531	0.221	7572.4
2002	3235.8	119.08	8073.5	30.96	0.048	0.476	5.954	0.238	8150.7
2003	3442.5	126.68	8589.1	32.937	0.051	0.507	6.334	0.253	8671.2
2004	3662.8	134.79	9138.9	35.046	0.054	0.539	6.74	0.27	9226.3
2005	3892.6	143.25	9712.2	37.244	0.057	0.573	7.162	0.286	9805.0
2006	4135.1	152.17	10317.3	39.565	0.061	0.609	7.609	0.304	10416.0
2007	4393.0	161.66	10960.7	42.032	0.065	0.647	8.083	0.323	11065.5
2008	4666.5	171.73	11643.2	44.649	0.069	0.687	8.586	0.343	11754.6
2009	4956.9	182.41	12367.6	47.427	0.073	0.73	9.121	0.365	12485.9
2010	5265.2	193.76	13136.9	50.377	0.078	0.775	9.688	0.388	13262.5
2011	5594.2	205.87	13957.6	53.525	0.082	0.823	10.293	0.412	14091.1
2012	5944.8	218.77	14832.6	56.88	0.088	0.875	10.938	0.438	14974.4
2013	6317.8	232.49	15763.1	60.448	0.093	0.93	11.625	0.465	15913.8
2014	6714.3	247.09	16752.5	64.243	0.099	0.988	12.354	0.494	16912.7
2015	7135.9	262.60	17804.2	68.276	0.105	1.05	13.13	0.525	17974.5
2016	7583.4	279.07	18921.0	72.558	0.112	1.116	13.953	0.558	19101.9
2017	8058.0	296.54	20105.0	77.099	0.119	1.186	14.827	0.593	20297.3
2018	8560.6	315.03	21359.0	81.908	0.126	1.26	15.751	0.63	21563.2
2019	9092.1	334.59	22685.2	86.994	0.134	1.338	16.73	0.669	22902.2
2020	9654.3	355.28	24088.0	92.373	0.142	1.421	17.764	0.711	24318.3

Sources: BTRE estimates; BTCE (1995a).

TABLE III.22 TOTAL CIVIL AVIATION EMISSION PROJECTIONS

Year	AFC (ML)	AFC (PJ)	CO_2 (Gg)	NO_X (Gg)	CH_4 (Gg)	NMVOC (Gg)	CO (Gg)	N_2O (Gg)	Total CO_2 equivalent (Gg)
1974	1577.8	57.67	3910.9	14.61	0.24	2.17	83.27	0.11	3952.4
1975	1730.9	63.31	4292.9	16.11	0.24	2.21	83.63	0.12	4338.1
1976	1750.0	64.01	4340.6	16.29	0.24	2.21	83.68	0.12	4386.3
1977	1802.6	65.93	4470.6	16.77	0.25	2.3	87.21	0.13	4517.7
1978	1921.9	70.30	4767.3	17.9	0.27	2.41	90.9	0.14	4817.4
1979	1893.3	69.25	4695.8	17.62	0.27	2.4	90.83	0.13	4745.2
1980	1970.2	72.08	4887.8	18.37	0.27	2.42	91.01	0.14	4938.2
1981	1962.1	71.78	4867.8	18.3	0.26	2.39	89.86	0.14	4917.9
1982	2095.1	76.69	5200.1	19.61	0.26	2.4	89.04	0.15	5253.4
1983	2037.0	74.55	5055.4	19.06	0.26	2.36	87.76	0.15	5107.3
1984	2028.9	74.26	5035.7	18.99	0.26	2.33	86.61	0.14	5087.3
1985	2177.5	79.73	5406.5	20.42	0.26	2.36	86.9	0.16	5461.7
1986	2271.9	83.20	5641.8	21.35	0.26	2.39	87.15	0.16	5699.3
1987	2380.3	87.17	5911.2	22.37	0.27	2.49	90.81	0.17	5971.4
1988	2617.4	95.88	6501.7	24.63	0.29	2.62	94.73	0.19	6567.7
1989	2816.4	103.18	6996.7	26.49	0.3	2.75	99.64	0.2	7067.7
1990	2741.0	100.39	6807.1	25.64	0.31	2.79	103.8	0.2	6876.3
1991	3036.5	111.35	7550.3	28.73	0.27	2.48	86.42	0.22	7626.1
1992	3244.3	119.02	8070.4	30.8	0.27	2.43	82.37	0.23	8151.0
1993	3461.4	126.99	8610.5	32.86	0.28	2.58	87.38	0.25	8696.5
1994	3581.4	131.42	8910.7	34.05	0.28	2.56	85.3	0.26	8999.5
1995	4006.0	147.04	9969.7	38.18	0.3	2.7	87.75	0.29	10068.8
1996	4329.3	158.94	10777.0	41.35	0.3	2.73	86.25	0.31	10883.8
1997	4489.4	164.83	11176.2	42.9	0.31	2.79	87.41	0.33	11286.9
1998	4773.2	175.27	11884.0	45.61	0.31	2.86	89.03	0.35	12001.5
1999	4614.9	169.44	11488.6	44.07	0.31	2.86	90.06	0.34	11602.4
2000	4518.1	165.88	11247.5	43.2	0.31	2.82	88.1	0.33	11359.0
2001	5110.8	187.69	12726.3	48.91	0.32	2.93	89.31	0.37	12852.0
2002	5444.0	199.96	13557.7	52.13	0.33	3	90.03	0.4	13691.4
2003	5749.1	211.18	14319.0	55.09	0.33	3.07	90.7	0.42	14459.9
2004	6073.0	223.10	15127.1	58.23	0.34	3.14	91.4	0.44	15275.9
2005	6407.2	235.40	15961.0	61.46	0.35	3.21	92.13	0.47	16117.8
2006	6757.5	248.29	16835.0	64.85	0.36	3.29	92.89	0.49	17000.2
2007	7128.1	261.93	17759.6	68.44	0.37	3.37	93.69	0.52	17933.7
2008	7518.8	276.31	18734.6	72.22	0.37	3.45	94.54	0.55	18918.1
2009	7931.3	291.49	19763.8	76.22	0.38	3.54	95.43	0.58	19957.2
2010	8367.0	307.52	20850.8	80.43	0.39	3.63	96.36	0.61	21054.7

Continued...

TABLE III.22 TOTAL CIVIL AVIATION EMISSION PROJECTIONS *(Continued)*

Year	AFC (ML)	AFC (PJ)	CO_2 (Gg)	NO_X (Gg)	CH_4 (Gg)	NMVOC (Gg)	CO (Gg)	N_2O (Gg)	Total CO_2 equivalent (Gg)
2011	8830.1	324.57	22006.2	84.91	0.40	3.73	97.36	0.65	22221.2
2012	9321.7	342.66	23232.8	89.67	0.41	3.83	98.41	0.68	23459.6
2013	9842.0	361.80	24531.0	94.7	0.43	3.94	99.53	0.72	24770.3
2014	10392.7	382.07	25905.0	100.02	0.44	4.06	100.71	0.76	26157.5
2015	10975.3	403.51	27358.5	105.66	0.45	4.18	101.95	0.08	27625.0
2016	11590.7	426.15	28893.9	111.61	0.46	4.31	103.26	0.85	29175.2
2017	12239.6	450.04	30513.1	117.88	0.48	4.44	104.64	0.90	30810.0
2018	12922.8	475.18	32217.6	124.48	0.49	4.58	106.09	0.95	32530.9
2019	13640.8	501.60	34009.1	131.42	0.51	4.73	107.61	1.00	34339.6
2020	14395.3	529.37	35891.7	138.71	0.52	4.88	109.21	1.05	36240.3

Sources: BTRE estimates; BTCE (1995a).

appendix 4

RAIL PROJECTIONS

RAIL MODEL SPECIFICATION

The BTRE model uses a combination of mathematical and econometric models to project rail task levels and the resulting fuel consumption. Because railways use both liquid fossil fuels and electricity, total ‘fuel consumption’ is expressed in petajoules of energy end-use. Fuel consumption is modelled as the product of the railway task and of fuel intensity. The railway task is broken down into the passenger and freight task, each of which has three sectors. The passenger task is comprised of urban passengers on light rail, urban passengers on heavy rail and non-urban passengers. The freight task is comprised of government bulk freight, government non-bulk freight and private freight. Passenger numbers and freight tonnages are modelled and then multiplied by average distances travelled to obtain task levels in passenger–kilometres (pkm) and tonne–kilometres (tkm).

The main bulk commodities carried on government railways are coal and grain, which are carried mostly from inland Australia to coastal ports for export. The tonnage of government bulk freight carried is therefore modelled as a function of total coal and grain export levels (BTCE 1991b: pp. 10–11).

The main commodity carried by private railway systems is iron ore. Production levels of iron ore are therefore used as the explanatory variable when modelling the tonnage of private freight carried.

Non-bulk freight tonnes carried on the government railways are assumed to be a function of income, as measured by the real gross non-farm product (BTCE 1991b: p. 8). Previous research has found freight rates to be statistically insignificant. Freight rates, therefore, are not included here as an explanatory variable (see BTCE 1995a: p. 44).

Non-urban passengers are modelled as a function of income (as measured by the real gross non-farm product). In earlier research, fares were found to be statistically insignificant and so are not included here as an explanatory variable (see BTCE 1995a: p. 44).

Urban rail passenger numbers are modelled separately for light rail (trams and monorail) and heavy rail (trains). For both light and heavy urban rail passengers, income levels and fares were the major explanatory variables. Income levels are measured by Australian private final consumption, and the fares variable (AUSTFAR) is an average over all urban public transport systems. As public transport fares increase (other things being equal) it is expected that fewer people will travel by train or tram.

Long-term projections are, arguably, best carried out using relatively simple models that rely only on variables of most significance in the longer term. The final specification of the model used by the BTRE is outlined in equations IV.1 to IV.7. See table IV.1 for a summary of statistics and diagnostics of the regression models.

TABLE IV.1 RESULTS OF THE BTRE RAIL MODEL

Dependent variable	*Diagnostics*	*Independent variables*	*Coefficient*	*Standard Error*
ln GBT	Adj. R^2 = 0.97	Constant	3.13	0.26
	Period: 1983Q1 to 2000Q2	ln CGEXP	0.72	0.03
	EM: OLS	ERRDUM	0.08	0.01
ln GNBT	Adj. R^2 = 0.77	Constant	5.33	0.87
	Period: 1983Q2 to 1993Q4	ln RGNF	0.91	0.08
	EM: OLS			
ln PFT	Adj. R^2 = 0.96	Constant	7.49	0.26
	Period: 1984Q1 to 2000Q2	ln IOP	0.98	0.03
	EM: OLS	ERRDUM	0.12	0.01
ln PASNU	Adj. R^2 = 0.64	Constant	12.75	1.05
	Period: 1981Q1 to 1999Q2	ln RGNF	0.16	0.09
	EM: OLS	BIDUM	0.06	0.03
		SERDUM	–0.07	0.02
		ADUM	–0.04	0.02
		AIRDUM	0.09	0.04
		ERRDUM	0.07	0.02
ln PASU(H)	Adj. R^2 = 0.89	Constant	14.72	0.27
	Period: 1981Q1 to 2000Q2	ln RAUSPFC	0.53	0.06
	EM: OLS	ln AUSTFAR	–0.44	0.10
ln PASU(L)	Adj. R^2 = 0.51	Constant	–1.02	1.70
	Period: 1991 to 2000 (A)	ln RAUSPFC	0.53	0.46
	EM: OLS	ln AUSTFAR	–0.20	1.16

Notes: Adj. R^2 refers to the adjusted R^2 statistic.
Period refers to the estimation period, where Q denotes quarterly data and A denotes annual data.
EM refers to the estimation method used, where OLS denotes Ordinary Least Squares estimation.

Source: BTRE estimates.

Fuel consumption is derived by multiplying the task level for each of the rail sectors by the estimated fuel intensity for each sector, and summing across all sectors.

$$\begin{aligned} FC = &(GBTKM \times FI_{GB}) + (GNBTKM \times FI_{GNB}) + (PFTKM \times FI_{PFT}) \\ &+ (PASKMNU \times FI_{PASNU}) + (PASKMU(H) \times FI_{PASU\text{-}H}) \\ &+ (PASKMU(L) \times FI_{PASU\text{-}L}) \end{aligned} \quad \text{(IV.1)}$$

where

FC is total rail fuel consumed (measured in petajoules of energy end-use);

GBTKM is government bulk freight tonne-kilometres (measured in billion tonne–kilometres);

FI_{GB} is the fuel intensity of trains carrying government bulk freight (measured in megajoules of energy end-use per tonne–kilometre);

GNBTKM is government non-bulk freight tonne–kilometres (measured in billion tonne–kilometres);

FI_{GNB} is the fuel intensity of trains carrying government non-bulk freight (measured in megajoules per tonne–kilometre);

PFTKM is private freight tonne–kilometres (measured in billion tonne–kilometres);

FI_{PF} is the fuel intensity of trains carrying government private freight (measured in megajoules per tonne–kilometre);

PASKMNU is the number of non-urban passenger kilometres travelled (measured in billion passenger–kilometres);

FI_{PASNU} is the fuel intensity of non-urban trains carrying passengers (measured in megajoules per passenger–kilometre);

PASKMU(H) is the number of heavy rail urban passenger kilometres travelled (measured in billion passenger–kilometres);

$FI_{PASU\text{-}H}$ is the fuel intensity of urban trains carrying passengers (measured in megajoules per passenger–kilometre);

PASKMU(L) is the number of light rail urban passenger kilometres travelled (measured in billion passenger–kilometres); and

$FI_{PASU\text{-}L}$ is the fuel intensity of urban trams and monorail carrying passengers (measured in megajoules per passenger–kilometre).

Government bulk freight tonnes carried are modelled as a function of the combined export level for coal and grain. The model is estimated on the basis of Ordinary Least Squares estimation (OLS) using quarterly data.

$$\ln GBT = 3.13 + 0.72 \ln CGEXP + 0.08\ ERRDUM \quad \text{(IV.2)}$$

where GBT is government bulk freight tonnes carried (measured in million tonnes), CGEXP is the aggregate level of coal and grain exports (measured in thousand tonnes), and ERRDUM is an error dummy variable from 1995Q1 (i.e. the first quarter of 1995) onwards.

Government bulk freight tonne–kilometres travelled is derived by multiplying government bulk freight tonnes carried by an average haul distance.

$$GBTKM = GBT \times \text{average haul distance} \tag{IV.2a}$$

where GBTKM is government bulk freight tonne–kilometres, GBT is government bulk freight tonnes carried and the average haul distance is the average distance travelled by government bulk freight (measured in kilometres).

Government non-bulk freight tonnes carried are modelled as a function of income, as measured by real gross non-farm product. The model is estimated on quarterly data (available only to 1993) using OLS.

$$\ln GNBT = 5.33 + 0.91 \ln RGNF \tag{IV.3}$$

where GNBT is government non-bulk freight tonnes carried (measured in million tonnes) and RGNF is the real gross non-farm product. Government non-bulk tonne–kilometres travelled are derived by multiplying the government non-bulk tonnes carried by an average haul distance.

$$GNBTKM = GNBT \times \text{average haul distance} \tag{IV.3a}$$

where GNBTKM is government non-bulk freight tonne–kilometres, GNBT is government non-bulk freight tonnes carried and the average haul distance is the average distance travelled by government non-bulk freight (measured in kilometres).

Private freight tonnes carried are modelled as a function of iron ore production levels. The model is estimated on quarterly data using OLS.

$$\ln PFT = 7.49 + 0.98 \ln IOP + 0.12\, ERRDUM \tag{IV.4}$$

where PFT is private freight tonnes carried (measured in million tonnes), IOP is the level of iron ore production (measured in thousand tonnes), and ERRDUM is an error dummy variable from 1992Q1 to 1994Q2.

Private freight tonne–kilometres travelled are derived by multiplying private freight tonnes carried by an average haul distance.

$$PFTKM = PFT \times \text{average haul distance} \tag{IV.4a}$$

where PFTKM is private freight tonne–kilometres and the average haul distance is the average distance travelled by private freight (measured in kilometres).

Non-urban passenger numbers are modelled as a function of real gross non-farm product. The model also includes a number of dummy variables to capture the effects of service frequency cuts in Victoria, the introduction of discount airfares, rail strikes, and the bicentenary celebrations in 1988. The model is estimated on quarterly data using OLS.

$$\ln PASNU = 12.75 + 0.16 \ln RGNF - 0.07\ SERDUM - 0.04\ ADUM + 0.09\ AIRDUM + 0.05\ BIDUM + 0.07\ ERRDUM \quad (IV.5)$$

where PASNU is the number of non-urban passengers, RGNF is real gross non-farm product, SERDUM is a dummy variable to account for service frequency cuts in Victorian trains from 1993Q3 onward, ADUM is a dummy variable which accounts for the introduction of discount airfares (from 1991Q1 onwards), AIRDUM is a dummy variable to allow for the airline pilots' dispute (in 1989-90), BIDUM is a dummy variable for the Bicentenary (1988Q1 to 1988Q3), and ERRDUM is an error dummy variable (1981Q1 to 1985Q4).

Non-urban passenger–kilometres (PASKMNU) are derived by multiplying non-urban passenger numbers (PASNU) by an average trip distance, that is

$$PASKMNU = PASNU \times \text{average trip distance} \quad (IV.5a)$$

Urban passenger numbers on trains are modelled as a function of real Australian private final consumption and a real urban public transport fares index. The model is estimated on quarterly data using OLS.

$$\ln PASU(H) = 14.72 + 0.53 \ln RAUSPFC - 0.44 \ln AUSTFAR \quad (IV.6)$$

where PASU(H) is the number of passengers travelling on urban heavy rail, RAUSPFC is real Australian private final consumption and AUSTFAR is a real urban public transport fares index (across all public transport modes).

Urban heavy rail passenger kilometres, PASKMU(H), are then derived by multiplying urban heavy rail passenger numbers, PASU(H), by an average trip distance:

$$PASKMU(H) = PASU(H) \times \text{average trip distance} \quad (IV.6a)$$

Urban passenger numbers on trams and monorail are also modelled as a function of real Australian private final consumption and a real urban public transport fares index. The model is estimated on annual data using OLS.

$$\ln PASU(L) = -1.02 + 0.53 \ln RAUSPFC - 0.20 \ln AUSTFAR \quad (IV.7)$$

where PASU(L) is the number of passengers travelling on urban light rail, with again RAUSPFC real Australian private final consumption and AUSTFAR a real urban public transport fares index (across all public transport modes).

Urban light rail passenger kilometres, PASKMU(L), are also derived by multiplying urban light rail passenger numbers, PASU(L) by an average trip distance:

$$PASKMU(L) = PASU(L) \times \text{average trip distance} \quad (IV.7a)$$

Data collected for each of the variables in equations IV.1 to IV.7a are detailed in table IV.7.

All models assume constant elasticities and are estimated using Ordinary Least Squares. All models, except urban light rail passengers, are estimated using quarterly data (which are then summed to give yearly estimates). PASU(L) is estimated using annual data.

Figures IV.1 to IV.6 graph the historical (or 'actual') and the fitted (or 'predicted') values for the dependent variables in each of the models. Utilising equation IV.I, each of the calculated rail tasks can be multiplied by its relevant fuel intensity and then summed to obtain an estimate of the total rail energy consumption (end-use).

Variables used in the analysis are specified as follows:

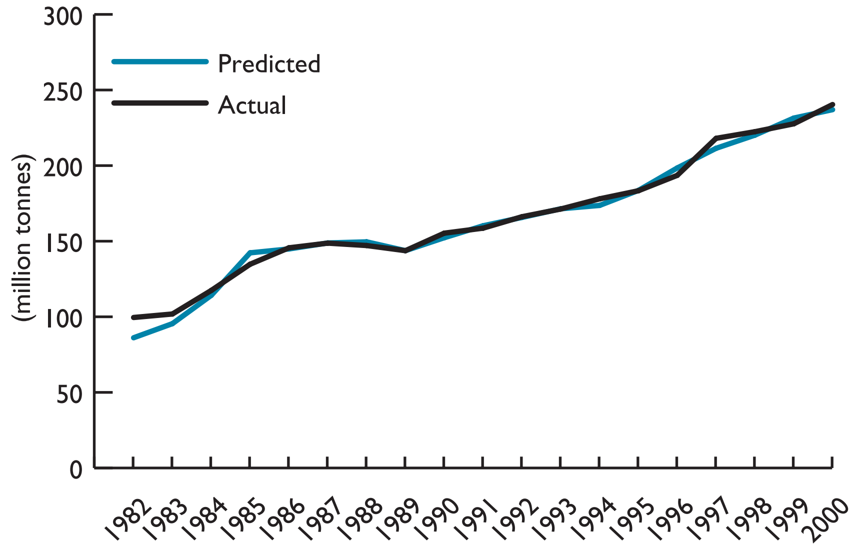
RGNF. The seasonally adjusted real gross non-farm product is an income variable and uses 1999 as the base year. It has been increasing every year since 1982, with the exception of the 1982–83 financial year. It can be expected that as income levels rise the number of non-urban rail passengers will increase, as will government non-bulk freight tonnes carried.

GNBT. Government non-bulk freight tonnes refers to tonnes carried, which differ from tonnes consigned. Tonnes carried are calculated for each State, even when the load travels from one State to another, and will be approximately 2.3 times the level of tonnes consigned (based on Apelbaum 1993: p. 37). Non-bulk commodities include beverages, tobacco, manufactured goods, machinery, transport equipment and live animals. Quarterly figures for government non-bulk tonnes were unavailable from 1994 onwards. Annual figures for 1994–1996 are BTRE estimates and figures for 1997 and 1998 are derived from Apelbaum (2001). The 1999 and 2000 figures are 'forecasts' derived from equation IV.3 above. In the ten year period from 1988 to 1998, the level of government non-bulk tonnes carried increased by 32 per cent.

GBT. Government bulk freight carried consists of crude materials, mineral fuels, lubricants, animal and vegetable oils, fats and waxes, chemical products, briquettes, grains, food, cement, gypsum, bulk fertiliser, iron, steel and petroleum. The major commodities, coal and grain, constitute approximately 75 per cent of the bulk goods carried on government railways (BTCE 1991b: p. 10). Between 1990 and 2000 bulk freight tonnes carried increased by 55 per cent. It is expected that as export levels of coal and grain increase the level of bulk freight tonnes carried will also increase.

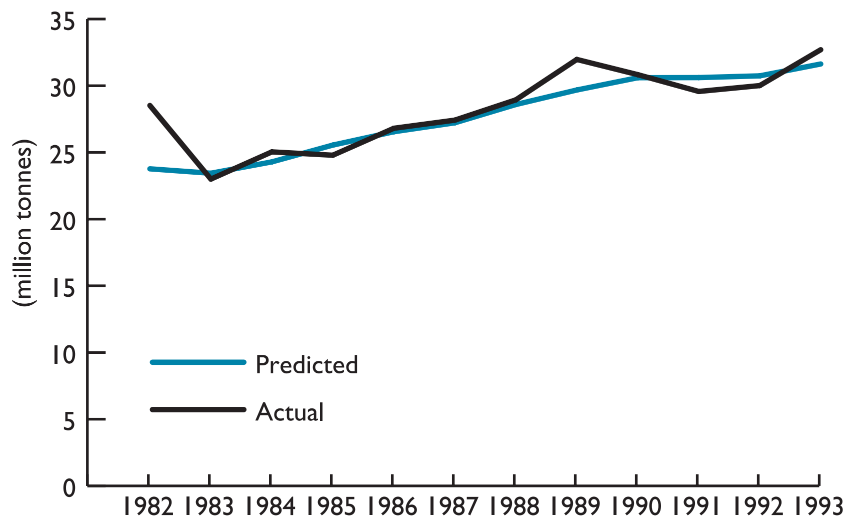
PFT. The major commodity carried on private railways is iron ore, though sugar and coal also constitute a substantial proportion of the freight carried. Between 1990 and 2000 tonnes carried by private railways increased by 35 per cent.

FIGURE IV.1 GOVERNMENT BULK FREIGHT TONNES CARRIED: ACTUAL AND PREDICTED



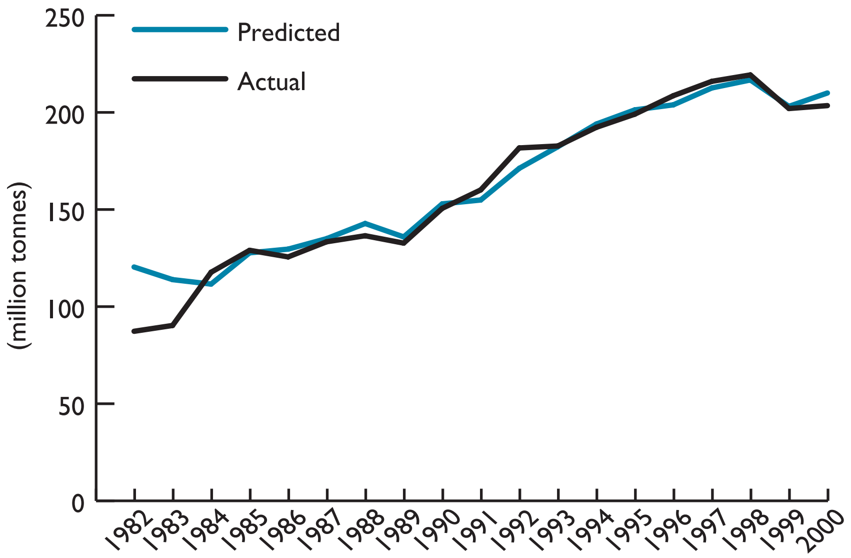
Sources: BTRE Indicators Database, BTRE estimates.

FIGURE IV.2 GOVERNMENT NON-BULK FREIGHT TONNES CARRIED: ACTUAL AND PREDICTED



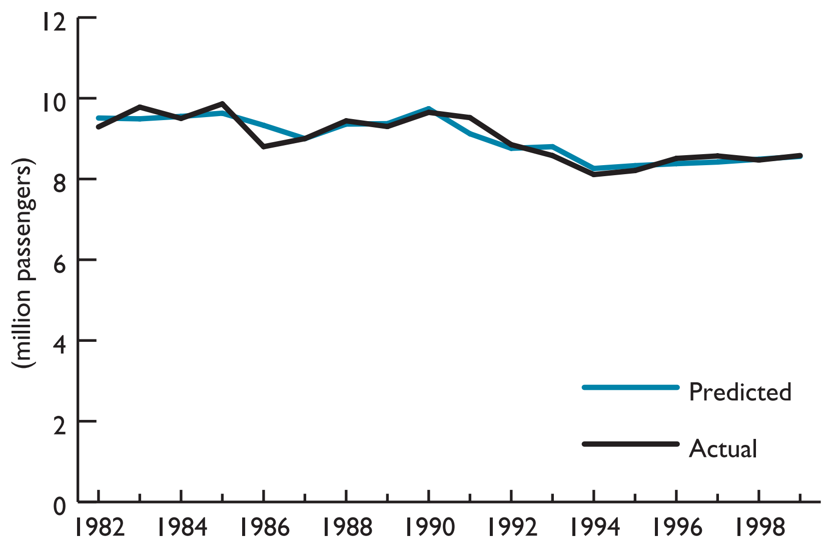
Sources: BTRE Indicators Database, BTRE estimates.

FIGURE IV.3 PRIVATE FREIGHT TONNES CARRIED: ACTUAL AND PREDICTED



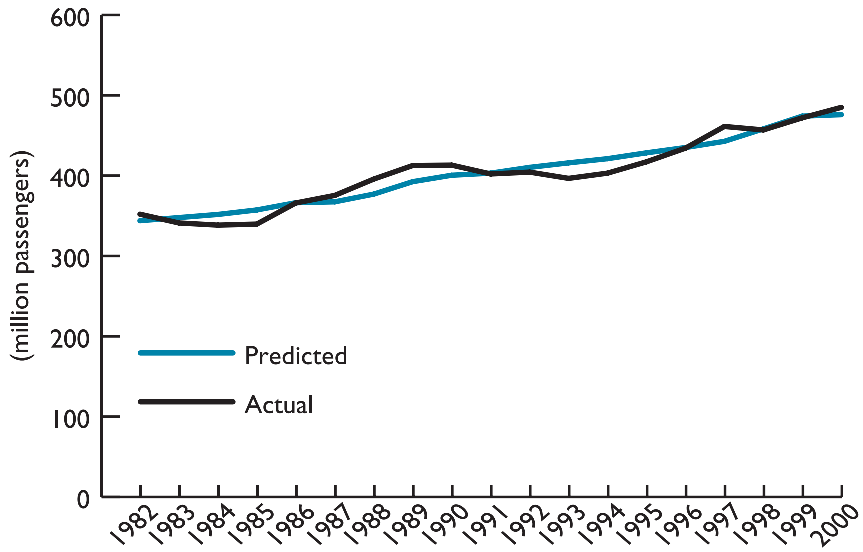
Sources: BTRE Indicators Database, BTRE estimates.

FIGURE IV.4 NON-URBAN PASSENGERS CARRIED: ACTUAL AND PREDICTED



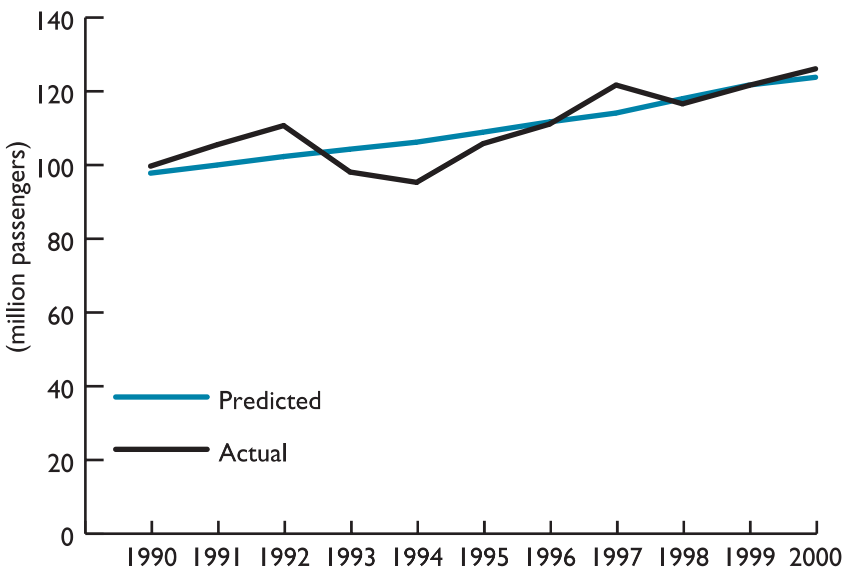
Sources: BTRE Indicators Database, BTRE estimates.

FIGURE IV.5 HEAVY RAIL URBAN PASSENGERS CARRIED: ACTUAL AND PREDICTED



Sources: BTRE Indicators Database, BTRE estimates.

FIGURE IV.6 LIGHT RAIL URBAN PASSENGERS CARRIED: ACTUAL AND PREDICTED



Sources: BTRE Indicators Database, BTRE estimates.

Rail passenger numbers—PASNU, PASU(H), PASU(L). Over the last 10 years, urban train and tram passenger numbers have increased by 21 per cent and 19 per cent, respectively, whilst non-urban rail passenger numbers have declined by 9.5 per cent during the same period.

AUSTFAR. AUSTFAR is an index of real urban public transport fares (across all public transport modes) and uses 1990 as the base year. The data is collected from each State for the BTRE Indicators Database (2002a). Since 1990, real fares have risen by 29 per cent. It is expected that as fares increase fewer passengers will travel by public transport, including rail.

Average distances. Average distances were derived separately for each segment of the rail sector.

For the government freight sector average distances travelled were calculated from data contained in Apelbaum (1997: p. 43) and from the ABS (1986a) for the years 1981–82 to 1983–84. Figures for 1990–91 and for 1994–95 were calculated using data from Apelbaum (1997: p. 43). The 1994–95 figure for government non-bulk freight was estimated using data in Apelbaum (1997). The average distance travelled was set to increase from 1984–85 at a trend growth rate to Apelbaum's figure for the year 1990–91 and again for the 1994–95 figure. The 1994–95 figures were assumed to remain constant for the years 1995–96 to 1999–2000.

The private freight average haul distance was calculated by dividing tonne–kilometres travelled by tonnes carried. The historical data needed are available for the years 1981–82 to 1990–91 in Cosgrove and Gargett (1992). Data for 1991–92 and 1992–93 were obtained from the Bureau's Indicators Database (BTRE 2002a). Data for 1994–95 were calculated using figures contained in Apelbaum (1997: p. 43), and for 1997–98, estimated using figures contained in Apelbaum (2001). A time series for average distance travelled was derived by applying the trend rate of decline for the intervening years. The 1997–98 figure was assumed to remain constant for the years 1998–99 and 1999–2000.

For both urban and non-urban passengers, average trip lengths to the year 1989–90 were calculated by dividing passenger–kilometres by passenger numbers from data available in Cosgrove and Gargett (1992) and the BTRE Indicators Database (2002a). Data for 1990–91, 1994–95 and 1997–98 were calculated using figures in Apelbaum (2001) and the intervening years were set to follow the prevailing trend line.

Table IV.2 summarises the estimated average distances travelled for each of the five main rail categories.

TABLE IV.2 ESTIMATED AVERAGE RAIL DISTANCES TRAVELLED, BY RAIL TASK

Year ending June	Non-urban passengers	Urban passengers	Non-bulk freight	Bulk freight	Private freight
	(km per passenger)		(km per tonne)		
1982	320.5	14.0	495.5	239.5	226.5
1983	314.2	14.0	485.6	224.6	227.3
1984	309.8	14.0	545.0	224.8	215.7
1985	292.9	14.1	558.7	225.3	220.2
1986	303.1	14.0	572.7	225.8	231.8
1987	293.4	14.0	587.0	226.2	229.6
1988	300.6	14.1	601.8	226.7	227.9
1989	287.9	14.3	616.9	227.2	212.6
1990	243.9	14.7	632.3	227.7	219.6
1991	248.2	14.8	648.2	228.2	223.4
1992	255.9	14.7	657.0	224.7	232.6
1993	263.9	15.0	666.0	221.4	224.9
1994	272.2	15.1	675.0	218.0	222.4
1995	280.6	15.1	684.2	214.7	219.9
1996	264.0	14.6	684.2	220.0	224.3
1997	248.5	14.0	684.2	220.0	228.7
1998	233.2	13.6	684.2	220.0	233.2
1999	233.2	13.6	684.2	220.0	233.2
2000	233.2	13.6	684.2	220.0	233.2

Sources: BTRE estimates; ABS (1986: p. 4); Apelbaum (2001: p. 4; 1997: p. 43; 1993: p. 37); Cosgrove & Gargett (1992: pp. 234, 236, 238, 239); BTRE Indicators Database.

Fuel intensity. Fuel consumption is modelled as the product of the task and the fuel intensity (measured in megajoules of energy used per unit task). The task comprises the six categories: private freight tonne–kilometres, government non-bulk tonne–kilometres, government bulk tonne–kilometres, urban heavy-rail passenger–kilometres, urban light rail passenger–kilometres, and non-urban passenger–kilometres. Historical fuel intensities were derived by dividing the energy consumed for a particular sector by its task level in years where the availability of raw data permitted. Some representative values, used in trying to compile consistent time-series for energy intensities, are given in table IV.3. These are based on Apelbaum (2001, 1997) and BTRE data.

TABLE IV.3 ENERGY CONSUMPTION, TASK AND DERIVED FUEL INTENSITY FOR RAIL—REPRESENTATIVE VALUES USING RAW DATA

	1984–85			1987–88			1990–91			1994–95			1997–98		
Rail Sector	EC (PJ)	Task (billion tkm)	FI (MJ/tkm)	EC (PJ)	Task (billion tkm)	FI (MJ/tkm)	EC (PJ)	Task (billion tkm)	FI (MJ/tkm)	EC (PJ)	Task (billion tkm)	FI (MJ/tkm)	EC (PJ)	Task (billion tkm)	FI (MJ/tkm)
Freight															
Govt. bulk															
Electric	0.42	n.a.	n.a.	1.22	n.a.	n.a.	2.18	n.a.	n.a.	2.21	n.a.	n.a.	1.92	n.a.	n.a.
Non-electric	11.78	n.a.	n.a.	10.59	n.a.	n.a.	6.96	n.a.	n.a.	6.45	n.a.	n.a.	7.87	n.a.	n.a.
Total govt. bulk	12.20	30.36	0.40	11.81	33.36	0.35	9.14	36.20	0.25	8.66	39.38	0.22	9.79	48.93	0.20
Govt. non-bulk	9.63	13.85	0.70	9.95	17.41	0.57	9.93	19.17	0.52	11.13	21.69	0.51	10.34	26.19	0.39
Total govt.	21.83	44.21	0.49	21.76	50.77	0.43	19.07	55.36	0.34	19.80	61.07	0.32	20.12	75.12	0.27
Private	3.74	28.40	0.13	4.09	31.12	0.13	4.42	35.76	0.12	4.49	43.79	0.10	4.80	51.15	0.09
Passenger Urban (heavy)		(billion/pkm)	(MJ/pkm)		(billion/pkm)	(MJ/pkm)		(billion/pkm)	(MJ/pkm)		(billion/pkm)	(MJ/pkm)		(billion/pkm)	(MJ/pkm)
Electric	2.86	n.a.	n.a.	3.07	n.a.	n.a.	3.05	n.a.	n.a.	3.19	n.a.	n.a.	3.45	n.a.	n.a.
Non-electric	0.77	n.a.	n.a.	0.72	n.a.	n.a.	0.60	n.a.	n.a.	0.40	n.a.	n.a.	0.60	n.a.	n.a.
Total heavy rail	3.63	5.61	0.65	3.79	6.45	0.59	3.65	6.75	0.54	3.59	7.51	0.48	4.05	7.77	0.52
Light rail (elec.)	0.22	0.69	0.32	0.21	0.73	0.29	0.22	0.70	0.32	0.23	0.57	0.40	0.27	0.62	0.44
Total urban	3.85	6.30	0.61	4.00	7.18	0.56	3.87	7.45	0.52	3.82	8.08	0.47	4.32	8.39	0.52
Total non-urban	2.70	2.89	0.93	2.62	2.84	0.92	2.18	2.48	0.88	1.91	2.27	0.84	2.40	2.38	1.01

n.a. not available

Notes: 1. EC = energy consumption (petajoules), FI = fuel intensity (megajoules per unit task).
2. Energy figures relate to end-use.
3. It is assumed here that electricity consumed in the freight sector is only due to trains carrying bulk freight.

Sources: BTRE estimates using data from Bush et al. (1993: p. 112); Apelbaum (2001; 1997: p. 126; 1993: pp. 94–95, 100, 153, 158); Cosgrove & Gargett (1992); BTRE Indicators Database.

Due to lack of data on the amount of fuel consumed by each category, fuel intensities could only be calculated for some years. Time series for each category were thus derived by interpolating for intervening years. Table IV.4 details the derived (smoothed) fuel intensity series for each of the rail tasks.

TABLE IV.4 ASSUMED FUEL INTENSITY TREND FOR RAIL

Year ending June	Non-urban passenger	Heavy rail urban passenger	Light rail urban passenger	Government non-bulk freight	Government bulk freight	Private freight
		(MJ/pkm)			(MJ/tkm)	
1982	1.08	0.75	0.37	0.81	0.47	0.15
1983	1.03	0.71	0.35	0.77	0.44	0.15
1984	0.98	0.68	0.33	0.73	0.42	0.14
1985	0.93	0.65	0.32	0.70	0.40	0.13
1986	0.93	0.63	0.31	0.65	0.39	0.13
1987	0.93	0.61	0.30	0.61	0.37	0.13
1988	0.92	0.59	0.29	0.57	0.35	0.13
1989	0.91	0.57	0.30	0.55	0.32	0.13
1990	0.89	0.56	0.31	0.54	0.28	0.13
1991	0.88	0.54	0.32	0.52	0.25	0.12
1992	0.87	0.52	0.34	0.52	0.24	0.12
1993	0.86	0.51	0.36	0.52	0.24	0.11
1994	0.85	0.49	0.38	0.51	0.23	0.11
1995	0.84	0.48	0.40	0.51	0.22	0.10
1996	0.89	0.49	0.41	0.47	0.21	0.10
1997	0.95	0.51	0.43	0.43	0.21	0.10
1998	1.01	0.52	0.44	0.39	0.20	0.09
1999	1.01	0.52	0.44	0.39	0.20	0.09
2000	1.01	0.52	0.44	0.39	0.20	0.09

Notes: Some detailed data were available for some years, in particular 1984–85, 1987–88, 1990–91, 1994–95 and 1997–98. Most values are very approximate (many being interpolated or assumed). Series have also been smoothed.
Part of the decline in heavy rail urban passenger and government bulk freight intensities is due to the increasing penetration of electric rail. Since end-use figures do not include generation and transmission losses for electricity, MJ end-use per unit task estimates for electric rail are substantially lower than for diesel rail.

Sources: BTRE estimates using data contained in Bush et al. (1993: p. 112); Apelbaum (2001: p. 5; 1997: p. 126; 1993: pp. 94–95, 98, 100, 153, 158); Cosgrove & Gargett (1992); BTRE Indicators Database.

An average fuel intensity index for the total rail sector can be calculated (using 1987–88 as a base year) by applying the 1987–88 fuel intensities to each of the rail tasks for each year (to determine an estimate of what annual fuel consumption would have been without any fuel efficiency improvements). The 'actual' annual fuel consumption series given in Bush et al. (1993: p. 112) and Apelbaum (2001) divided by the corrected fuel consumption (CFC) multiplied by 100 gives an average fuel intensity index. In 1987–88 (the base year), the average fuel intensity index equals 100. Equations IV.8 and IV.9 summarise the calculation.

$$CFC = \sum_n (Task_n \times FI_{1988,n}) \qquad (IV.8)$$

for n = GB, GNB, PF, PASNU, PASU(H) AND PASU(L)

$$\text{Average FI (index)} = (FC / CFC) \times 100 \qquad (IV.9)$$

where CFC is the corrected fuel consumption (detrending for fuel intensity decreases), $Task_n$ is the specific rail task, $FI_{1988,n}$ is the specific fuel intensity in 1987–88 and FC is the actual total fuel consumption. (Table IV.9 presents the average fuel intensity series for rail transport.)

Assumptions

In order to project total fuel consumption to the year 2019–20 it has been necessary to make assumptions about the explanatory variables in equations IV.1 to IV.7.

Real gross non-farm product (RGNF) was assumed to increase by an average of 3 per cent per annum to the year 2019–20. The exact annual growth rate projections were an average of GTEM, G-Cubed and Monash projections (AGO 2001, pers. comm.)—see Appendix VI, table VI.3. Real Australian private final consumption (RAUSPFC) was assumed to grow at the same rate as RGNF.

Iron ore production levels have been forecast by ABARE (2001: p. 141) to increase by 3 per cent per annum between 2000–01 and 2005–06. It was assumed that ABARE's trend increase over the period from 2000–01 to 2005–06 will continue to the year 2019–20.

ABARE (2001: p. 34) also forecast increases in coal and grain exports for the period 1999–2000 to 2005–06 of 3.2 per cent. These trends were assumed to continue to the year 2019–20.

The real urban fares index (AUSTFAR) was assumed to remain unchanged from the fourth quarter 2000 level (at 136.4) over the projection period.

Average distances travelled by passengers were assumed to remain constant at the level estimated for 2000, for both non-urban and urban travel.

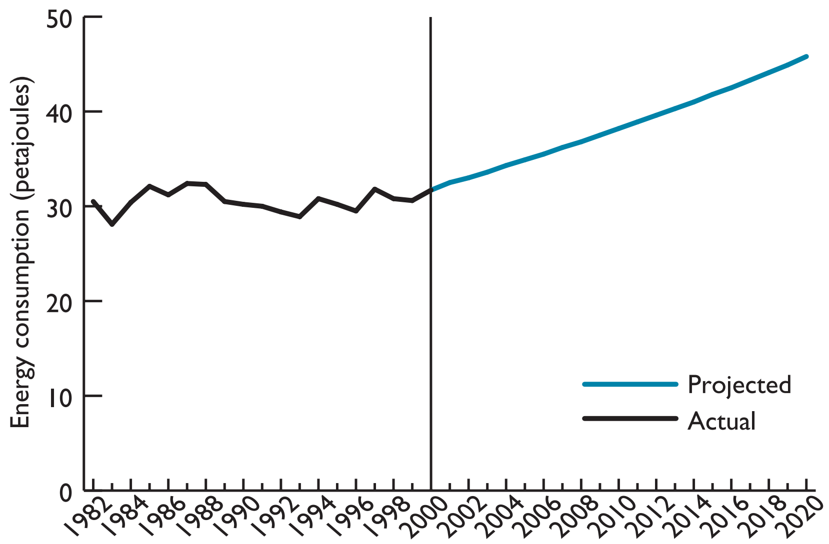
Average freight haul distances were assumed to remain constant at their 1994–95 levels for government railways (684 kilometres for government non-bulk railways and 220 kilometres for government bulk railways). Average freight haul distances were assumed to remain constant at their 1997–98 levels (233 kilometres) for private railways.

Based on long-term trends, it was assumed that fuel efficiency would improve by between 10 and 15 per cent by the year 2019–20, depending on the rail sector (see table IV.8). Though the level of fuel efficiency improvement is a fairly arbitrary assumption, rail is responsible for only a small proportion of total transport energy consumption and the overall base case is not strongly influenced by it. For example, fuel intensity increasing or decreasing by an extra 5 percentage points would only vary projected total transport emissions by less than 0.2 per cent.

Fuel projection results and scenarios

Using the BTRE model and the assumptions about the independent variables detailed above, total rail energy consumption is projected to increase from about 32 PJ in 2000 to around 38 PJ in the year 2010 and to around 46 PJ in the year 2020. Table IV.7 details the results of the projection models for each of the variables. Figure IV.7 graphs the actual and projected trends in total rail energy consumption.

FIGURE IV.7 ACTUAL AND PROJECTED RAIL ENERGY CONSUMPTION



Sources: Bush et al. (1993: p. 112); Apelbaum (2001: p. 5; 1997: p. 126); BTRE estimates

Rail energy end-use is thus estimated to increase by approximately 44 per cent between 1999–2000 and 2019–20. During the same period government non-bulk tonnes carried is estimated to increase by 94 per cent, with government bulk tonnes increasing by 54 per cent and private freight tonnes carried by 96 per cent. For passengers, urban numbers are estimated to increase by 40 per cent and non-urban passenger numbers by only 10 per cent. Basically, rail transport is projected to maintain reasonably strong growth.

Table IV.5 details the effect of changing the assumption on fuel efficiency improvements (as fuel efficiency improves, the level of fuel consumption falls).

TABLE IV.5 RAIL ENERGY CONSUMPTION USING ALTERNATIVE LEVELS OF FUEL EFFICIENCY

Fuel efficiency improvement by 2019–20	*Energy end-use consumption in 2019–20 (petajoules)*
0 per cent	53.4
10–15 per cent [a]	45.8
20 per cent	42.7

a. Base case scenario. The base case has slower projected efficiency improvement than historically for some sectors, and could possibly be regarded as a likely upper bound for future rail energy consumption.

Source: BTRE estimates.

GREENHOUSE GAS EMISSIONS

Railway traction consumes predominantly automotive diesel oil (ADO) and electricity. Based on figures contained in Apelbaum (2001), industrial diesel fuel (IDF), coal and natural gas (NG) consume less than one-tenth of 1 per cent of total fuel consumption for rail transport and are therefore considered insignificant for total emission projection purposes. Each fuel source of energy is responsible for different rates of emission for each of the greenhouse gases. Once projected, it is necessary to breakdown total fuel consumption estimates into the separate fuel types in order to make forecasts of emission levels.

It is assumed that IDF (plus coal and NG) consumption remains at negligible levels over the forecast period.

Electricity consumption is primarily due to the movement of urban passengers and government bulk freight. By multiplying urban passenger–kilometres by the urban passenger fuel intensity, total energy consumed (end-use) for the movement of urban passengers can be calculated.

In 1997–98, over 95 per cent of the urban rail passenger transport task was accomplished by electric rail. It is assumed that this proportion will not change significantly over the period 1999–2000 to 2019–20.

It is assumed that electricity will retain its 20 per cent share of energy consumption by government bulk rail freight, as the sector grows.

The level of ADO consumed is the residual of the total energy consumption projections once the IDF and electricity consumption projections have been subtracted. Table IV.10 details the energy projections.

On an end-use basis, electricity use does not result in emissions of greenhouse gases. Yet the generation of electricity is responsible for significant rates of emission. Emissions from the generation of electricity used by trains and trams are estimated as follows.

Emission levels depend upon the primary fuel used to generate the electricity. New South Wales, Queensland, South Australia and Western Australia use black coal as the major fuel to generate electricity, with smaller amounts of natural gas also being used. Victoria uses brown coal and natural gas.

The energy needed to generate electricity depends on the efficiency with which electricity is generated, and this varies from State to State. The efficiency of electricity generation and transmission is typically stated in terms of the percentage of energy input (PJ of coal, say) which is transformed into energy output (PJ of electricity). Based on figures from Apelbaum (2001, 1993), the average Australian efficiency, excluding Victoria, is around 33.9 per cent (and for Victoria about 27 per cent). That is, for every petajoule of electricity consumed by electric trains and trams, approximately 3 PJ of primary energy are required to generate the electricity end-use. It was assumed that the average efficiency of Australian electricity generation will improve by 10 per cent by the year 2020.

Emission rates differ between the different fuels used to generate the electricity. For Victoria, emission rates will differ during the day because, essentially, brown coal is used for the base load and natural gas for peak loads (Armour & Jordan 1992: p. 7). The BTCE (1995a: p. 59) used figures contained in Armour and Jordan (1992: p.9) and statistics provided by the Victorian Public Transport Corporation (PTC) on proportions of rail car kilometres travelled during peak and off-peak times. These statistics allowed the calculation that on average approximately 283 grams of CO_2 were released for every megajoule of end-use electricity consumed in 1993 by Victorian trains. For the rest of Australia, it was calculated that approximately 271 grams of CO_2 were produced, on average, per megajoule of end-use electricity consumed (BTCE 1995a, NGGIC 1994, Apelbaum 1993). Based on Apelbaum (2001), the BTRE has estimated a weighted average of around 270 grams of CO_2 equivalent per megajoule (of electricity end-use consumed by Australian railways for traction) for the year 2000.

Table IV.6 details the conversion factors used to calculate greenhouse gas emissions for trains and trams.

TABLE IV.6 RAIL EMISSION CONVERSION FACTORS

(grams per megajoule end-use)

Gas	*Electricity*	*ADO*	*IDF*
CO_2	268.92	69.70	69.70
NO_X	1.030	1.710	1.710
CH_4	0.016	0.006	0.006
NMVOC	0.0	0.124	0.124
CO	0.043	0.580	0.580
N_2O	0.002	0.002	0.002

Notes: 0.0 means assumed negligible.
Emission factors for electricity use include the combustion of primary fuels by electric power stations, whereas all other conversion factors refer solely to end-use emissions.

Sources: IPCC/OECD (1994: p. 1.44); BTRE estimates based on NGGIC (1994: p. 12); Amour & Jordan (1992: p. 9); and BTCE (1995a).

Multiplying the fuel consumption of each fuel type by the relevant emission factor (and summing over all fuels), rail carbon dioxide equivalent emission levels are projected to increase from 3518 gigagrams in 1999–2000 to 4114 gigagrams in 2009–10 and to 4848 gigagrams in the year 2014–15. Excluding emissions from electricity generation, carbon dioxide equivalent emission levels are projected to increase from 1782 gigagrams in 1999–2000 to 2186 gigagrams in 2009–10 and to 2651 gigagrams in the year 2019–20 (see table IV.11).

(Note that for projection purposes, the task split between 'government' and 'private' is based on the division of the Australian rail task between public and privately owned railways as at the year 2000. Current (and future) rail privatisation and ownership changes will make the division given here fairly arbitrary — and projections of 'total' rail freight tasks are more meaningful than the 'government' and 'private' freight subtotals.)

The models used to project fuel consumption for rail depend on both the rail task levels and fuel intensity. The BTRE models were derived for use in long-term projections and therefore do not include all variables which may be relevant in the short-term. Of course, the results of the BTRE projections also depend heavily on the assumptions used for the future values of the models' explanatory variables.

TABLE IV.7 RAIL PROJECTIONS

Year ending June	PASNU ('000)	NU average trip (km)	PASKM NU (billion)	RGNF ($million)	PASU(H) (million)	PASU(L) (million)	PASU (million)	U(H) average trip (km)	U(L) average trip (km)	PASKMU(H) (billion)	PASKMU(L) (billion)	PASKMU (billion)	RAUSPFC ($million)	AUSTFAR (index)
1982	9287.82	320.5	2.98	326125	352.00	102.00	454.00	16.3	6.12	5.74	0.62	6.36	95225.0	52.7
1983	9781.54	314.2	3.07	321203	341.15	100.85	442.00	16.3	6.12	5.56	0.62	6.18	107398	59.4
1984	9500.10	309.8	2.94	334021	338.36	105.64	444.00	16.4	6.12	5.55	0.65	6.20	117515	64.4
1985	9860.61	292.9	2.89	353092	339.71	104.13	443.84	16.5	6.24	5.61	0.65	6.25	127632	68.6
1986	8797.05	303.1	2.67	368444	366.01	113.39	479.40	16.4	6.21	6.00	0.70	6.71	143156	74.4
1987	9003.42	293.4	2.64	378588	375.41	117.49	492.90	16.4	6.21	6.16	0.73	6.89	157285	82.7
1988	9438.54	300.6	2.84	399653	395.73	110.02	505.75	16.3	6.21	6.45	0.68	7.13	175871	89.1
1989	9304.57	287.9	2.68	416568	412.65	111.13	523.78	16.5	6.21	6.81	0.69	7.50	196039	92.5
1990	9651.50	243.9	2.35	430689	413.10	87.12	500.22	16.5	6.21	6.83	0.54	7.37	217340	100.0
1991	9523.97	248.2	2.36	430849	402.06	105.53	507.58	17.0	6.29	6.83	0.66	7.49	232508	106.9
1992	8848.63	255.9	2.26	432923	404.45	110.69	515.14	17.1	5.98	6.93	0.66	7.59	244194	108.8
1993	8579.56	263.9	2.26	446732	396.55	98.09	494.64	17.3	5.68	6.85	0.56	7.41	255389	111.3
1994	8108.53	272.2	2.21	465517	403.06	95.32	498.38	17.4	5.40	7.03	0.51	7.54	266377	113.8
1995	8211.77	280.6	2.30	490459	417.24	105.82	523.06	17.6	5.13	7.33	0.54	7.88	282723	117.5
1996	8513.23	264.0	2.25	507995	434.23	111.10	545.34	17.0	5.11	7.37	0.57	7.94	301673	122.6
1997	8566.18	248.5	2.13	524657	461.21	121.73	582.94	16.4	5.08	7.55	0.62	8.17	315354	124.3
1998	8470.91	233.2	1.98	550817	456.91	116.55	573.46	15.8	5.06	7.22	0.59	7.81	335130	123.5
1999	8584.09	233.2	2.00	578941	472.05	121.60	593.64	15.8	5.06	7.46	0.61	8.07	353985	122.1
2000	8615.96	233.2	2.01	603748	484.99	126.10	611.08	15.8	5.06	7.66	0.64	8.30	373113	128.9
2001	8672.22	233.2	2.02	628291	480.89	124.70	605.59	15.8	5.06	7.60	0.63	8.23	398628	136.2
2002	8722.34	233.2	2.03	650865	489.35	126.99	616.34	15.8	5.06	7.73	0.64	8.38	412580	136.4

Continued...

TABLE IV.7 RAIL PROJECTIONS *(Continued)*

Year ending June	PASNU ('000)	NU average trip (km)	PASKM NU (billion)	RGNF ($million)	PASU(H) (million)	PASU(L) (million)	PASU (million)	U(H) average trip (km)	U(L) average trip (km)	PASKMU(H) (billion)	PASKMU(L) (billion)	PASKMU (billion)	RAUSPFC ($million)	AUSTFAR (index)
2003	8771.46	233.2	2.05	673646	498.28	129.33	627.61	15.8	5.06	7.87	0.65	8.53	427020	136.4
2004	8820.86	233.2	2.06	697223	507.37	131.72	639.09	15.8	5.06	8.02	0.67	8.68	441966	136.4
2005	8867.55	233.2	2.07	720137	516.63	134.14	650.77	15.8	5.06	8.16	0.68	8.84	457434	136.4
2006	8913.14	233.2	2.08	743120	526.06	136.62	662.67	15.8	5.06	8.31	0.69	9.00	473445	136.4
2007	8958.61	233.2	2.09	766647	535.66	139.13	674.79	15.8	5.06	8.47	0.70	9.17	490015	136.4
2008	9003.58	233.2	2.10	790528	545.43	141.70	687.13	15.8	5.06	8.62	0.72	9.34	507166	136.4
2009	9048.11	233.2	2.11	814786	555.39	144.31	699.69	15.8	5.06	8.78	0.73	9.51	524917	136.4
2010	9092.24	233.2	2.12	839433	565.52	146.96	712.48	15.8	5.06	8.94	0.74	9.68	543289	136.4
2011	9136.63	233.2	2.13	864857	575.84	149.67	725.51	15.8	5.06	9.10	0.76	9.86	562304	136.4
2012	9181.13	233.2	2.14	890986	586.35	152.43	738.78	15.8	5.06	9.27	0.77	10.04	581984	136.4
2013	9225.32	233.2	2.15	917581	597.05	155.24	752.28	15.8	5.06	9.44	0.78	10.22	602354	136.4
2014	9269.13	233.2	2.16	944603	607.94	158.10	766.04	15.8	5.06	9.61	0.80	10.41	623436	136.4
2015	9312.47	233.2	2.17	971984	619.04	161.01	780.05	15.8	5.06	9.78	0.81	10.60	645256	136.4
2016	9355.08	233.2	2.18	999550	630.33	163.98	794.31	15.8	5.06	9.96	0.83	10.79	667840	136.4
2017	9396.65	233.2	2.19	1027073	641.83	167.00	808.83	15.8	5.06	10.14	0.84	10.99	691215	136.4
2018	9436.88	233.2	2.20	1054301	653.55	170.07	823.62	15.8	5.06	10.33	0.86	11.19	715407	136.4
2019	9475.42	233.2	2.21	1080959	665.47	173.21	838.68	15.8	5.06	10.52	0.88	11.39	740447	136.4
2020	9512.16	233.2	2.22	1106886	677.62	176.40	854.01	15.8	5.06	10.71	0.89	11.60	766362	136.4

Continued...

TABLE IV.7 RAIL PROJECTIONS *(Continued)*

Year ending June	*GNBT (million tonnes)*	*GBT (million tonnes)*	*GNB average haul (km)*	*GB average haul (km)*	*GNBTKM (billion)*	*GBTKM (billion)*	*PFT (million)*	*PF average haul (km)*	*PFTKM (billion)*	*CGEXP ('000 tonnes)*	*IOP ('000 tonnes)*	*FC (PJ)*
1982	28.52	99.54	495.50	239.50	14.13	23.84	87.27	226.45	19.76	54519	86.19	30.5
1983	23.00	101.85	485.60	224.60	11.17	22.88	90.28	227.27	20.52	62699	81.39	28.1
1984	25.04	117.43	545.00	224.80	13.65	26.40	117.70	215.74	25.39	80514	79.74	30.4
1985	24.79	134.75	558.67	225.28	13.85	30.36	128.98	220.16	28.40	109100	91.54	32.1
1986	26.81	145.62	572.68	225.76	15.35	32.87	125.59	231.75	29.11	111863	92.93	31.2
1987	27.42	148.72	587.05	226.24	16.10	33.65	133.36	229.55	30.61	116144	96.89	32.4
1988	28.94	147.14	601.77	226.72	17.41	33.36	136.51	227.94	31.12	116978	102.61	32.3
1989	31.97	143.74	616.87	227.20	19.72	32.66	132.67	212.59	28.20	110716	97.59	30.5
1990	30.83	155.31	632.34	227.69	19.49	35.36	150.55	219.59	33.06	119937	110.06	30.2
1991	29.57	158.63	648.20	228.17	19.17	36.20	160.06	223.42	35.76	128689	111.56	30.0
1992	30.01	166.18	657.02	224.74	19.72	37.35	181.66	232.56	42.25	134861	116.08	29.4
1993	32.70	171.29	665.96	221.35	21.78	37.92	182.74	224.87	41.09	141347	116.13	28.9
1994	33.56	178.01	675.02	218.02	22.65	38.81	192.27	222.38	42.76	143907	123.78	30.8
1995	31.71	183.38	684.20	214.74	21.69	39.38	199.14	219.91	43.79	146628	137.00	30.2
1996	30.55	193.55	684.20	220.00	20.90	42.58	208.56	224.26	46.77	153957	147.88	29.5
1997	37.53	218.04	684.20	220.00	25.68	47.97	216.00	228.68	49.40	168238	154.35	31.8
1998	38.28	222.42	684.20	220.00	26.19	48.93	219.33	233.20	51.15	177854	157.39	30.8
1999	37.02	227.64	684.20	220.00	25.33	50.08	202.00	233.20	47.11	190608	147.27	30.6
2000	38.58	240.39	684.20	220.00	26.39	52.89	203.47	233.20	47.45	197045	152.40	31.7

Continued...

TABLE IV.7 RAIL PROJECTIONS *(Continued)*

Year ending June	*GNBT (million tonnes)*	*GBT (million tonnes)*	*GNB average haul (km)*	*GB average haul (km)*	*GNBTKM (billion)*	*GBTKM (billion)*	*PFT (million)*	*PF average haul (km)*	*PFTKM (billion)*	*CGEXP ('000 tonnes)*	*IOP ('000 tonnes)*	*FC (PJ)*
2001	40.07	241.36	684.20	220.00	27.42	53.10	230.23	233.20	53.69	202071	167.48	32.5
2002	41.44	246.67	684.20	220.00	28.35	54.27	236.96	233.20	55.26	208283	172.51	33.0
2003	42.85	252.26	684.20	220.00	29.32	55.50	243.89	233.20	56.88	214865	177.68	33.6
2004	44.30	257.97	684.20	220.00	30.31	56.75	251.03	233.20	58.54	221655	183.01	34.3
2005	45.80	263.80	684.20	220.00	31.34	58.04	258.37	233.20	60.25	228659	188.50	34.9
2006	47.35	269.78	684.20	220.00	32.40	59.35	265.93	233.20	62.01	235884	194.16	35.5
2007	48.95	275.88	684.20	220.00	33.49	60.69	273.70	233.20	63.83	243338	199.98	36.2
2008	50.60	282.13	684.20	220.00	34.62	62.07	281.71	233.20	65.69	251028	205.98	36.8
2009	52.30	288.51	684.20	220.00	35.78	63.47	289.95	233.20	67.62	258960	212.16	37.5
2010	54.05	295.04	684.20	220.00	36.98	64.91	298.43	233.20	69.59	267144	218.53	38.2
2011	55.86	301.72	684.20	220.00	38.22	66.38	307.16	233.20	71.63	275585	225.08	38.9
2012	57.73	308.55	684.20	220.00	39.50	67.88	316.14	233.20	73.72	284294	231.84	39.6
2013	59.66	315.54	684.20	220.00	40.82	69.42	325.39	233.20	75.88	293277	238.79	40.3
2014	61.65	322.68	684.20	220.00	42.18	70.99	334.91	233.20	78.10	302545	245.95	41.0
2015	63.70	329.98	684.20	220.00	43.58	72.60	344.70	233.20	80.38	312105	253.33	41.8
2016	65.81	337.45	684.20	220.00	45.03	74.24	354.78	233.20	82.74	321968	260.93	42.5
2017	68.00	345.09	684.20	220.00	46.52	75.92	365.16	233.20	85.15	332142	268.76	43.3
2018	70.25	352.90	684.20	220.00	48.06	77.64	375.84	233.20	87.65	342638	276.82	44.1
2019	72.57	360.89	684.20	220.00	49.65	79.40	386.83	233.20	90.21	353465	285.13	44.9
2020	74.97	369.06	684.20	220.00	51.29	81.19	398.15	233.20	92.85	364635	293.68	45.8

Sources: BTRE estimates; BTRE Indicators Database; Apelbaum (2001; 1997: pp. 43, 44, 45); Cosgrove & Gargett (1992); ABS (1986a, p. 4); State Rail and Transit Authorities (2001, pers. comm.); ABS (2001d).

TABLE IV.8 ASSUMED SPECIFIC FUEL INTENSITIES

Year ending June	PASNU (MJ/pkm)	PASU (H) (MJ/pkm)	PASU (L) (MJ/pkm)	GNB (MJ/tkm)	GB (MJ/tkm)	PF (MJ/tkm)
1982	1.08	0.75	0.37	0.81	0.47	0.15
1983	1.03	0.71	0.35	0.77	0.44	0.15
1984	0.98	0.68	0.33	0.73	0.42	0.14
1985	0.93	0.65	0.32	0.70	0.40	0.13
1986	0.93	0.63	0.31	0.65	0.39	0.13
1987	0.93	0.61	0.30	0.61	0.37	0.13
1988	0.92	0.59	0.29	0.57	0.35	0.13
1989	0.91	0.57	0.30	0.55	0.32	0.13
1990	0.89	0.56	0.31	0.54	0.28	0.13
1991	0.88	0.54	0.32	0.52	0.25	0.12
1992	0.87	0.52	0.34	0.52	0.24	0.12
1993	0.86	0.51	0.36	0.52	0.24	0.11
1994	0.85	0.49	0.38	0.51	0.23	0.11
1995	0.84	0.48	0.40	0.51	0.22	0.10
1996	0.89	0.49	0.41	0.47	0.21	0.10
1997	0.95	0.51	0.43	0.43	0.21	0.10
1998	1.01	0.52	0.44	0.39	0.20	0.09
1999	1.01	0.52	0.44	0.39	0.20	0.09
2000	1.01	0.52	0.44	0.39	0.20	0.09
2001	1.00	0.51	0.43	0.39	0.20	0.09
2002	1.00	0.51	0.43	0.39	0.20	0.09
2003	0.99	0.51	0.43	0.39	0.20	0.09
2004	0.99	0.51	0.43	0.38	0.19	0.09
2005	0.98	0.50	0.43	0.38	0.19	0.09
2006	0.98	0.50	0.42	0.38	0.19	0.09
2007	0.97	0.50	0.42	0.37	0.19	0.09
2008	0.97	0.49	0.42	0.37	0.19	0.09
2009	0.96	0.49	0.42	0.37	0.19	0.09
2010	0.96	0.49	0.41	0.36	0.18	0.09
2011	0.95	0.49	0.41	0.36	0.18	0.09
2012	0.95	0.48	0.41	0.36	0.18	0.09
2013	0.94	0.48	0.41	0.36	0.18	0.08
2014	0.94	0.48	0.41	0.35	0.18	0.08
2015	0.93	0.48	0.40	0.35	0.18	0.08
2016	0.93	0.47	0.40	0.35	0.18	0.08
2017	0.92	0.47	0.40	0.34	0.17	0.08
2018	0.92	0.47	0.40	0.34	0.17	0.08
2019	0.91	0.47	0.40	0.34	0.17	0.08
2020	0.91	0.46	0.39	0.34	0.17	0.08

Sources: BTRE estimates using data contained in Bush et al. (1993: p. 112); Apelbaum (2001; 1997; 1993); Cosgrove & Gargett (1992,); BTRE Indicators Database.

TABLE IV.9 RAIL FUEL INTENSITY INDEX

Year ending June	*Average FI index*
1982	121.1
1983	120.9
1984	114.6
1985	113.2
1986	103.2
1987	103.6
1988	100.0
1989	92.5
1990	88.4
1991	86.6
1992	81.1
1993	77.2
1994	79.7
1995	78.0
1996	74.5
1997	71.6
1998	68.9
1999	68.7
2000	68.4
2001	68.0
2002	67.4
2003	66.9
2004	66.4
2005	65.8
2006	65.3
2007	64.8
2008	64.3
2009	63.7
2010	63.2
2011	62.7
2012	62.2
2013	61.7
2014	61.2
2015	60.7
2016	60.3
2017	59.8
2018	59.3
2019	58.8
2020	58.3

Notes: Part of the decline in intensity is due to the increasing penetration of electric rail. End-use figures for electricity consumption do not include generation and transmission losses.

Sources: BTRE estimates using data contained in Bush et al. (1993: p. 112); Apelbaum (2001; 1997; 1993); Cosgrove & Gargett (1992); BTRE Indicators Database.

TABLE IV.10 RAIL ENERGY CONSUMPTION PROJECTIONS (END-USE)

(petajoules)

Year ending June	*ADO/IDF*	*Electricity*	*Total*
1990	24.71	5.46	30.2
1991	24.51	5.50	30.0
1992	23.75	5.66	29.4
1993	23.30	5.63	28.9
1994	25.12	5.65	30.8
1995	24.25	5.93	30.2
1996	23.73	5.76	29.5
1997	25.63	6.14	31.8
1998	24.74	6.03	30.8
1999	24.38	6.22	30.6
2000	25.29	6.42	31.7
2001	26.12	6.35	32.5
2002	26.62	6.43	33.0
2003	27.13	6.51	33.6
2004	27.66	6.60	34.3
2005	28.19	6.68	34.9
2006	28.74	6.77	35.5
2007	29.30	6.86	36.2
2008	29.86	6.95	36.8
2009	30.44	7.04	37.5
2010	31.03	7.13	38.2
2011	31.63	7.22	38.9
2012	32.25	7.32	39.6
2013	32.88	7.41	40.3
2014	33.52	7.51	41.0
2015	34.17	7.61	41.8
2016	34.83	7.71	42.5
2017	35.51	7.81	43.3
2018	36.21	7.91	44.1
2019	36.91	8.02	44.9
2020	37.63	8.12	45.8

Sources: BTRE estimates; Apelbaum (2001; 1997: pp. 121–123); Bush et al. (1993)

TABLE IV.11 RAIL EMISSION PROJECTIONS

(gigagrams)

	CO_2		NO_x		CH_4		NMVOC		CO		N_2O		CO_2 equivalent		Total CO_2
Year	Non-elec	Elec	Non-elec	Elec	Non-elec	Elec	Non-elec	Elec	Non-elec	Elec	Non-elec	Elec	Non-elec	Elec	equivalent
1990	1722	1472	42.3	5.6	0.15	0.09	3.1	0.0	14.3	0.2	0.05	0.01	1741	1477	3218
1991	1708	1481	41.9	5.7	0.15	0.09	3.0	0.0	14.2	0.2	0.05	0.01	1727	1486	3213
1992	1656	1526	40.6	5.8	0.14	0.09	2.9	0.0	13.8	0.2	0.05	0.01	1673	1532	3205
1993	1624	1517	39.8	5.8	0.14	0.09	2.9	0.0	13.5	0.2	0.05	0.01	1641	1522	3163
1994	1751	1522	42.9	5.8	0.15	0.09	3.1	0.0	14.6	0.2	0.05	0.01	1769	1527	3297
1995	1690	1599	41.5	6.1	0.15	0.09	3.0	0.0	14.1	0.3	0.05	0.01	1708	1604	3312
1996	1654	1552	40.6	5.9	0.14	0.09	2.9	0.0	13.8	0.2	0.05	0.01	1672	1557	3229
1997	1787	1654	43.8	6.3	0.15	0.10	3.2	0.0	14.9	0.3	0.05	0.01	1806	1660	3465
1998	1725	1626	42.3	6.2	0.15	0.10	3.1	0.0	14.4	0.3	0.05	0.01	1743	1632	3375
1999	1699	1675	41.7	6.4	0.15	0.10	3.0	0.0	14.1	0.3	0.05	0.01	1717	1681	3398
2000	1763	1730	43.2	6.6	0.15	0.10	3.1	0.0	14.7	0.3	0.05	0.01	1782	1737	3518
2001	1820	1712	44.7	6.5	0.16	0.10	3.2	0.0	15.1	0.3	0.05	0.01	1840	1718	3558
2002	1855	1733	45.5	6.6	0.16	0.10	3.3	0.0	15.4	0.3	0.05	0.01	1875	1739	3614
2003	1891	1756	46.4	6.7	0.16	0.10	3.4	0.0	15.7	0.3	0.05	0.01	1911	1762	3673
2004	1928	1778	47.3	6.8	0.17	0.11	3.4	0.0	16.0	0.3	0.06	0.01	1948	1784	3733
2005	1965	1801	48.2	6.9	0.17	0.11	3.5	0.0	16.4	0.3	0.06	0.01	1986	1807	3794
2006	2003	1824	49.1	7.0	0.17	0.11	3.6	0.0	16.7	0.3	0.06	0.01	2025	1831	3855
2007	2042	1848	50.1	7.1	0.18	0.11	3.6	0.0	17.0	0.3	0.06	0.01	2064	1855	3918
2008	2081	1872	51.1	7.2	0.18	0.11	3.7	0.0	17.3	0.3	0.06	0.01	2104	1879	3982

Continued...

TABLE IV.11 RAIL EMISSION PROJECTIONS *(continued)*

(gigagrams)

	CO_2		NO_x		CH_4		NMVOC		CO		N_2O		CO_2 equivalent		Total CO_2
Year	*Non-elec*	*Elec*	*Non-elec*	*Elec*	*Non-elec*	*Elec*	*Non-elec*	*Elec*	*Non-elec*	*Elec*	*Non-elec*	*Elec*	*Non-elec*	*Elec*	*equivalent*
2009	2122	1896	52.1	7.2	0.18	0.11	3.8	0.0	17.7	0.3	0.06	0.01	2145	1903	4048
2010	2163	1921	53.1	7.3	0.19	0.11	3.8	0.0	18.0	0.3	0.06	0.01	2186	1928	4114
2011	2205	1946	54.1	7.4	0.19	0.12	3.9	0.0	18.3	0.3	0.06	0.01	2229	1953	4182
2012	2248	1972	55.1	7.5	0.19	0.12	4.0	0.0	18.7	0.3	0.06	0.01	2272	1979	4251
2013	2291	1998	56.2	7.6	0.20	0.12	4.1	0.0	19.1	0.3	0.07	0.01	2316	2005	4321
2014	2336	2024	57.3	7.7	0.20	0.12	4.2	0.0	19.4	0.3	0.07	0.02	2361	2031	4392
2015	2382	2051	58.4	7.8	0.21	0.12	4.2	0.0	19.8	0.3	0.07	0.02	2407	2058	4465
2016	2428	2078	59.6	7.9	0.21	0.12	4.3	0.0	20.2	0.3	0.07	0.02	2454	2085	4539
2017	2475	2105	60.7	8.0	0.21	0.12	4.4	0.0	20.6	0.3	0.07	0.02	2502	2112	4614
2018	2524	2133	61.9	8.2	0.22	0.13	4.5	0.0	21.0	0.3	0.07	0.02	2551	2140	4691
2019	2573	2161	63.1	8.3	0.22	0.13	4.6	0.0	21.4	0.3	0.07	0.02	2600	2169	4769
2020	2623	2189	64.4	8.4	0.23	0.13	4.7	0.0	21.8	0.3	0.08	0.02	2651	2197	4848

Notes: 'Non-elec' refers to (end-use) emissions for non-electrified railways.
'Elec' refers to emissions from the generation of electricity for trains and trams.

Source: BTRE estimates.

appendix 5

SHIPPING PROJECTIONS

INTRODUCTION

Shipping has been an important mode of transport throughout Australia's history. In the nineteenth century, sea transport offered the readiest means of transport for passengers and freight between coastal cities. Early patterns of colonial railway development did not reduce the need for sea transport—railways radiated outwards into the hinterland from coastal cities, rather than linking them. Until recent times, when air travel became an affordable mode of transport to many people, the main means of entering or leaving Australia was by sea.

Australia produces and exports large quantities of bulk commodities such as iron ore, alumina, coal and grain. Large tonnages, coupled with large distances to overseas destinations, allow economies of scale that make shipping a cost-effective mode of freight transport.

A major issue in modelling greenhouse gas emissions by international shipping is the attribution of bunker fuel use among the various countries. According to Intergovernmental Panel on Climate Change (IPCC) guidelines, the attribution problem is still subject to debate. To ensure that all fuel use is accounted for, the IPCC recommends that *countries should record separately the quantities of fuel uplifted by international ships* (IPCC/OECD 1994: p. 1.11). In accordance with this recommendation, the BTRE has modelled separately fuel uplifted in Australia by international and coastal shipping.

INTERNATIONAL SHIPPING

Fuel is more expensive in Australia than in other countries, and only a small proportion of the fuel required for the international shipping task (to and from Australia) is therefore uplifted in Australia (about 8 per cent). The approach adopted by the BTRE in modelling the uplift of bunker fuel in Australia for international shipping involves two parts. Firstly, a model of the total international shipping task servicing Australian trade (and consequent total fuel use) comprises the basic model. Secondly, once total fuel use has been modelled, the fraction of this total that is uplifted in Australia is estimated.

Both parts of the modelling procedure are documented below, starting with the relationship that defines the fraction of fuel uplifted in Australia.

Modelling the fraction of total fuel for international shipping uplifted in Australia

The fraction of the total bunker fuel needed for the international shipping task into and out of Australia is dependent on what might be termed the 'mix effect'. Non-bulk ships are more likely to uplift fuel in Australia than are bulk ships. Large bulk ships are generally company ships on regular runs between specified ports. Refuelling is generally arranged at the least expensive port (usually overseas). Liner ships, on the other hand, have more changeable port call schedules and are therefore obliged to refuel in Australia more often (because of port call logistics). If there is an increase in the proportion of non-bulk ships undertaking Australia's international shipping task, it is likely that the proportion of fuel uplifted in Australia will increase.

Although it has been thought that the operation of the mix effect is heavily influenced by changes in Australia's exchange rate, between the years of 1984–85 and 1997–98, Apelbaum's (2001) data on the relative proportion of fuel uplifted in Australia has only varied by at most 2 per cent. For this reason, the amount of fuel uplifted in Australia has been fixed in our model at the 1997–98 figure of 7.4 per cent.

In the fuel consumption relationship outlined in equation V.1, the fraction of fuel uplifted in Australia has been set to the above proportion,

$$AC / TFC = 0.074 \qquad (V.1)$$

where

AC (Australian consumption) is the amount of fuel uplifted in Australia by international ships (in megalitres); and

TFC (total fuel consumption) is the total fuel required to undertake the international shipping task to and from Australia (in megalitres).

Modelling total fuel used in trade to and from Australia

To estimate the relationship defined in equation V.1, it was necessary to calculate TFC, the amount of fuel required to complete the international shipping task to and from Australia.

Australia's international shipping task can be split into three categories: the inward freight task, *fuel task (in);* the outward freight task, *fuel task (out);* and the passenger task, *fuel task (pass)*. The lack of suitable data on passenger numbers (and on fuel intensities of passenger ships), coupled with the relatively small size of the passenger sector, resulted in passenger numbers not being explicitly included in the shipping models. The amount of fuel required to complete each category was calculated as shown in equations V.2 to V.4, where FI refers to the relevant fuel intensity:

fuel task (in) = average distance (in) x [FI liner x non-bulk imports + FI bulk ship x bulk imports] (V.2)

fuel task (out) = average distance (out) x [FI liner x non-bulk exports + FI bulk ship x bulk exports] (V.3)

TFC = fuel task (in) + fuel task (out) (V.4)

In order to use these identities in forecasting, models had to be derived for bulk exports, non-bulk imports, bulk imports and non-bulk exports.

Projection models for bulk and non-bulk freight entering and leaving Australia were obtained by estimating a series of regression equations (V.5 to V.8). A summary of the regression results for all models is given in Table V.1.

Tonnages of bulk exports were estimated by equation V.5:

Bulk exports = 1.2263 x EXP – 16070482 (V.5)

Bulk exports (measured in tonnes) are explained by EXP, the sum of six major bulk commodities: iron, coal, alumina, oil/petroleum products, grains and sugar (all measured in tonnes).

Non-bulk imports were modelled using gross national expenditure and the real trade weighted index as the explanatory variables.

ln (non-bulk imports) = 1.5627 x ln SGNE + 0.1153 x ln RTWI – 0.2562 x DV1 – 4.9483 (V.6)

where non-bulk imports is the level of non-bulk imports in tonnes, SGNE is Australian seasonally adjusted gross national expenditure, RTWI is the real trade-weighted index and DV1 Is a dummy variable for the years 1989–90 to 1993–94.

The regression equation for bulk imports was constructed in a similar manner to the bulk exports equation. The tonnage of bulk imports is regressed on the sum of two major bulk imports: fuel and chemicals (measured in million dollars). The model is outlined in equation V.7:

bulk imports = 2021.8 x IMP + 9712637 (V.7)

where bulk imports is the level of bulk imports in tonnes and IMP is the sum of the values of the tonnages of fuel and chemicals imported (in millions of dollars).

Non-bulk exports are considered to be determined by the income of the Group of Seven (G7) major OECD economies and the real trade weighted index (an index of exchange rates between Australia and its major trading partners). G7GDP was chosen because it is more readily available both historically and for future projections than a trade-weighted measure of overseas income. Although G7GDP is calculated from the gross domestic products of seven countries, it is considered to be a measure of world GDP, because when GDP is high in the G7 countries, it is typically also high in non-G7 countries as a result of flow-on effects. For instance, when GDP is high in the G7 countries, more goods are demanded from non-G7 countries which then increases the GDP of non-G7 countries. This implies that G7GDP can be an appropriate measure for the income of Australia's trading partners, despite a significant portion of Australia's trade being undertaken with non-G7 countries.

$$\ln(\text{non-bulk exports}) = 1.1969 \times \ln G7GDP - 0.1847 \times \ln RTWI + 0.5985 \times DV2 + 3.8441 \quad (V.8)$$

where non-bulk exports is the level of non-bulk exports in tonnes, G7GDP is an index of real gross domestic product in the G7 countries, DV2 is a dummy variable applied from 1994–95 onwards and RTWI is Australia's real trade-weighted index.

The results of the international shipping models are summarised in Table V.1

TABLE V.1 RESULTS OF THE INTERNATIONAL SHIPPING MODELS

Dependent variable	*R^2*	*Independent variables*	*Coefficient*	*Standard error*
Bulk exports	0.994	constant	16070482	6109173
		EXP	1.2238	0.0227
ln(non-bulk imports)	0.981	constant	–4.9483	1.1778
		DV1	–0.2562	0.0240
		ln RTWI	0.1153	0.1342
		ln SGNE	1.5627	0.0656
Bulk imports	0.905	constant	9712637	1720556
		IMP	2021.8	163.23
ln(non-bulk exports)	0.978	constant	3.8441	2.5515
		DV2	0.5985	0.0661
		ln RTWI	–0.1847	0.1929
		ln G7GDP	1.1969	0.1914

Source: BTRE estimates.

The average distance variables used in equations V.2 and V.3 represent the length of a typical voyage in any given year. Historical values for the average distances for inward and outward freight were calculated by weighting a series of representative distances by the freight tonnages to or from eight regions as shown in equations V.9 and V.10. These relations were then used in projecting changes in regional shares in Australia's international sea traffic.

$$\text{average distance (out)} = \frac{\Sigma_{\alpha} \text{ tonnes of freight to region } \alpha \text{ x distance to region } \alpha}{\text{total tonnes of freight from Australia}} \quad \text{(V.9)}$$

$$\text{average distance (in)} = \frac{\Sigma_{\alpha} \text{ tonnes of freight to region } \alpha \text{ x distance to region } \alpha}{\text{total tonnes of freight to Australia}} \quad \text{(V.10)}$$

Fuel intensity variables have been split into the two categories of bulk ships and liner ships.

BTCE (1995a: p. 104) found that Apelbaum's (1993) fleet average fuel intensity figures coincided closely with Drewry's Bulk Ships (Drewry 1993 and earlier issues) fuel intensities time series (under the assumption the bulk ships experienced 50 per cent backhaul). From this we have taken the fuel intensity for bulk ships to be equivalent to Apelbaum's (2001) 1984–85 to 1997–98 fleet average figures adjusted upwards by 5 per cent (to closer match the Drewry's results for bulk ships with 50 per cent backhaul).

By calculating the proportional difference between the fuel intensities for liner and bulk ships as provided in BTCE (1995a: p. 251), liner ships were found to be on average 1.59 times as fuel intensive as bulk ships. Therefore, this analysis uses the relation that liner ships are 1.59 times as fuel intensive as bulk ships.

BTCE shipping projections (1995a: p. 251) applied a 1.8 per cent improvement per year in fuel intensities for both bulk ships and liner ships. For these revised projections, 1.8 per cent per annum improvement in fuel intensities is again assumed.

The fuel tasks were then calculated by applying the time series for fuel intensities, freight tasks and average distances to equations V.2 and V.3. Subsequent substitution into equation V.4 provided a time series for the total amount of fuel required to complete Australia's international shipping task. By applying the relationship defined in equation V.1 the amount of fuel uplifted in Australia for each year was calculated.

Variables

There are a number of variables used in equations V.1 to V.8 whose inclusion, for various reasons, may not be readily apparent.

G7GDP. G7GDP is an index of the gross domestic products of the Group of Seven, major industrialised countries comprising the United States, Canada, the United Kingdom, Germany Italy France and Japan. G7GDP is included in the model for non-bulk exports to capture the effect of overseas economic activity on the level of non-bulk exports. As G7GDP rises, the economies of the G7 countries are assumed to require increased amounts of raw materials. Australian non-bulk commodity exports should increase as a result. The coefficient of G7GDP can be expected to be positive as a result.

RTWI. A real trade-weighted index for Australia (RTWI) is calculated as:

$$\text{RTWI} = \text{TWI x (CPI/G7CPI)} \quad \text{(V.11)}$$

where TWI is Australia's trade weighted index, CPI is Australia's consumer price index and G7CPI is the average of the consumer price indexes in the G7 countries.

The RTWI is included to capture the effect of exchange rates on the level of non-bulk exports. When the RTWI falls, Australian exports become cheaper overseas and demand increases. RTWI can therefore be expected to have a negative coefficient in the non-bulk exports model. Similarly, in the non-bulk imports model the RTWI captures the effect of exchange rates on non-bulk imports so that it can be expected that RTWI has a positive coefficient in the non-bulk imports model.

SGNE. Seasonally adjusted gross national expenditure is a measure of the level of spending in Australia. When SGNE rises, Australians are spending more and hence demanding more goods. The demand for imports will rise as a result of the increased demand in the Australian economy. The coefficient on non-bulk imports is therefore expected to be positive.

Assumptions

The projection of total fuel uplifted in Australia by international ships was calculated in three stages. First, projections of the explanatory variables in equations V.5 to V.8 were substituted into the equations used to project future tonnages of bulk and non-bulk exports and imports. Second, the projections of bulk and non-bulk exports and imports, along with projections of average distance and fuel intensity, were substituted into equations V.2 to V.4 to obtain a projection for the total fuel task. Third, by rearranging equation V.1 and substituting in projections of the total fuel task, a projection of the total fuel uplifted in Australia by international ships was estimated.

For some variables, projected values could not be obtained through modelling, and assumptions had to made regarding their likely future behaviour. The following is a list of these variables and the relevant assumptions.

EXP. EXP is the sum of the tonnages of six major bulk exports. The EXP projection was calculated from projections of the six major bulk exports. The bulk exports projections are continuations of the projections outlined in the BTCE Report 88 (1995a: pp. 107-108), originating from ABARE trend projections.

In detail:

Iron ore:	2000–2020, an increase of 2.2 milion tonnes per year
Coal:	2000–2020, an increase of 5.56 million tonnes per year
Alumina:	2000–2020, an increase of 154 000 tonnes per year
Oil/petroleum (includes crude oil, LPG, petroleum products and liquefied natural gas):	2000–2020, a decrease of 2160 tonnes per year.
Coarse grain (includes oats, wheat and barley):	2000–2020, an increase of 372 630 tonnes per year
Sugar:	2000–2020, an increase of 122 400 tonnes per year

SGNE. As in the BTCE Report 88 (1995a: p. 108), seasonally adjusted gross national expenditure was assumed to grow by 3.05 per cent per year from 2000–2020.

IMP. IMP is the sum of the two major bulk imports: fuel and chemicals. The projections for the two bulk imports were continued from the BTCE (1995a: p. 108) upward trend projections for fuel imports to grow by $196 million per year and chemical imports to grow by $378 million per year.

G7GDP. G7GDP was assumed to grow by 2.5 per cent per year for the years 2000–2020 (BTCE 1995a: p. 108).

RTWI. The real trade-weighted index was assumed to decrease by 0.8 per cent per year from 2000–2003, and decrease by 0.4 per cent per year for 2004–2008. From 2008 onwards it is assumed to remain unchanged (BTCE 1995a: p. 108).

Average distance. The average distance in and out of Australia also changes over time as markets change and, thus, a projection of average distances was also required. Average distance projections were formulated by considering the different growth rate trends to each of the main Australian trade regions, and their relevant distances. Weighted sums (by the relevant freight tonnages, as in equations V.9 and V.10) of these trends then allowed the calculation of scale factors (for future average distances relative to current ones). These factors were applied to the actual values for the average distances to obtain projected average distance estimates. The rates at which the tonnages to and from Australia are expected to grow are listed in table V.2, together with the average distances to each region.

TABLE V.2 PROJECTED IMPORT AND EXPORT GROWTH RATES BY REGION, 2000–2020

(per cent per year)

Region	Distance (km)	Bulk Exports	Bulk Imports	Non-Bulk Exports	Non-Bulk Imports
Africa	11000	0.62	4.29	3.87	3.87
Asia	7180	1.08	2.62	2.90	3.66
Europe	20440	0.27	–6.31	0.89	2.39
India	12900	0.78	0.72	2.78	3.83
North America	17950	0.31	–9.16	1.07	–3.82
Pacific	3750	1.38	1.60	1.79	2.65
South America	11430	1.55	–8.37	3.05	0.36
Unknown or not specified	12093	0.19	4.06	2.51	4.19

Note: Some growth rates produced unrealistic results for 2020 export/import levels to certain regions. In these cases the growth rates were adjusted, or left at a constant level.
Source: BTRE estimates.

The growth rates suggest a trend towards our growing import/export trade relation with Asia, and a slowing towards the more traditional markets of Europe and the United States. This is reflected in the results as a shrinking average distance, suggesting greater tonnages being traded with closer regions.

Fuel consumption and emission projections

To convert fuel consumption to greenhouse gas emissions, the total fuel consumption has to be divided into the different types of fuel. Three types of fuel are used in international shipping: industrial diesel fuel (IDF), automotive diesel oil (ADO) and fuel oil (FO). The proportions of each fuel type have remained relatively constant over recent times. The projections for the amount of fuel uplifted in Australia by international ships is therefore divided into the three fuel types based on shares of 6.2 per cent IDF, 13.5 per cent ADO and 80.3 per cent FO (BTCE 1995: p. 110). The fuel consumption figures were converted to greenhouse gas emissions by multiplying by the conversion factors in Table V.3.

TABLE V.3 EMISSION FACTORS FOR INTERNATIONAL SHIPPING

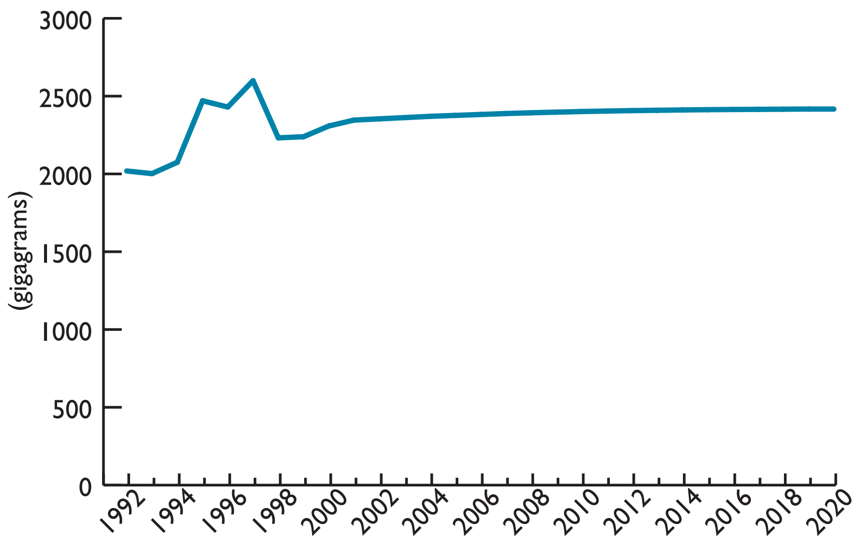
(g/MJ)

	Fuel		
Gas	*ADO*	*IDF*	*FO*
CH_4	0.005	0.005	0.003
N_2O	0.002	0.002	0.002
NO_x	1.52	1.52	2.00
CO	0.475	0.475	0.044
NMVOCs	0.105	0.150	0.063
CO_2	69.7	70.2	73.3

Source: BTCE (1995: pp.180-181).

With the proportions of ADO, IDF and FO given above, greenhouse gas emissions are projected to increase slightly between 2000 and 2020. The increase in carbon dioxide emissions over the period 1992–2020 is illustrated below in figure V.1. Projections of fuel use and greenhouse gas emissions are included in tables V.6 and V.7.

FIGURE V.1 CO_2 EQUIVALENT EMISSIONS FROM FUEL UPLIFTED IN AUSTRALIA BY INTERNATIONAL SHIPS



Sources: BTRE estimates

COASTAL SHIPPING

Modelling fuel consumption

The proportion of Australian transport fuel consumed by coastal shipping is relatively small in comparison to other modes (in particular road transport). Consequently, few attempts have been made to develop models of fuel consumption for coastal shipping. The Bureau (see BTCE 1995a) has developed a model to provide long-term projections of greenhouse emissions from coastal shipping. This model is applied in the current analysis.

The amount of fuel consumed in coastal shipping is calculated in BTCE (1995a: p. 112) model by:

$$FU = \text{coastal task} \times \text{average distance} \times \text{fuel intensity} \qquad (V.12)$$

where FU is the quantity of fuel uplifted as coastal bunkers in MJ, coastal task is tonnes of coastal freight shipped and the fuel intensity (in MJ/tkm) refers to the Australian coastal fleet. By obtaining projections for the coastal task, average distance and fuel intensity, it is possible to estimate future fuel consumption.

For this analysis, the coastal task is taken to consist solely of the freight task. The passenger task has been found in the past to account for a very small percentage of the coastal shipping fuel use (BTCE 1995a: p. 113) and is therefore not taken into account here.

The freight task was divided into two components: bulk and non-bulk. Each component was modelled separately.

Bulk freight was modelled with the sum of seven major bulk commodities (bauxite/alumina, petroleum products, petroleum oil, sugar, iron ore, coal/coke and fertilisers/minerals) as the explanatory variable—outlined in equation V.13 (having a regression fit of $R2 = 0.945$).

$$\ln CBLK = -0.1689 + 1.0149 \times \ln CCOM$$
$$\qquad\qquad (1.0579) \quad (0.607) \qquad (V.13)$$

Note: numbers in the parentheses are standard errors.

Here CBLK is the tonnage of coastal bulk freight and CCOM is the sum of the tonnages of seven major bulk commodities. The positive coefficient on CCOM indicates that, as the tonnages of the seven major bulk exports increase, so does the total bulk tonnage.

Non-bulk freight is a relatively small proportion of the total freight carried by coastal ships. In 1993, it comprised 8.3 per cent of total coastal freight. This figure remained relatively stable during the period 1983–1993. Since 1983, non- bulk freight has been growing on average by 14 280 tonnes year (BTCE 1995a: p. 112). Given that non-bulk freight is only a small section of the market, is growing slowly and there is a lack of suitable data for modelling purposes, a model for non-bulk freight was not constructed. Projections for non-bulk freight were obtained by assuming the task will continue to grow by 14 280 tonnes per year.

In contrast to international shipping, it is unlikely that ships performing the coastal task would refuel in another country. Therefore it can be assumed that the total fuel uplifted in Australia by coastal ships is equal to the amount of fuel consumed.

BTCE (1995: pp. 113-114) calculated the fuel intensity from aggregate fuel consumption data and found the 'Calculated Fleet Average' to be an accurate representation of the fuel intensity of Australia's coastal fleet and also to be roughly the same as Apelbaum's (1993) fleet average. Therefore, the fuel intensities of the coastal fleet for this analysis have been taken as Apelbaum's (2001) 'Fleet Average' for the years of 1994–95 to 1997–98. A 1.7 per cent decrease in fuel intensity was assumed thereafter.

Assumptions

To project the level of bulk coastal freight activity, a series of projections for the tonnages of the seven major bulk exports are required. With the exception of the tonnage of fertilisers/minerals, the projections for tonnages shipped were calculated from equation V.14.

$$\text{Tonnage shipped} = \text{proportion shipped} \times \text{tonnage produced} \qquad (V.14)$$

where tonnage shipped is the tonnage of each commodity carried on coastal ships, tonnage produced is the tonnage of each commodity produced, and proportion shipped is the proportion of total production, which is carried on coastal ships. The proportion shipped is calculated from historical data on tonnages shipped and tonnages produced. Because there have been distinct trends in the proportions of commodities transported by coastal ships between 1983 and 1993, it is reasonable to assume that these trends will continue. The projections of the proportion shipped are given in table V.4.

TABLE V.4 ASSUMED CHANGE IN PROPORTION OF PRODUCTION SHIPPED BY COASTAL SHIPPING

Commodity	*Assumption*
Bauxite/alumina	Increase by 1.29 per cent per year
Petroleum products	Decrease by 1.31 per cent per year
Petroleum oil	Decrease by 5.75 per cent per year
Sugar	Decrease by 3.13 per cent per year
Iron ore	Decrease by 3.39 per cent per year
Coal/coke	Decrease by 4 per cent per year

Source: BTCE (1995a: p. 115).

The projections for the production of the individual commodities are listed below, and are continuations from BTCE (1995a: pp. 115–116) projections.

Bauxite/alumina	2000–2020: increase of 2.4 per cent per year
Petroleum products	2000–2020: increase of 1.5 per cent per year
Petroleum oil	2000–2020: increase of 0.7 per cent per year
Sugar	2000–2020: increase of 3.4 per cent per year
Iron ore	2000–2020: increase of 1.8 per cent per year
Coal/coke	2000–2020: increase of 3.6 per cent per year

The projections for the tonnages of each commodity produced and the proportion of production that is transported by ship were substituted into equation V.14 to calculate the projections of the tonnages of each commodity transported by ship.

The category of fertilisers/minerals covers a wide variety of materials. As data are not available for the production of many different types of fertilisers and minerals, a projection for the amount shipped was made based on the tonnages shipped between 1983 and 1993 (DTC 1993c). As a result, the amount of fertilisers/minerals shipped was assumed to increase at the rate of 3.6 per cent per year.

The projections for the tonnages of each of the seven commodities were summed and substituted into equation V.13 to project the tonnage of bulk freight transported by coastal ships from 2000 to 2020.

Coastal shipping task is expressed in both tonne-kilometres and tonnes. Tonne–kilometres have been calculated by multiplying port-to-port tonnages by port-to-port distances. The average distance used for projections by BTCE (1995a: p. 117) was 2168 kilometres, which was assumed to remain constant. For this analysis we also assume a constant average distance of 2168 kilometres.

FUEL CONSUMPTION AND EMISSIONS

By substituting the projections for the freight task, fuel intensity and average distance into equation V.12, a projection for the amount of fuel consumed in coastal shipping is calculated. The results are given in table V.8.

Coastal shipping uses five main types of fuel: automotive diesel oil (ADO), industrial diesel fuel (IDF), fuel oil (FO), black coal (BC) and natural gas (NG). The proportions used are assumed to remain at constant levels (BTCE 1995a: p. 117) and the proportions used are based on Apelbaum's (2001) 1994–95 shares.

Assuming that the proportions of fuel do not change over time, fuel consumption by coastal shipping is converted in greenhouse gas emissions by using the conversion factors listed in table V.5.

TABLE V.5 EMISSION FACTORS FOR COASTAL SHIPPING

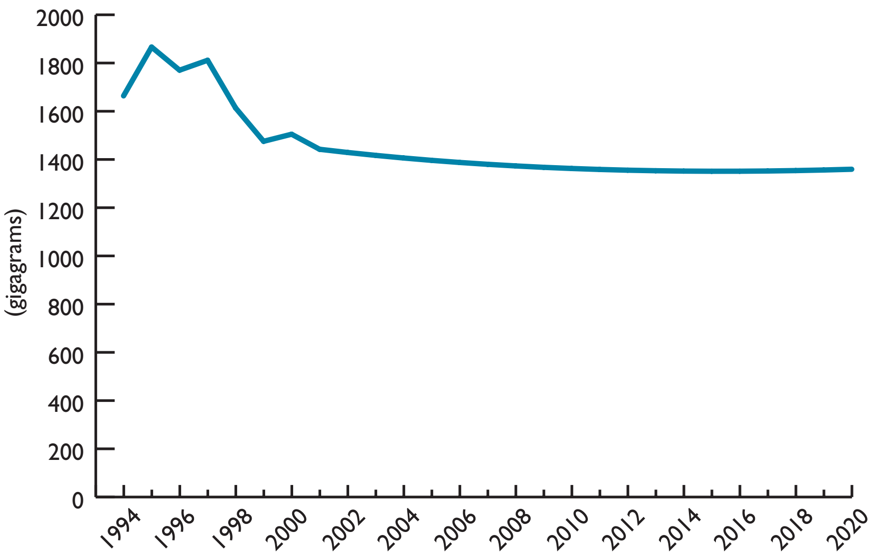
(g/MJ)

Gas	Fuel ADO	IDF	FO	BC	NG
CH_4	0.005	0.005	0.003	0.002	0.243
N_2O	0.002	0.002	0.002	0.001	0.001
NO_x	1.52	1.52	2.00	0.31	0.243
CO	0.475	0.475	0.044	0.088	0.095
NMVOCs	0.105	0.150	0.063	0.0	0.029
CO_2	69.7	70.2	73.3	90.0	51.3

Source: BTCE (1995a).

Greenhouse gas emissions are expected to decrease slightly over the projection period. Carbon dioxide levels are illustrated below in figure V.2. Projections for all greenhouse gases from coastal shipping are given in table V.9.

FIGURE V.2 CO_2 EQUIVALENT EMISSIONS FROM COASTAL SHIPPING



Sources: BTRE estimates.

TABLE V.6 FUEL UPLIFTED IN AUSTRALIA FOR INTERNATIONAL SHIPPING

(PJ end-use)

Year	*ADO*	*IDF*	*FO*	*Total*
1992	3.75	1.72	22.33	27.81
1993	3.72	1.71	22.14	27.57
1994	3.86	1.77	22.94	28.57
1995	4.59	2.11	27.31	34.01
1996	4.52	2.07	26.86	33.45
1997	4.83	2.22	28.73	35.78
1998	4.15	1.91	24.68	30.74
1999	4.16	1.91	24.76	30.83
2000	4.29	1.97	25.52	31.78
2001	4.36	2.00	25.94	32.30
2002	4.38	2.01	26.03	32.42
2003	4.39	2.02	26.12	32.53
2004	4.41	2.02	26.20	32.63
2005	4.42	2.03	26.28	32.72
2006	4.43	2.03	26.34	32.81
2007	4.44	2.04	26.40	32.88
2008	4.45	2.04	26.46	32.95
2009	4.46	2.05	26.50	33.01
2010	4.46	2.05	26.55	33.06
2011	4.47	2.05	26.58	33.10
2012	4.47	2.05	26.61	33.14
2013	4.48	2.06	26.64	33.18
2014	4.48	2.06	26.66	33.20
2015	4.49	2.06	26.68	33.23
2016	4.49	2.06	26.70	33.25
2017	4.49	2.06	26.71	33.26
2018	4.49	2.06	26.72	33.27
2019	4.49	2.06	26.72	33.28
2020	4.49	2.06	26.72	33.28

Source: BTRE estimates.

TABLE V.7 INTERNATIONAL SHIPPING EMISSION PROJECTIONS

(Gg)

Year	CH_4	N_2O	NO_X	CO	NMVOCs	CO_2
1992	0.09	0.06	52.98	3.58	2.06	2019.30
1993	0.09	0.06	52.54	3.55	2.04	2002.43
1994	0.10	0.06	54.44	3.68	2.12	2074.94
1995	0.12	0.07	64.81	4.38	2.52	2470.16
1996	0.11	0.07	63.75	4.31	2.48	2429.56
1997	0.12	0.07	68.18	4.61	2.65	2598.50
1998	0.10	0.06	58.57	3.96	2.28	2232.26
1999	0.10	0.06	58.75	3.97	2.28	2239.03
2000	0.11	0.06	60.55	4.10	2.35	2307.81
2001	0.11	0.06	61.55	4.16	2.39	2345.72
2002	0.11	0.06	61.78	4.18	2.40	2354.47
2003	0.11	0.07	61.99	4.19	2.41	2362.49
2004	0.11	0.07	62.18	4.21	2.42	2369.77
2005	0.11	0.07	62.35	4.22	2.42	2376.40
2006	0.11	0.07	62.51	4.23	2.43	2382.41
2007	0.11	0.07	62.65	4.24	2.44	2387.84
2008	0.11	0.07	62.78	4.25	2.44	2392.71
2009	0.11	0.07	62.89	4.25	2.44	2396.98
2010	0.11	0.07	62.99	4.26	2.45	2400.75
2011	0.11	0.07	63.08	4.27	2.45	2404.05
2012	0.11	0.07	63.15	4.27	2.45	2406.90
2013	0.11	0.07	63.22	4.28	2.46	2409.33
2014	0.11	0.07	63.27	4.28	2.46	2411.37
2015	0.11	0.07	63.31	4.28	2.46	2413.03
2016	0.11	0.07	63.35	4.29	2.46	2414.36
2017	0.11	0.07	63.37	4.29	2.46	2415.36
2018	0.11	0.07	63.39	4.29	2.46	2416.07
2019	0.11	0.07	63.40	4.29	2.46	2416.51
2020	0.11	0.07	63.41	4.29	2.46	2416.71

Source: BTRE estimates.

TABLE V.8 FUEL CONSUMPTION IN COASTAL SHIPPING

(PJ end-use)

Year	ADO	IDF	FO	Coal	NG	Fuel consumed
1994	5.29	0.45	12.58	3.57	0.04	21.93
1995	5.93	0.51	14.11	4.00	0.05	24.60
1996	5.62	0.48	13.38	3.79	0.05	23.33
1997	5.76	0.49	13.69	3.88	0.05	23.88
1998	5.13	0.44	12.20	3.46	0.04	21.27
1999	4.69	0.40	11.15	3.16	0.04	19.45
2000	4.78	0.41	11.38	3.23	0.04	19.83
2001	4.58	0.39	10.90	3.09	0.04	19.01
2002	4.54	0.39	10.80	3.06	0.04	18.84
2003	4.50	0.39	10.71	3.04	0.04	18.68
2004	4.47	0.38	10.63	3.01	0.04	18.53
2005	4.44	0.38	10.56	2.99	0.04	18.41
2006	4.41	0.38	10.49	2.97	0.04	18.29
2007	4.38	0.38	10.43	2.96	0.04	18.19
2008	4.36	0.38	10.38	2.94	0.04	18.10
2009	4.34	0.37	10.34	2.93	0.04	18.02
2010	4.33	0.37	10.30	2.92	0.04	17.96
2011	4.32	0.37	10.27	2.91	0.04	17.91
2012	4.31	0.37	10.25	2.91	0.04	17.87
2013	4.30	0.37	10.23	2.90	0.04	17.84
2014	4.30	0.37	10.22	2.90	0.04	17.82
2015	4.29	0.37	10.22	2.90	0.04	17.81
2016	4.29	0.37	10.22	2.90	0.04	17.81
2017	4.30	0.37	10.22	2.90	0.04	17.82
2018	4.30	0.37	10.24	2.90	0.04	17.85
2019	4.31	0.37	10.25	2.91	0.04	17.88
2020	4.32	0.37	10.28	2.91	0.04	17.92

Source: BTRE estimates.

TABLE V.9 COASTAL SHIPPING EMISSION PROJECTIONS

(Gg)

Year	CH_4	N_2O	NO_X	CO	NMVOCs	CO_2
1994	0.08	0.05	35.00	3.60	1.42	1645.65
1995	0.09	0.06	39.26	4.04	1.59	1845.95
1996	0.09	0.06	37.24	3.83	1.51	1750.95
1997	0.09	0.06	38.11	3.92	1.54	1791.61
1998	0.08	0.05	33.95	3.49	1.37	1596.07
1999	0.07	0.05	31.04	3.19	1.26	1459.22
2000	0.08	0.05	31.65	3.25	1.28	1488.33
2001	0.07	0.05	30.34	3.12	1.23	1426.44
2002	0.07	0.05	30.06	3.09	1.22	1413.39
2003	0.07	0.04	29.81	3.06	1.21	1401.52
2004	0.07	0.04	29.58	3.04	1.20	1390.77
2005	0.07	0.04	29.37	3.02	1.19	1381.10
2006	0.07	0.04	29.19	3.00	1.18	1372.47
2007	0.07	0.04	29.03	2.98	1.18	1364.85
2008	0.07	0.04	28.89	2.97	1.17	1358.20
2009	0.07	0.04	28.77	2.96	1.16	1352.49
2010	0.07	0.04	28.66	2.95	1.16	1347.69
2011	0.07	0.04	28.58	2.94	1.16	1343.78
2012	0.07	0.04	28.52	2.93	1.15	1340.72
2013	0.07	0.04	28.47	2.93	1.15	1338.49
2014	0.07	0.04	28.44	2.92	1.15	1337.07
2015	0.07	0.04	28.42	2.92	1.15	1336.45
2016	0.07	0.04	28.43	2.92	1.15	1336.60
2017	0.07	0.04	28.45	2.92	1.15	1337.50
2018	0.07	0.04	28.48	2.93	1.15	1339.14
2019	0.07	0.04	28.53	2.93	1.16	1341.50
2020	0.07	0.04	28.60	2.94	1.16	1344.58

Source: BTRE estimates.

TABLE V.10 SHIPPING TASK PROJECTIONS

Year	EXP ('000 tonnes)	IMP ($ million)	SGNE ($ million)	Non-Bulk In ('000 tonnes)	Bulk In ('000 tonnes)	Non-Bulk Out ('000 tonnes)	Bulk Out ('000 tonnes)
1992	267716	8307	445184	6365	28030	9459	307250
1993	276798	10482	461320	6183	32542	9695	317235
1994	290891	10487	476451	6011	35818	8757	333637
1995	294886	11677	507131	9545	36377	11424	350976
1996	285195	13213	523836	9325	37731	13071	359835
1997	329326	14192	542302	10232	39599	15890	388107
1998	350614	14715	574925	11871	41106	18179	409681
1999	347300	16057	609932	12510	43777	20278	411821
2000	372393	20153	637704	13936	42628	20732	441496
2001	380800	20727	658748	14169	51619	22338	449885
2002	389206	21301	680487	14893	52779	23177	460173
2003	397613	21875	702943	15653	53940	24047	470462
2004	406020	22449	726140	16461	55100	24932	480751
2005	414427	23023	750103	17309	56261	25849	491040
2006	422834	23597	774856	18202	57422	26799	501328
2007	431241	24171	800426	19140	58582	27785	511617
2008	439648	24745	826840	20127	59743	28807	521906
2009	448055	25319	854126	21175	60903	29845	532195
2010	456461	25893	882312	22277	62064	30919	542483
2011	464868	26467	911429	23437	63224	32033	552772
2012	473275	27041	941506	24656	64385	33187	563061
2013	481682	27615	972575	25940	65545	34382	573349
2014	490089	28189	1004670	27290	66706	35620	583638
2015	498496	28763	1037825	28710	67866	36903	593927
2016	506903	29337	1072073	30205	69027	38232	604216
2017	515310	29911	1107451	31777	70187	39609	614504
2018	523716	30485	1143997	33431	71348	41035	624793
2019	532123	31059	1181749	35171	72509	42513	635082
2020	540530	31633	1220747	37001	73669	44044	645371

Continued...

TABLE V.10 SHIPPING TASK PROJECTIONS *(Continued)*

Year	*Average Dist. In (km)*	*Average Dist. Out (km)*	*FI Liner (MJ/tkm)*	*FI Dry Bulk (MJ/tkm)*	*CBLK ('000 tonnes)*	*CNBLK ('000 tonnes)*	*CCOM ('000 tonnes)*
1992	10900	10128	0.16	0.10	n.a.	n.a.	n.a.
1993	10815	9794	0.16	0.10	n.a.	n.a.	n.a.
1994	10617	9897	0.16	0.10	39587	2828	37189
1995	10813	9925	0.17	0.11	45040	4150	39397
1996	10533	9654	0.17	0.11	43458	4339	39421
1997	10409	9733	0.17	0.10	44725	4417	41119
1998	10391	9714	0.14	0.08	47638	4883	43692
1999	9702	9842	0.13	0.08	43322	5065	38164
2000	9932	9679	0.13	0.08	44637	5692	40786
2001	9820	9665	0.13	0.08	45085	5706	41100
2002	9717	9650	0.13	0.08	45477	5720	41452
2003	9621	9636	0.12	0.08	45910	5734	41841
2004	9532	9622	0.12	0.08	46386	5749	42269
2005	9449	9607	0.12	0.07	46905	5763	42734
2006	9373	9593	0.12	0.07	47466	5777	43239
2007	9302	9579	0.11	0.07	48072	5791	43782
2008	9237	9565	0.11	0.07	48723	5806	44366
2009	9177	9551	0.11	0.07	49418	5820	44990
2010	9121	9537	0.11	0.07	50160	5834	45655
2011	9070	9523	0.11	0.07	50948	5849	46362
2012	9022	9509	0.10	0.07	51785	5863	47112
2013	8978	9495	0.10	0.06	52670	5877	47905
2014	8938	9482	0.10	0.06	53605	5891	48743
2015	8900	9468	0.10	0.06	54592	5906	49627
2016	8865	9454	0.10	0.06	55630	5920	50557
2017	8833	9441	0.10	0.06	56723	5934	51535
2018	8803	9427	0.09	0.06	57870	5949	52562
2019	8775	9414	0.09	0.06	59075	5963	53640
2020	8749	9401	0.09	0.06	60337	5977	54769

n.a. not available
Sources: BTCE(1995a), Apelbaum (2001, pers comm), ABS–AUSTATS (2001), BTRE estimates.

appendix 6

AGGREGATE PROJECTION DATA AND PARAMETER ASSUMPTIONS

TABLE VI.1 STATE AND TERRITORY POPULATION PROJECTIONS

(thousand persons)

Year	*NSW*	*Vic*	*Qld*	*SA*	*WA*	*Tas*	*NT*	*ACT*	*Total*
1990	5832.1	4378.1	2904.8	1431.2	1615.0	462.1	163.9	282.8	17070
1991	5896.4	4414.5	2966.9	1444.1	1636.7	466.0	166.0	289.4	17280
1992	5955.2	4444.7	3038.6	1452.2	1658.1	468.6	167.9	294.8	17480
1993	6004.7	4463.6	3122.8	1458.7	1679.2	470.9	171.3	298.8	17670
1994	6056.4	4477.9	3194.1	1461.4	1705.1	471.5	173.2	301.2	17841
1995	6120.4	4507.3	3270.2	1463.6	1734.6	471.9	177.7	304.4	18050
1996	6241.7	4585.2	3365.1	1479.4	1779.1	475.9	184.0	309.5	18420
1997	6280.4	4611.5	3408.5	1479.3	1803.0	472.4	187.6	307.2	18550
1998	6358.1	4672.4	3469.8	1488.7	1839.9	472.0	190.8	308.3	18800
1999	6412.8	4713.0	3513.0	1493.4	1861.3	470.4	192.9	310.3	18967
2000	6474.0	4764.3	3560.9	1496.7	1887.2	468.3	195.5	312.0	19159
2001	6528.4	4810.0	3607.2	1500.5	1910.5	466.3	197.7	313.4	19334
2002	6579.9	4853.1	3654.4	1505.4	1932.3	464.5	199.7	314.6	19504
2003	6632.1	4895.0	3702.1	1510.9	1954.4	462.7	201.5	315.3	19674
2004	6684.8	4935.5	3749.8	1517.1	1976.7	460.5	203.0	315.6	19843
2005	6737.5	4976.0	3797.9	1523.0	1999.1	458.2	204.5	315.9	20012
2006	6788.2	5014.9	3845.0	1528.3	2020.9	455.8	206.0	315.9	20175
2007	6838.5	5053.7	3892.3	1533.4	2042.7	453.3	207.4	315.9	20337
2008	6888.3	5092.1	3939.5	1538.3	2064.4	450.7	208.9	315.9	20498
2009	6938.0	5130.7	3986.9	1543.2	2086.1	448.0	210.4	315.8	20659
2010	6988.0	5169.4	4034.5	1548.1	2108.1	445.3	211.9	315.7	20821
2011	7030.7	5202.6	4078.1	1551.4	2127.9	442.2	213.1	315.1	20961
2012	7073.6	5235.9	4122.0	1554.7	2147.8	438.9	214.4	314.6	21102
2013	7116.2	5268.9	4165.9	1558.0	2167.8	435.5	215.7	314.0	21242
2014	7159.0	5302.0	4210.1	1561.3	2187.9	432.2	217.1	313.4	21383
2015	7201.5	5335.0	4254.2	1564.5	2207.9	428.8	218.4	312.8	21523
2016	7241.6	5365.9	4297.0	1567.3	2227.2	425.2	219.7	312.1	21656
2017	7281.6	5396.9	4339.9	1570.1	2246.6	421.6	221.1	311.4	21789
2018	7321.8	5427.8	4383.1	1572.7	2265.9	417.7	222.3	310.6	21922
2019	7361.5	5458.4	4426.0	1575.4	2285.3	414.0	223.7	309.7	22054
2020	7401.3	5489.1	4469.1	1578.0	2304.5	410.0	225.1	308.9	22186

Sources: BTRE estimates based on AGO-supplied data assumptions and ABS (2001b) long-term projections (Series III).

TABLE VI.2 CAPITAL CITY POPULATION PROJECTIONS

(thousand persons)

Year	*Syd*	*Mel*	*Bne*	*Adl*	*Per*	*Hob*	*Dar*	*Cbr*	*Total*
1990	3632.1	3127.2	1330.6	1046.9	1173.7	188.8	75.2	282.8	10857
1991	3672.2	3153.3	1359.0	1056.3	1189.5	190.4	76.2	289.4	10986
1992	3711.9	3179.8	1389.5	1062.6	1207.4	191.8	76.6	294.8	11115
1993	3746.0	3198.6	1425.6	1067.7	1225.2	193.2	77.8	298.8	11233
1994	3781.5	3214.1	1455.9	1069.9	1246.4	193.8	78.2	301.2	11341
1995	3824.7	3240.7	1488.6	1071.8	1270.2	194.3	79.9	304.4	11475
1996	3903.8	3302.5	1530.4	1083.7	1305.3	196.3	82.5	309.5	11714
1997	3940.1	3327.2	1550.3	1083.1	1323.6	195.2	84.5	307.2	11811
1998	3996.5	3379.5	1580.7	1090.7	1347.9	195.0	86.6	308.3	11985
1999	4042.1	3417.8	1601.7	1093.1	1364.4	194.2	88.1	310.3	12112
2000	4094.1	3463.5	1624.7	1097.6	1385.2	193.3	89.6	312.0	12260
2001	4140.1	3504.3	1646.6	1102.5	1403.4	192.4	90.9	313.4	12393
2002	4182.4	3542.1	1668.6	1108.3	1419.9	191.5	91.8	314.6	12519
2003	4225.9	3579.0	1690.9	1114.7	1436.5	190.6	92.7	315.3	12646
2004	4270.4	3614.8	1713.1	1121.7	1453.4	189.7	93.4	315.6	12772
2005	4315.0	3650.6	1735.6	1128.6	1470.3	188.8	94.0	315.9	12899
2006	4358.5	3685.4	1757.6	1135.0	1486.9	187.8	94.7	315.9	13022
2007	4401.8	3720.1	1779.7	1141.3	1503.3	186.8	95.4	315.9	13144
2008	4445.0	3754.7	1801.8	1147.4	1519.7	185.7	96.0	315.9	13266
2009	4488.4	3789.4	1823.9	1153.7	1536.1	184.7	96.7	315.8	13389
2010	4532.1	3824.3	1846.2	1159.9	1552.7	183.6	97.3	315.7	13512
2011	4571.3	3855.1	1866.7	1165.1	1567.7	182.3	98.0	315.1	13621
2012	4610.6	3886.0	1887.3	1170.2	1582.9	180.9	98.5	314.6	13731
2013	4650.0	3916.8	1908.0	1175.3	1597.9	179.7	99.1	314.0	13841
2014	4689.7	3947.8	1928.8	1180.5	1613.1	178.4	99.7	313.4	13951
2015	4729.3	3978.6	1949.7	1185.8	1628.2	177.0	100.3	312.8	14062
2016	4767.6	4008.1	1969.9	1190.6	1642.9	175.6	100.9	312.1	14168
2017	4805.9	4037.5	1990.2	1195.4	1657.6	174.1	101.5	311.4	14274
2018	4844.5	4067.1	2010.7	1200.3	1672.3	172.6	102.1	310.6	14380
2019	4883.0	4096.4	2031.1	1205.1	1686.9	171.1	102.7	309.7	14486
2020	4921.6	4125.9	2051.6	1209.9	1701.5	169.7	103.3	308.9	14592

Sources: BTRE estimates based on AGO-supplied data assumptions and ABS (2001b) long-term projections (Series III).

TABLE VI.3 BASE CASE GDP GROWTH ASSUMPTIONS

(per cent change per annum)

Financial year	*Australian real GDP growth*
2001	3.75
2002	3.50
2003	3.50
2004	3.50
2005	3.16
2006	3.21
2007	3.14
2008	3.10
2009	3.05
2010	3.01
2011	3.04
2012	3.01
2013	2.97
2014	2.93
2015	2.88
2016	2.81
2017	2.72
2018	2.61
2019	2.48
2020	2.35

Source: AGO (2001, pers. comm.)

TABLE VI.4 ENERGY CONSUMPTION (END-USE) BY DOMESTIC CIVIL TRANSPORT

(Petajoules)

Year	*Cars*	*LCVs*	*Trucks*	*Other Motor Vehicles*	*Rail (non-electric)*	*Rail (electric)*
1971	268	40	75	9.5	22.3	2.8
1972	279	42	78	9.8	23.4	2.7
1973	289	45	81	10.2	24.7	2.7
1974	309	50	85	10.6	26.0	2.6
1975	327	55	89	11.0	27.4	2.6
1976	340	60	94	11.5	26.0	2.5
1977	356	67	100	11.8	27.4	2.6
1978	369	73	104	12.0	27.7	2.6
1979	381	79	114	12.3	28.3	2.7
1980	383	77	123	12.9	28.1	2.7
1981	387	77	128	13.6	28.1	2.8
1982	405	81	140	14.5	27.6	2.8
1983	403	79	131	15.7	25.1	3.0
1984	418	85	136	17.0	27.1	3.3
1985	432	93	147	18.3	28.6	3.5
1986	444	93	146	18.9	27.4	3.8
1987	453	95	149	19.7	28.4	3.9
1988	472	102	157	20.4	27.8	4.5
1989	496	104	158	21.5	25.4	5.2
1990	510	103	155	21.6	24.7	5.5
1991	511	107	139	21.4	24.5	5.5
1992	518	109	136	21.4	23.8	5.7
1993	529	111	144	21.4	23.3	5.6
1994	536	110	147	21.6	25.1	5.7
1995	555	115	152	21.7	24.2	5.9
1996	567	119	157	21.9	23.7	5.8
1997	571	120	159	22.0	25.6	6.1
1998	578	126	168	22.2	24.7	6.0
1999	590	128	170	22.3	24.4	6.2
2000	600	130	171	22.2	25.3	6.4

Continued...

Note: 'Other motor vehicles' includes buses, motorcycles and off-road recreational vehicles.

TABLE VI.4 ENERGY CONSUMPTION (END-USE) BY DOMESTIC CIVIL TRANSPORT *(Continued)*

(Petajoules)

Year	*Maritime*	*Air*	*Total*
1971	50	26	493.5
1972	50	27	512.4
1973	50	29	531.5
1974	51	30	564.4
1975	45	33	590.7
1976	41	33	609.2
1977	48	34	647.2
1978	57	37	681.8
1979	49	36	702.2
1980	54	38	717.9
1981	53	37	726.6
1982	44	40	754.6
1983	43	39	739.7
1984	43	39	768.1
1985	40	39	801.3
1986	40	42	815.2
1987	41	44	834.2
1988	40	47	870.1
1989	37	46	893.9
1990	33	37	890.1
1991	31	46	886.4
1992	29	50	892.2
1993	28	52	914.9
1994	28	54	927.8
1995	31	62	966.8
1996	30	68	992.6
1997	30	71	1004.3
1998	28	71	1024.0
1999	26	70	1037.2
2000	26	73	1053.7

Notes: 'Air' is total domestic aviation (i.e. including general aviation).
'Maritime' includes small pleasure craft and ferries.

Sources: BTRE estimates, Apelbaum Consulting Group (2001), ABARE (1999), ABS (2001a).

TABLE VI.5 BASE CASE PROJECTIONS OF ENERGY CONSUMPTION (END-USE) BY DOMESTIC CIVIL TRANSPORT

(Petajoules)

Year	*Cars*	*LCVs*	*Trucks*	*Other motor vehicles*	*Rail (non-electric)*	*Rail (electric)*
2001	610.9	134.3	175.5	21.8	26.1	6.4
2002	635.4	138.1	178.5	22.6	26.6	6.4
2003	648.1	142.6	182.6	22.8	27.1	6.5
2004	657.8	147.2	186.7	23.0	27.7	6.6
2005	667.6	150.6	189.3	23.2	28.2	6.7
2006	674.5	154.1	193.1	23.4	28.7	6.8
2007	682.3	158.4	196.7	23.6	29.3	6.9
2008	689.4	162.8	200.5	23.8	29.9	6.9
2009	695.7	167.3	204.3	23.9	30.4	7.0
2010	701.2	171.7	208.2	24.1	31.0	7.1
2011	707.2	176.6	212.2	24.3	31.6	7.2
2012	712.5	181.3	216.4	24.5	32.2	7.3
2013	717.2	185.9	220.7	24.6	32.9	7.4
2014	721.4	190.6	225.0	24.8	33.5	7.5
2015	724.9	195.3	229.1	24.9	34.2	7.6
2016	728.0	199.8	233.4	25.1	34.8	7.7
2017	730.9	204.1	237.5	25.3	35.5	7.8
2018	733.3	208.2	241.7	25.4	36.2	7.9
2019	735.2	211.9	245.3	25.6	36.9	8.0
2020	736.5	214.8	248.6	25.7	37.6	8.1

Continued...

Note: 'Other motor vehicles' includes buses, motorcycles and off-road recreational vehicles.

TABLE VI.5 BASE CASE PROJECTIONS OF ENERGY CONSUMPTION (END-USE) BY DOMESTIC CIVIL TRANSPORT ***(Continued)***

(Petajoules)

Year	*Maritime*	*Air*	*Total*
2001	25.6	77.1	1077.6
2002	25.5	80.9	1114.0
2003	25.4	84.5	1139.6
2004	25.3	88.3	1162.6
2005	25.2	92.2	1183.0
2006	25.2	96.1	1201.8
2007	25.1	100.3	1222.5
2008	25.1	104.6	1242.9
2009	25.1	109.1	1262.9
2010	25.0	113.8	1282.2
2011	25.0	118.7	1303.0
2012	25.1	123.9	1323.3
2013	25.1	129.3	1343.1
2014	25.1	135.0	1362.9
2015	25.1	140.9	1382.1
2016	25.2	147.1	1401.1
2017	25.2	153.5	1419.9
2018	25.3	160.1	1438.2
2019	25.4	167.0	1455.2
2020	25.5	174.1	1470.9

Notes: 'Air' is total domestic aviation (i.e. including general aviation).
'Maritime' includes small pleasure craft and ferries.

Source: BTRE estimates.

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abbreviations

ABBREVIATIONS

AAA	Australian Automobile Association
ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
Adl	Adelaide
ADR	Australian Design Rule
ADO	Automotive diesel oil
AFCP	Alternative fuels conversion program
AFIS	Automotive Fuels Information Service
AGO	Australian Greenhouse Office
AGPS	Australian Government Publishing Service
AIP	Australian Institute of Petroleum
ANGVC	Australasian Natural Gas Vehicles Council
ARRB	Australian Road Research Board
Artic	Articulated Truck
Avgas	Aviation gasoline
Avtur	Aviation turbine fuel
BAU	Business-as-usual
Bne	Brisbane
BTCE	Bureau of Transport and Communications Economics
BTE	Bureau of Transport Economics
BTR	Bureau of Tourism Research
BTRE	Bureau of Transport and Regional Economics
BTS	Bureau of Transport Statistics, US Department of Transportation
CBD	Central business district
Cbr	Canberra
CH_4	Methane
CI	Compression-ignition

CNG	Compressed natural gas
CNGIP	CNG infrastructure program
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2-e	CO_2–equivalent emissions (includes effects of emissions of carbon dioxide, methane and nitrous oxide)
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAFGS	Diesel and Alternative Fuels Grants Scheme
Dar	Darwin
DISR	Department of Industry, Science and Resources
DOE	United States Department of Energy
DPIE	Department of Primary Industries and Energy
DTLR	Department of Transport and Local Government and the Regions
EPAV	Environment Protection Authority of Victoria
ERG	Expert Reference Group
ESMVI	Environmental Strategy for the Motor Vehicle Industry
FC	Fuel consumption
FFC	Full fuel cycle
FORS	Federal Office of Road Safety
GCM	Gross combination mass
g/pkm	grams per passenger–kilometre
g/tkm	grams per tonne–kilometre
Gg	Gigagrams (10^9 grams, equals 1000 tonnes)
GTEM	Global trade (general) equilibrium model
GVM	Gross vehicle mass
GWP	Global Warming Potential
HC	Hydrocarbon
Hob	Hobart
IC	Industry Commission
IDF	Industrial diesel fuel
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
ITS	Intelligent Transport Systems
km	Kilometres
kt	Kilotonnes
L	Litres
LCV	Light commercial vehicle
LNG	Liquified (or liquid) natural gas
LPG	Liquified (or liquid) petroleum gas
LSD	Low sulphur diesel
m	Metres

Mel	Melbourne
MJ	Megajoules (million joules)
MMRF–Green	Monash Multi-Regional Forecasting–Green model
Mt	Megatonnes (million tonnes)
N2O	Nitrous oxide
NAFC	National Average Fuel Consumption
NELA	Nelson English, Loxton & Andrews Pty Ltd
NEPC	National Environment Protection Council
NG	Natural gas
NGGIC	National Greenhouse Gas Inventory Committee
NGV	Natural gas vehicle
NMHC	Non-methane hydrocarbons
NMVOC	Non-methane volatile organic compound
NO_x	Nitrogen oxides
NREL	National Energy Renewable Laboratory
OEM	Original Equipment Manufacturers
ORP	Optimal road pricing
Per	Perth
pkm	passenger–kilometres
PJ	Petajoules (10^{15} joules)
PM	Particulate matter
PMV	passenger motor vehicle
RTSA	Railway Technical Society of Australasia
SI	Spark-ignition
skm	seat–kilometres
SMVU	Survey of Motor Vehicle Use
SO_2	Sulphur dioxide
Syd	Sydney
t	Tonnes
tkm	tonne–kilometres
TDM	Transport demand management
THC	Total hydrocarbons
ULSD	Ultra low sulphur diesel
UK	United Kingdom
US	United States of America
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey