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Population Growth and Greenhouse Gas Emissions

Sources, trends and projections in Australia

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List of Abbreviations

ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
BTE, BTCE	Bureau of Transport (and Communications) Economics
CH_4	methane
CHP	combined heat and power
CO	carbon monoxide
CO_2	carbon dioxide
CO_2-e	carbon dioxide equivalent
EU	European Union
FOSS	energy from fossil fuel sources
F&GC	forest and grassland conversion
GDP	gross domestic product
Gg	gigagrams (kilotonnes)
GNP	gross national product
GWP	global warming potential
HES	Household Expenditure Survey
HFCs	hydrofluorocarbons
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
LUCF	land-use change and forestry
Mt	megatonnes
Mtoe	megatonnes of oil equivalent
N_2O	nitrous oxide
NEM	National Electricity Market
NGGI	National Greenhouse Gas Inventory
NGGIC	National Greenhouse Gas Inventory Committee
NMVOCs	non-methane volatile organic compounds
OECD	Organisation for Economic Co-operation and Development
PFCs	perfluorocarbons
PJ	petajoules
SF_6	sulfur hexafluoride
SO_x	oxides of sulfur
t	metric tonne
TFC	Total Final Consumption of Energy
TPES	Total Primary Energy Supply
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change

Executive Summary

There has been growing public concern in recent years over the effects of population growth on resource use and the state of the natural environment in Australia. Much of the opposition to continued high levels of immigration to Australia is based on these concerns, and terms such as ‘carrying capacity’ and ‘ecologically sustainable population’ have entered the lexicon.

Calls for stabilisation of population growth on environmental grounds have been met by arguments that environmental decline is caused by other factors and that the effects of increasing numbers of people can be offset by changes in consumption habits and the technologies used to produce goods and dispose of wastes.

This paper is the first comprehensive investigation of the relationship between population growth and greenhouse gas emissions in Australia. There are four parts to the analysis each of which reaches some striking conclusions.

Per capita emissions

The first part calculates the total greenhouse gas emissions per capita for industrialised countries using the official reports to the United Nations. In addition, the economic and industrial structures of selected countries are examined to illustrate which countries have peculiar circumstances predisposing them to higher greenhouse gas emissions.

Among industrialised countries, Australia has the highest greenhouse gas emissions per person at 26.7 tonnes per annum; this is twice the average level for all other industrialised countries (13.4 tonnes) and 25% higher than emissions per person in the USA (21.2 tonnes). While the USA has higher energy and fugitive emissions per capita (20.6 tonnes compared to Australia’s 17.6 tonnes), Australia has much higher levels of emissions from agriculture and land-use change.

Analysis of energy-related emissions in 1997 by source shows that Australia’s energy-related emissions source profile is not markedly different from other developed countries except for larger emissions from industry and slightly lower emissions from the residential and commercial sectors. Interestingly, the percentage of Australia’s energy-related emissions arising from transport is less than the OECD and EU average, and less than the percentages in the USA, UK and Canada. This goes some way to dispelling the myth that Australia’s size necessitates proportionally higher transport use.

When industrial emissions are broken down by category, the most notable feature is the size of Australia’s emissions from the non-ferrous metals sector (mainly aluminium). Compared to all other countries examined, Australia generates a much larger proportion of its emissions from non-ferrous metals, but a smaller proportion from chemical and petrochemical industries. The percentage of Australia’s emissions from ‘other industries’ is also smaller than the OECD average.

Population growth and growth in emissions

The second part of this study decomposes trends in energy-related emissions in OECD countries into their constituent parts in order to isolate the effect of population growth in each of the countries selected.

The analysis shows that Australia's population growth has been one of the main factors driving growth in domestic greenhouse gas emissions. Unlike most other developed countries, the impact of population growth on emissions has not been offset by increased use of non-fossil fuel energy sources or by the use of less emission-intensive fuels (such as natural gas in preference to coal). Consequently, Australia's population growth has produced a large increase in greenhouse gas emissions. Of the developed countries examined in this paper, Australia experienced the second-largest increase in energy-related carbon dioxide (CO_2) emissions between 1982 and 1997 (38%). Only New Zealand performed worse with a 77% increase over the same period.

The role of migration

The third part of this analysis considers the impact of migration to Australia on global greenhouse gas emissions by comparing per capita emissions in Australia with a weighted average of emissions over the period 1985-86 to 1996-97 in countries which provide immigrants to Australia and countries to which Australians emigrate.

A large proportion of Australia's recent population growth, and hence growth in greenhouse gas emissions, can be attributed to high rates of immigration (around 900,000 people between 1986 and 1997). From a global perspective, some of these emissions would have been created regardless, and Australia's immigration program has merely shifted the source. However, the average emissions per capita in the countries of origin is only 42% of average emissions in Australia (6.7 tonnes pa from energy in 1995 compared to 15.8 tonnes in Australia). The implication is that as immigrants alter their lifestyle to that of Australians, they increase global greenhouse gas emissions.

Future population scenarios

The fourth part of this study examines the likely effects of population growth on Australia's future greenhouse gas emissions. Using a specially developed model of the factors that influence energy emissions, projections are made of emissions growth through to 2020 under a number of population policy scenarios in which immigration and fertility rates vary.

The impact of immigration and population growth is projected to result in increasing greenhouse emissions over the next two decades, while feasible changes in fertility will have little impact over that time-frame. Australia's population policy decisions will have a substantial impact on growth of greenhouse gas emissions. In the absence of new policies, energy-related emissions in 2020 could range from 385 Mt CO_2 with zero net immigration to 450 Mt with net immigration of 140,000 pa. In other words, a high immigration policy is likely to increase Australia's greenhouse gas emissions by 16% by 2020 compared to a zero net immigration policy.

While the two immigration scenarios result in a difference of 65 Mt CO_2 in Australia's energy-related emissions by 2020, the world's greenhouse gas emissions would increase by only around half of this amount since immigrants to Australia come from countries that have per capita emissions levels around half of Australia's.

Policy implications

The Australian government will need to introduce further policies to restrict emissions from the energy sector in order to meet our international obligations under the Kyoto Protocol. Population policy could be an important tool for meeting Australia's target, particularly in subsequent commitment periods. The government could reduce energy-related emissions during the commitment period by up to 6% of 1990 levels by restricting the immigration intake from now until 2012. Conversely, any increase in the current immigration intake will require more severe restrictions on the economy to control emission-producing activities if Australia is to meet its international targets.

This analysis highlights the importance of incorporating environmental considerations into population policy decisions. The experience of the GST package has shown that the impact of major public policy decisions is not confined to the portfolio of the minister or department responsible for that policy. This is illustrated again in the case of population policy. Clearly, any attempts to rapidly increase Australia's population will produce a sharp increase in greenhouse gas emissions. However, even modest increases will make it more difficult for Australia to achieve future emission reduction targets.

1. Introduction

There has been growing public concern in recent years over the effects of population growth on resource use and the state of the natural environment in Australia. Much of the opposition to continued high levels of immigration is based on these concerns, and terms such as ‘carrying capacity’ and ‘ecologically sustainable population’ have entered the lexicon. Extreme positions have been taken. A new business group has called for a population of 50 million by 2050, and one commentator has called for a population of 6 to 12 million.[1] Neither of these is demographically or socially tenable.

Calls for stabilisation of population growth on environmental grounds have been met by arguments that environmental decline is caused by other factors and that the effects of increasing numbers of people can be offset by changes in consumption habits and the technologies used to produce goods and dispose of wastes.

One way of understanding the various influences is through the well-known IPAT formula, in which environmental impact (I) is set equal to the product of population (P), affluence (A) interpreted as consumption per person, and technology (T). Thus:

$$I = P \bullet A \bullet T$$

The IPAT formula is conceptually helpful but of little practical use without much more careful specification. However, it is apparent from the formula that population growth will not lead to environmental decline if the level of consumption per person falls correspondingly or if technologies change in ways that mitigate the effects. While consumption patterns do shift with growing wealth, most of the emphasis has been placed on the effects of technological change, and it is for this reason that those who argue that we should not be concerned about population growth are sometimes referred to as ‘technological optimists’.

While technological optimists have been able to build persuasive rebuttals of the arguments of the ‘population pessimists’ with respect to many aspects of environmental decline, they encounter much more difficulty with the critical issue of climate change. Changing energy-dependent lifestyles and shifting away from fossil fuels are hard enough without the added pressure of a rapidly growing population.

This paper is the first comprehensive investigation of the relationship between population growth and greenhouse gas emissions in Australia. It has four parts. The first part (in Section 2) calculates the total greenhouse gas emissions per capita for the so-called Annex B countries, that is, the 35 industrialised countries that have emission reduction obligations under the 1997 Kyoto Protocol. While emissions per capita have been calculated many times before for energy-related emissions, this appears to be the first time that they have been calculated for emissions from all sources and sinks as reported by the various parties to the United Nations. In addition, the economic and industrial structures of selected Annex B countries are examined to illustrate which countries have peculiar circumstances predisposing them to higher greenhouse gas emissions.

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[1] See *The Australian* 25 November 1999 and Flannery (1994).

The second part (Section 3) decomposes trends in energy-related emissions in OECD countries into their constituent parts in order to isolate the effect of population growth in each of the countries selected. The analysis also illustrates the influences of improvements in energy efficiency, changing industrial structure and shifts towards energy sources with lower greenhouse gas intensities. Australia's emissions and trends are compared to those of other developed countries.

While the first two parts of this study compare Australia's greenhouse gas emissions to those of other OECD countries, the next two focus on Australia alone. The third part (Section 4) considers the impact of migration on Australia's greenhouse gas emissions by comparing per capita emissions in Australia with a weighted average of emissions over the period 1986-1997 in countries which provide immigrants to Australia and countries to which Australians emigrate.

The fourth part (Section 5) examines the likely effects of population growth on Australia's future greenhouse gas emissions. Using a specially developed model of the factors that influence energy emissions, projections are made of emissions growth through to 2020 under a number of population policy scenarios. The analysis illustrates the potential contribution of population policies, including immigration, to meeting emission reduction obligations under the Kyoto Protocol.

2. Greenhouse gas emissions in developed countries

2.1 Total and per capita greenhouse emissions

Notions of fairness and justice underpin international negotiations to reduce greenhouse gas emissions. The concepts of burden sharing and 'common but differentiated responsibilities' enshrined in the UN Framework Convention on Climate Change (UNFCCC) are based on the widespread belief that nations that have contributed most to the problem of climate change should do most to solve it.

One of the most important principles referred to internationally is that of polluter pays. The most common interpretation of polluter pays is that national targets for the reduction of greenhouse gas emissions should be based on the historical contribution of each nation to global emissions. The most important factor in determining this contribution is the level of emissions per capita. A number of studies of burden sharing or differentiation have identified emissions per capita as the foremost criterion on which emission reduction targets should be based (for example, Elzen *et al*. 1999; Torvanger and Godal 1999; Walz *et al*. 1997). Other criteria include: the ability to pay (usually measured by GNP per capita), emissions intensity of output and dependence on fossil fuels.

Due to measurement complexities, perceptions of emissions per capita have to date been based on energy emissions only, and on this basis it is widely believed that the USA has the world's highest emissions per capita. However, the provisions of the UNFCCC require Parties to compile and submit to the UN systematic and comprehensive inventories of emissions from all sources and sinks. The availability of these data on a consistent basis for Annex B (industrialised) countries now makes it possible to make a more thorough comparison of national emissions.

Comprehensive greenhouse gas emissions

Table 1 presents comprehensive emissions by sector for each Annex B country in 1995. It also presents 1995 population and per capita emissions. Figure 1 presents graphically the size and breakdown of per capita emissions for selected Annex B countries. For those countries where the Land-Use Change and Forestry (LUCF) sector is a net carbon sink, the block of sequestered emissions below the zero line must be subtracted from the emissions above the line to obtain net emissions per capita. Figure A1.1 in Appendix 1 presents the same information as Figure 1 for all Annex B countries.

The information presented in Table 1 and Figures 1 and A1.1 has been obtained from an Addendum to the Second compilation and synthesis of national communications presented under the Review of the Implementation of Commitments and of Other Provisions of the Convention (referred to from now on as UNFCCC 1998).[2]

The emissions data presented in Table 1 represents carbon dioxide-equivalent (CO_2-e) emissions of the three main greenhouse gases – carbon dioxide (CO_2), methane (CH_4)

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[2] FCCC/CP/1998/11/Add.2, http://www.unfccc.org/resource/docs/cop4/11a02.pdf

Table 1 Total emissions, breakdown by source and per capita emissions for Annex B countries, 1995 (Mt CO_2-e)[a]

	Energy		Industry	Agriculture	Waste	LUCF	Other	Total	Population 1995 (millions)	Per capita emissions (t CO_2-e/ capita)
	Fuel combustion	Fugitive								
Australia	291.77	25.58	7.45	87.36	16.36	51.87	1.55	481.94	18.07	26.67
Austria	50.05	2.46	11.49	5.41	4.63	-13.58	4.13	64.59	8.06	8.01
Belgium[c]	112.83	0.95	14.27	11.52	4.99	-2.06	0.06	142.56	10.14	14.06
Bulgaria	59.34	5.57	8.18	3.40	10.96	-7.52	0.06	79.98	8.41	9.51
Canada	478.96	48.20	36.34	25.04	19.47	0.00	3.31	611.32	29.62	20.64
Czech Republic	130.37	8.51	5.22	3.45	3.02	-5.45	0.30	145.42	10.33	14.08
Denmark	58.91	0.71	1.31	16.17	1.55	-0.96	0.46	78.14	5.23	14.94
Estonia	20.93	0.00	0.22	0.84	0.67	-13.27	0.00	9.39	1.49	6.30
Finland	57.33	0.08	1.77	4.64	2.79	-10.50	0.08	56.19	5.11	11.00
France	365.79	14.33	40.79	48.88	19.15	-46.80	9.93	452.06	58.14	7.78
Germany[e]	885.13	24.57	50.31	61.52	39.90	-30.00	0.00	1031.43	81.66	12.63
Greece	84.79	1.03	8.33	8.37	2.77	0.00	0.00	105.29	10.45	10.08
Hungary	58.97	6.62	2.28	3.06	6.11	-4.80	0.00	72.23	10.23	7.06
Iceland	1.77	0.08	0.46	0.29	0.04	0.00	0.01	2.65	0.27	9.81
Ireland	33.27	0.23	2.58	19.28	2.95	-6.23	0.75	52.83	3.6	14.68
Italy	425.20	10.07	29.31	41.84	21.65	-24.51	12.39	515.95	57.3	9.00
Japan[e]	1162.10	3.55	68.65	20.65	28.54	-94.62	1.51	1190.38	125.57	9.48
Latvia	12.16	0.46	0.13	5.81	0.64	-10.48	0.04	8.76	2.52	3.48
Lithuania[b]	37.75	0.55	2.64	7.15	3.49	-8.85	4.09	46.81	3.72	12.58
Luxembourg	9.16	0.04	0.41	0.51	0.08	-0.30	0.01	9.92	0.41	24.19
Monaco[d]	0.08	0.00	0.00	0.00	0.05	0.00	0.00	0.13	0.03	4.30
Netherlands	183.66	3.57	7.61	18.31	9.13	-1.70	1.48	222.06	15.46	14.36
New Zealand	24.95	1.19	2.74	44.33	2.77	-13.49	0.20	62.69	3.66	17.13
Norway	29.89	2.35	8.52	3.88	6.78	-13.64	0.34	38.12	4.36	8.74
Poland[c]	365.18	18.90	13.76	22.87	17.96	-41.95	0.23	396.94	38.59	10.29
Portugal[c]	47.92	0.26	4.01	6.33	13.77	-1.15	0.27	71.41	9.92	7.20
Russian Fed[c]	1607.27	297.20	24.37	114.53	41.04	-568.00	9.95	1526.37	148.2	10.30
Slovakia	45.99	2.25	3.43	4.24	1.45	-5.12	0.19	52.42	5.37	9.76
Slovenia[b]	13.60	1.07	0.64	2.35	1.60	-2.29	1.79	18.75	1.99	9.42
Spain[c]	221.62	13.41	18.85	37.64	15.30	-28.97	0.04	277.88	39.21	7.09
Sweden	56.29	0.02	5.17	4.20	1.28	-30.00	0.25	37.21	8.83	4.21
Switzerland	40.95	0.34	2.71	5.84	2.85	-5.10	0.12	47.72	7.08	6.74
Ukraine[b]	671.17	130.81	33.70	50.50	19.68	-51.98	7.25	861.12	51.55	16.70
United Kingdom	533.77	23.94	28.93	26.19	38.44	9.95	1.53	662.75	58.61	11.31
United States	5206.40	202.49	96.43	268.23	236.44	-428.00	0.00	5581.99	263.17	21.21
Total	13385.31	851.36	542.98	984.59	598.30	-1409.50	62.33	15015.37	1106.36	13.57

a. Main gases (CO_2, CH_4, N_2O), excluding bunkers and non-CO_2 emissions from LUCF. Year is 1995 unless stated otherwise.

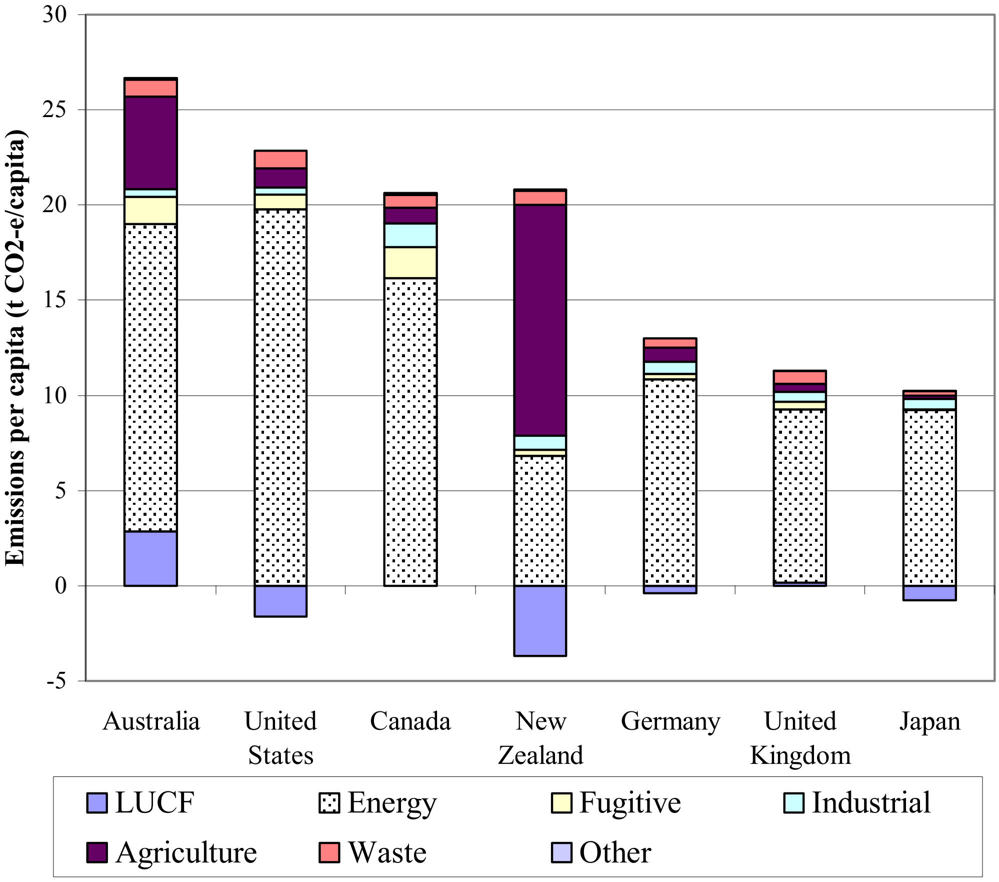
b. 1990 data. c. 1994 data. d. 1996 data.

e. Combination of 1994 and 1995 data.

Note: there are a number of instances where countries did not report emissions and emissions have been counted as zero.

Source: UNFCCC 1998. Population data obtained from IEA 1997, pp. 48–57. Monaco's population was obtained from http://www.monaco.monte-carlo.mc/us/presentation/index.html.

Figure 1 Greenhouse gas emissions per capita by source for selected countries, 1995



Note: For those countries where the LUCF sector is a net sink (eg. New Zealand), the block of sequestered emissions below the zero line in the figure must be subtracted from the emissions above the line to obtain net emissions per capita.

and nitrous oxide (N_2O). Emissions of these gases are reported consistently and are available for almost all Annex B countries (UNFCCC 1998, Tables A.1, A.2, A.6, A.7, A.8 and A.9). Emissions of other greenhouse gases (HFCs, PFCs and SF_6) are not included because a number of Annex B countries have not reported these emissions (UNFCCC 1998, Table A.10). Although potent greenhouse gases, the contribution made by these gases to total CO_2-e emissions is relatively small. For example, in Australia these gases contributed 0.3% of 1996 CO_2-e emissions (NGGIC 1998, p. xviii). Emissions of the three main greenhouse gases were converted to carbon dioxide equivalents using the global warming potentials reported by the Intergovernmental Panel on Climate Change (NGGIC 1999a, pp. vi, xiv) and aggregated according to source (see Table 1).

Emissions of CO_2 from the land-use change and forestry sector (LUCF) are also incorporated into Table 1 (UNFCCC 1998, Table A.5). The UNFCCC did not report the emissions of other gases (CH_4, N_2O etc.) from this sector.

A number of sources of greenhouse gas emissions have been excluded from this analysis. Emissions from international bunkers (fuel used in international shipping and aviation) are excluded because they are not included in national inventories. Greenhouse precursor gases, comprising carbon monoxide (CO), oxides of nitrogen

(NO_x) and non-methane volatile organic compounds (NMVOC), were also excluded from these calculations.

There are several Annex B countries that did not report 1995 emissions information to the UNFCCC, requiring the use of emissions data for these countries from earlier years. In the case of the Ukraine, Slovenia and Lithuania the most recent emissions data were from 1990. For Belgium, Poland, Portugal, the Russian Federation and Spain, 1994 data were used. For Germany and Japan, a combination of 1995 and 1994 data were used. Monaco reported data from 1996 instead of 1995.

A number of countries did not report emissions and removals for some sectors, particularly LUCF. The UNFCCC noted an inconsistency in methods of reporting LUCF emissions (UNFCCC 1998, Table A.2). Canada, Greece, Iceland and Monaco did not report emissions or removals from the LUCF sector at all (at least in a form that satisfied IPCC guidelines). Estimates of Sweden's 1995 LUCF emissions were not available so 1992 estimates were used. Finland reported a range of emissions estimates to account for 'cultivated peatlands and non-viable drainage areas' (UNFCCC 1998, Table A.5) so an average was used. Australia was the only country to report the Forest and Grassland Conversion (F&GC) subsector of LUCF separately. This subsector was responsible for 'an additional 80,972 Gg of CO_2 in 1995' (UNFCCC 1998, Table A.5).[3]

Omissions existed for other sectors as well. Spain reported an estimate of '2,657 Gg of emissions [of CO_2] from waste' that was 'not included in the Party's national total'. Instead, Spain included an estimate of 863 Gg CO_2 in its national total, which 'included emissions resulting from both non-renewable waste and torches in the chemical industry and refineries' (UNFCCC 1998, Table A.2.). Spain also reported 17,554 Gg CO_2 of emissions from agriculture for information purposes only (meaning it is not included in their inventory). Sweden, Finland, Iceland and Estonia did not report estimates for fugitive emissions of CH_4. Similarly, Monaco did not provide estimates of CH_4 or N_2O emissions from any sector, but indicated such emissions were negligible (UNFCCC 1998, Tables A.7, A.9.).

Results

Of the Annex B countries, Australia has the highest greenhouse gas emissions per person at 26.7 tonnes per annum; this is twice the average level for all other industrialised countries (13.4 tonnes) and 25% higher than emissions per person in the USA (21.2 tonnes).

While the USA has higher energy and fugitive emissions per capita (20.6 tonnes compared to Australia's 17.6 tonnes), Australia has much higher levels of emissions from agriculture and land-use change. Australia's emissions from land clearing fell sharply between 1990 and 1995, and it is likely that the difference between Australia and the USA in the earlier year would have been greater than in 1995. The year 1990

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[3] This figure has been revised down slightly in more recent inventories as methodologies have improved (for example, NGGIC 1999a). However, it would be inconsistent to use revised Australian data for comparison with unrevised international data. On the other hand, because Australia is one of the few countries where emissions from F&GC are significant it may be appropriate to use recent data. Hamilton & Vellon (1999) report revised 1995 F&GC emissions at 62.7 Mt CO_2. Accordingly, using recent data reduces emissions by 18.2 Mt CO_2 and per capita emissions by 1.01 Mt CO_2-e/capita.

is especially important because it is the base year for calculating mandatory emission targets in the commitment period 2008-2012 under the Kyoto Protocol.

In descending order, the six Annex B nations with the highest per capita emissions are: Australia (26.7), Luxembourg (24.2), USA (21.2), Canada (20.6), New Zealand (17.3) and Ukraine (16.7). The next five countries have emissions per capita of 14 to 15 tonnes. Luxembourg's very high emissions are due to the presence of a large steel plant combined with a small population. New Zealand has low energy emissions (due to the predominance of hydro-electricity) but very high emissions from agriculture (due to the large number of livestock). These are offset to some extent by the net sink provided by forests in that country.

Among larger countries at the other end of the scale, France (7.8), Germany (12.6), Spain (7.1), Italy (9.0) and Japan (9.5) are notable. Their low emissions are due to a combination of energy efficiency, industrial structure and the use of nuclear power.

2.2 Sectoral emissions of developed countries

The per capita and total emissions data presented above illustrate some of structural characteristics that result in certain countries emitting relatively large quantities of greenhouse gases. For example, the large agricultural sectors of Australia, Ireland and New Zealand account for relatively large agricultural greenhouse gas emissions from these countries. High levels of energy-related emissions can often be accounted for by a country's reliance on fossil fuels for electricity generation and the presence of energy-intensive industries. On the other hand, the use of nuclear and hydroelectric power partly explains the lower emissions of Japan and some European countries.

Sectoral contribution to energy-related emissions

The following subsection examines energy-related emissions in more detail, in an attempt to identify the extent to which the structural characteristics of economies result in higher emissions. For selected Annex B countries, energy-related emissions have been broken down according to the broad sector of the economy responsible for those emissions. The proportions of emissions originating from each sector for selected countries are presented in Figure 2.

The information in Figure 2 is derived from the International Energy Agency's *Energy balances of OECD countries* publication (IEA 1998). Energy use and fuel mix data for each sector has been combined with carbon dioxide (CO_2) emission factors for each fuel type to generate CO_2 emissions from each sector.[4] The emission factors used are those prescribed by the IPCC (IPCC 1997b, p. 1.6). Emissions from heat and electricity generation and distribution have been assigned to the sectors responsible for ultimately consuming the heat and electricity (detailed data are

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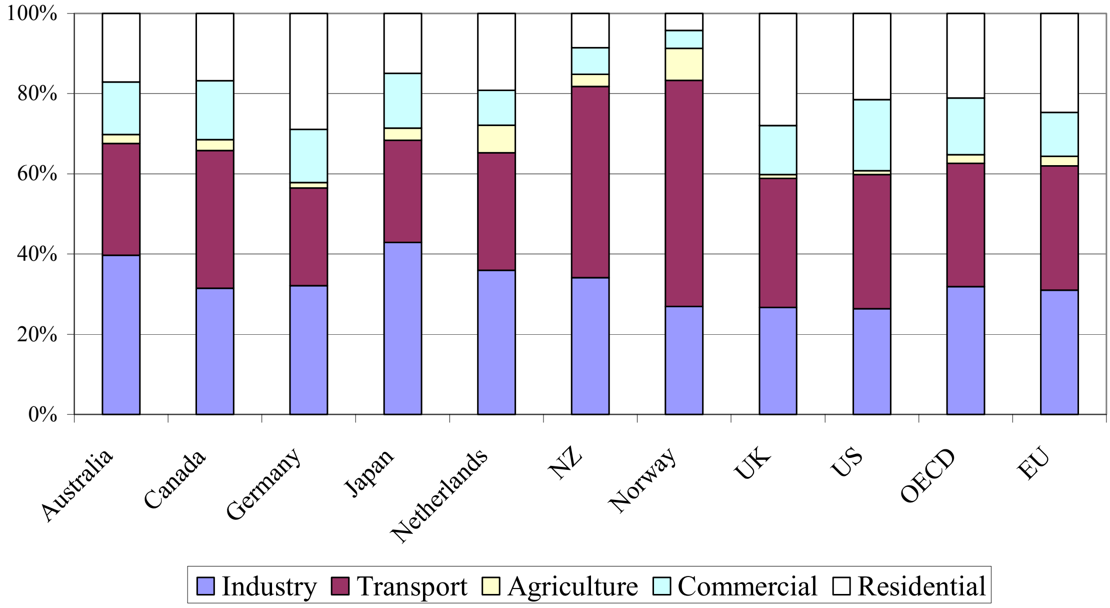
[4] Feedstocks used in the chemical and petrochemical industry are treated according to IPCC guidelines. That is, it is assumed that 75% of the carbon in naphtha feedstocks is fixed in the products of the industry and never released in to the atmosphere. Also 80% of the carbon in LPG and ethane feedstocks, 33% of the carbon in natural gas feedstocks and 50% in diesel feedstocks are assumed to be fixed (IPCC 1997a, pp. 1.25-28). These sources account for around 95% of total OECD feedstocks (IEA 1997, pp. II.4-6). The remainder comprise mainly heavy fuel oil, liquefied natural gas and refinery gas, and it is assumed that 50% of the carbon in these feedstocks is fixed.

presented in Table A2.1 in Appendix 2).[5] Similarly, emissions from fuel used in the manufacture of petroleum, natural gas and coal by-products have been assigned to those sectors consuming each of these fuels.

The results in Figure 2 illustrate which sectors are responsible for energy-related emissions in the selected countries. One of the most striking features is that New Zealand and Norway generated a much larger proportion of energy emissions from transport – well above the OECD and EU averages, and larger than the proportion observed for countries often perceived as having large transport requirements, namely Australia, Canada and the USA. However, this result can be attributed to the fact that New Zealand and Norway derive a large proportion of their electricity from hydroelectric (emissions-free) sources. As a result, the percentage of their emissions from transport is larger. Other notable features include the large proportion of emissions in Australia, Japan and New Zealand emissions arising from the industrial sector – significantly above the OECD average. For the USA, UK and Norway, industrial emissions are below the OECD average. Energy use in the industrial sector is examined further below.

Figure 2 Energy-related CO_2 emissions by sector in selected countries, 1997



Source: IEA 1998, pp. II.17, 47, 53, 71, 101, 137, 161, 167, 173, 215, 221

Australia's energy-related emissions share profile is not markedly different from other developed countries except for larger emissions from industry and slightly lower emissions from the residential and commercial sectors compared to the OECD average. However, on a per capita basis Australia's energy emissions are around 52% higher than the OECD average largely because emissions from industry are high. Interestingly, the share of Australia's energy-related emissions arising from transport

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[5] For combined heat and power (CHP) generation, heat production is essentially a by-product of electricity generation. Accordingly, it could be argued that all the fuel used in these plants is for the generation of electricity and any heat produced requires no (additional) energy. However, this leads to the perverse conclusion that heat is generated without the need for energy. To overcome this, it is assumed that heat generation is thermodynamically efficient, i.e. one terajoule of heat requires one terajoule of fuel.

is less than the OECD and EU average. However, on a per capita basis transport emissions are around one-third higher than the OECD average, although substantially less than in the USA and Canada.[6] The information in Figure 2 is presented per capita terms in Appendix 2, Figure A2.1. This goes some way to dispelling the belief that Australia's size necessitates proportionally higher transport use.

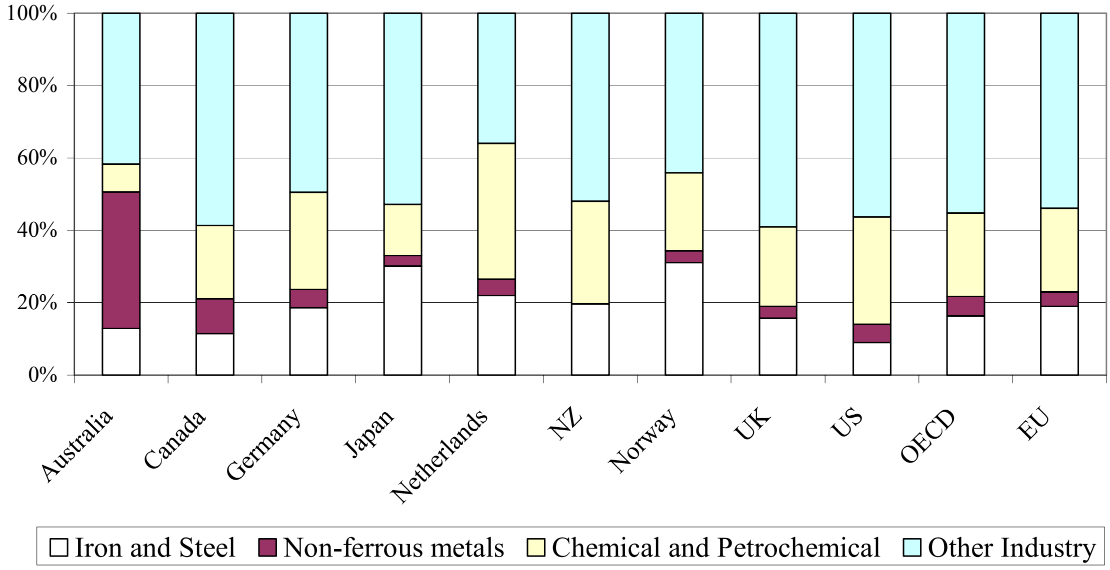
The industrial sector

The disaggregation presented in Figure 2 helps illustrate the contribution to energy-related emissions of broad sectors of the economy. However, these broad groups are still highly aggregated, particularly the industrial sector, and the analysis conceals the contributions of particular activities to that sector's emissions.

To overcome this limitation, the industrial sector has been further disaggregated into the main fuel-consuming activities. This enables an examination of how the structure of each country's industrial sector influences energy-related emissions. Each selected country's industrial sector has been broken down into four groups: iron and steel, non-ferrous metals, chemical and petrochemical and all other industry.[7] Emissions have been calculated in the same manner as for the previous analysis.

The findings are shown in Figure 3. The most striking feature here is the size of Australia's emissions from the non-ferrous metals (mainly aluminium smelting).

Figure 3 Energy-related CO_2 emissions by industry in selected countries, 1997



Source: IEA 1998, pp. II.17, 47, 53, 71, 101, 137, 161, 167, 173, 215, 221.

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[6] The percentage of energy-related emissions from transport in Figure 2 (28%) differs from the 23% presented in the latest NGGI (NGGIC 1999a, p. xix) for several reasons. The higher percentage of emissions in Figure 2 result from the inclusion of emissions from fuel used in international aviation and shipping (i.e., to and from Australia), emissions from electricity used by railways and emissions from fuel used in the manufacture of transport fuels. In addition, for cross-country consistency default IPCC greenhouse gas emission factors for petroleum products, which are around 3-7% higher than factors used in the NGGI, have been used. If the NGGI factors are more accurate, the proportion of Australia's energy-related CO_2 emissions from transport is smaller than indicated in Figure 2.

[7] Including non-metallic minerals, transport equipment, machinery, mining and quarrying, food and tobacco, paper, pulp and printing, wood and wood products, construction, textiles and leather and others.

Compared to all other countries examined, Australia generates a much larger proportion of its emissions from non-ferrous metals but a smaller proportion from chemical and petrochemical industries.[8] Australia's large aluminium smelting industry is almost entirely dependent on coal-fired electricity, explaining a large part of Australia's industry emissions.[9] The percentage of Australia's emissions from 'other industries' is also smaller than the OECD average. Clearly, the higher proportion of emissions from industry observed in Figure 2 can be explained by Australia's disproportionately large non-ferrous metals industry.

Of the other countries, the Netherlands and New Zealand have a much larger share of emissions from the chemical and petrochemical industries. The Netherlands has a large petrochemical industry[10] whereas New Zealand's petrochemical industry is almost entirely natural gas-based. It produces synthetic petroleum fuels and fertilisers to support its relatively large agricultural sector. The share of emissions produced by the petrochemical and chemical industries in New Zealand is particularly large because many other of its industries rely on hydroelectric power, whereas the chemical industry relies heavily on fossil fuels. The information presented in Figure 3 is presented in per capita terms in Appendix 2, Figure A2.2.

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[8] It is unclear why New Zealand has reported zero energy use in non-ferrous metals, particularly since it has a medium-sized aluminium smelter (Comalco 1999). However, this smelter is supplied by hydroelectric (emissions-free) power so this failure to report energy use should make little difference to the findings in Figure 3 (assuming New Zealand has reported fuel use in electricity production accurately).

[9] Except for one small hydro-powered aluminium smelter, Australian smelters are dependent on coal-fired electricity. Canada and the USA also have large non-ferrous metal sectors, but not relative to their industrial sectors as a whole. They also derive more power from hydro and nuclear power.

[10] The Netherlands produces, in energy terms, almost one-third of total European Union petroleum product exports (IEA 1998, pp. II. 47, 161).

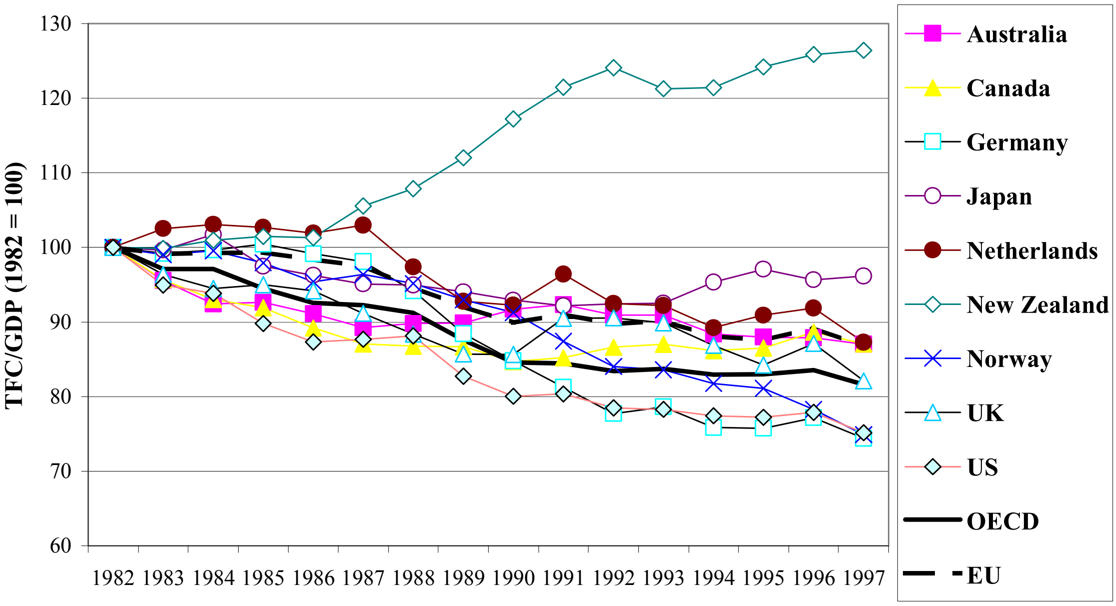
3. Determinants of emissions growth in Australia and other OECD countries

The previous section examined comprehensive greenhouse emissions in 1995 and energy emissions by sector in 1997 for selected countries. Although providing an informative snapshot of each country's particular circumstances in those years, a static analysis provides no information on trends in emissions. An analysis of emissions trends is not possible for comprehensive emissions due to a lack of data prior to 1990, and inconsistencies in reporting and availability of data from 1990 to 1995. In addition, over the five-year period little information would be gained about long-term trends. Such an analysis would merely highlight the 1991-2 worldwide recession and collapse of the economies of Eastern Europe and the Former Soviet Union. To overcome this limitation, information on energy use and energy-related emissions from 1982 to 1997 has been analysed to examine some of the trends in OECD countries over a longer period. This enables changes in economic structure, the effect of new projects and technology and changing consumption habits to be captured. The data used in this section are set out in detail in Appendix 4.

3.1 Trends in energy-intensity and per capita emissions

Figure 4 illustrates trends in the energy-intensity of economic activity, measured in units of Total Final Consumption of energy per unit of GDP (TFC/GDP) in selected countries and the OECD and EU. The energy consumed to generate a dollar of GDP has declined over the period in all countries except New Zealand. The greatest decreases in energy-intensity have occurred in Germany, the USA and Norway. Japan has not improved as much as other countries, a result that can be attributed to a combination of events prior to 1982 including economic restructuring that replaced highly energy-intensive industries and

Figure 4 Trends in energy intensity of economic output for selected countries, 1982-1997

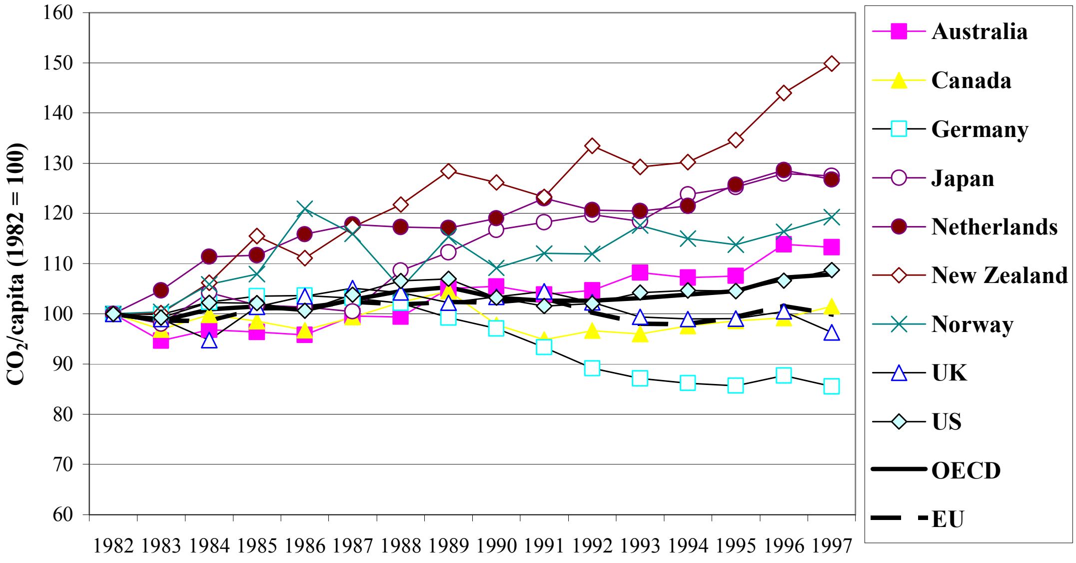


Source: Appendix 4, Table A4.5 and A4.6.

pressures from the 1970s oil crisis that led to the adoption of more energy-efficient practices. The New Zealand result is surprising and reflects a sharp increase in energy-intensity in the period 1986-1992.[11] Without more detailed analysis it remains unclear how energy use became uncoupled from economic growth during this period, although in all likelihood economic restructuring replaced low energy-intensive activities with highly energy-intensive value-adding industries.[12] Australia exhibited a decrease in energy-intensity until around 1987, but has shown little improvement since. Similarly, Canada's energy intensity has increased since 1990. Overall from 1982 to 1997, Australia, Canada, the Netherlands and the European Union all experienced a similar improvement, but were behind the USA, Germany, Norway and the UK.

Of equal interest is the information presented in Figure 5. This figure illustrates changes in energy-related CO_2 emissions per capita from 1982 to 1997. Again, New Zealand stands out as the worst performer, for the reasons discussed above. Japan and the Netherlands also exhibit a significant increase in per capita emissions, rising almost 30% in each country. Germany, the United Kingdom, Canada and the European Union have contained their per capita emissions. One of the better performers in energy-intensity, Norway, is not a good performer in per capita emissions. The reason for this becomes apparent when changes in GDP/capita for Norway are examined (see Section 3.2). Australia's per capita emissions increased slightly more than the OECD average and the US. Incidentally, Australia, Canada and the US have had high per capita energy-related emissions throughout the 1982 to 1997 period. New Zealand's recent increase still leaves it as the second lowest emitter per capita (behind Norway, see Appendix 4).

Figure 5 Trends in per capita energy-related CO_2 emissions, 1982-1997



Source: Appendix 4, Table A4.8.

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[11] The New Zealand economy performed poorly during this period, growing 0.2% in five years, whereas final energy consumption grew around 18%.

[12] Such as the synthetic fuels industry.

3.2 Decomposition analysis

The factors contributing to the growth of greenhouse gas emissions can be examined in more detail. This subsection decomposes energy-related emissions growth or decline into changes in selected demographic, economic and energy- and emissions-related variables. Energy-related emissions of carbon dioxide (CO_2) for a given year can be decomposed using the following equation:

$$CO_2 = \frac{CO_2}{FOSS} \bullet \frac{FOSS}{TPES} \bullet \frac{TPES}{TFC} \bullet \frac{TFC}{GDP} \bullet \frac{GDP}{POP} \bullet POP$$

where:

CO_2 = energy-related CO_2 emissions;

FOSS = fossil fuel consumption (measured in PJ);

TPES = total primary energy supply (measured in PJ);

TFC = total final consumption of energy (measured in PJ);

GDP = gross domestic product (measured in inflation-adjusted own currencies); and

POP = population.

Each factor in the equation can be interpreted as follows:

$\frac{CO_2}{FOSS}$ is the CO_2 intensity of fossil fuel combustion, mainly reflecting the fuel mix;

$\frac{FOSS}{TPES}$ indicates the proportion of total energy obtained from fossil sources;

$\frac{TPES}{TFC}$ represents the amount of primary energy required to deliver energy for final consumption and reflects both conversion efficiency and he fuel mix. The share of electricity in final energy consumption is the main influence;

$\frac{TFC}{GDP}$ is the energy intensity of economic output, reflecting both efficiency of energy use and economic structure; and

$\frac{GDP}{POP}$ is a measure of economic output per capita.

Changes in any of the factors will influence energy-related CO_2 emissions. Similarly, changes in CO_2 emissions between two years can be explained by the changes in the above factors (see Appendix 3 for detail on the relationship between changes in each variable and CO_2 emissions). The equation presented above has been used to decompose growth of energy-related CO_2 emissions between 1982 and 1997. Detailed data are presented in Appendix 4.

Figure 6 shows changes in the decomposition variables for Australia between 1982 and 1997. Over this period, energy-related CO_2 emissions grew by 38%. This growth can be explained by the large increase in population and GDP per capita, slightly offset by lower energy use per unit of GDP and slightly improved conversion efficiency or fuel mix changes. Over this period the proportion of electricity in total final consumption of energy has increased from 15.6% to 19.6% (see Table A4.9), whilst changes in the fuel mix or operating practices have resulted in more thermally-efficient electricity production.

Figure 6 Contributions to growth in CO_2 emissions, Australia 1982-1997

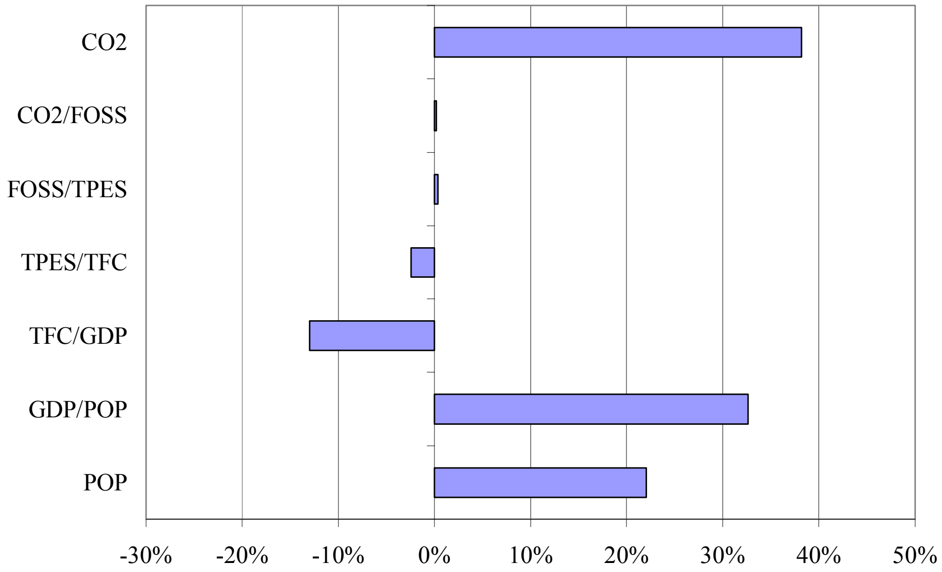

Figure 7 shows the decomposition again but divides the period 1982-1997 into three five-year periods. This enables a closer examination of the timing of changes in the decomposition variables. The most notable feature is the increasing rate of growth of CO_2 emissions since the early 1980s. The figure shows that population growth during 1982-87 and 1987-92 was slightly higher than 1992-1997 – a fact consistent with changing immigration levels.[13] Growth in GDP per capita was very low between 1987-92, principally because the period includes the recession of 1991-92. The other notable feature is the dramatic improvement in energy-intensity of economic activity in the mid-eighties – perhaps a result of growth of the services sector, a declining manufacturing base and improved energy efficiency. A smaller improvement occurred in the mid-nineties. Overall, these factors combine to produce cumulative increases in energy-related CO_2 emissions of 6.6%, 13.1% and 14.6% for each period (compounding to 38%).

How does the growth of energy-related CO_2 emissions in Australia compare to that in other developed countries? Figure 8 presents a comparison between Australia and the OECD as a whole. Over the 1982-97 period, OECD emissions grew 21%, or a little more than half the growth of Australia's emissions. Much of this difference can be

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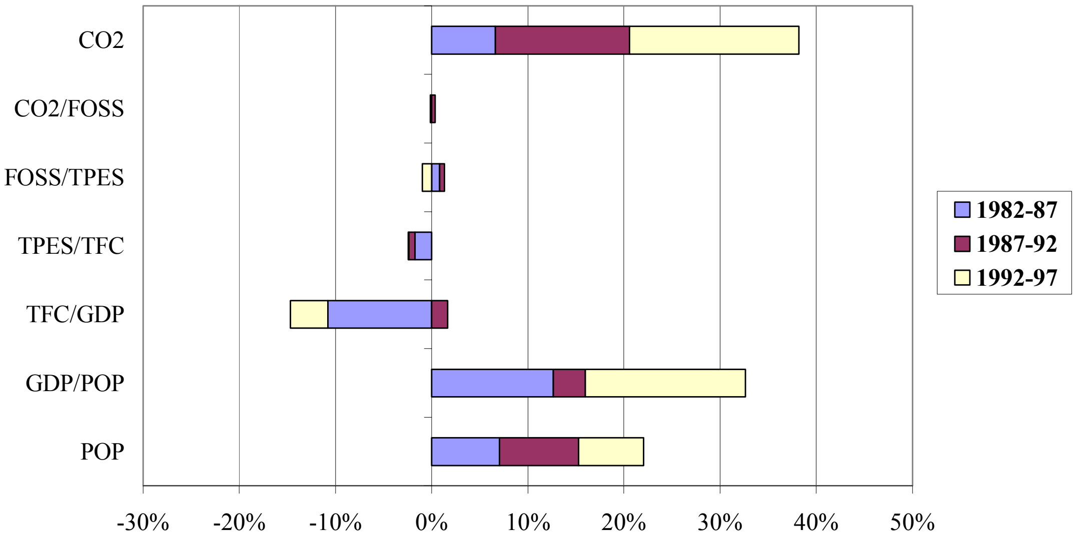
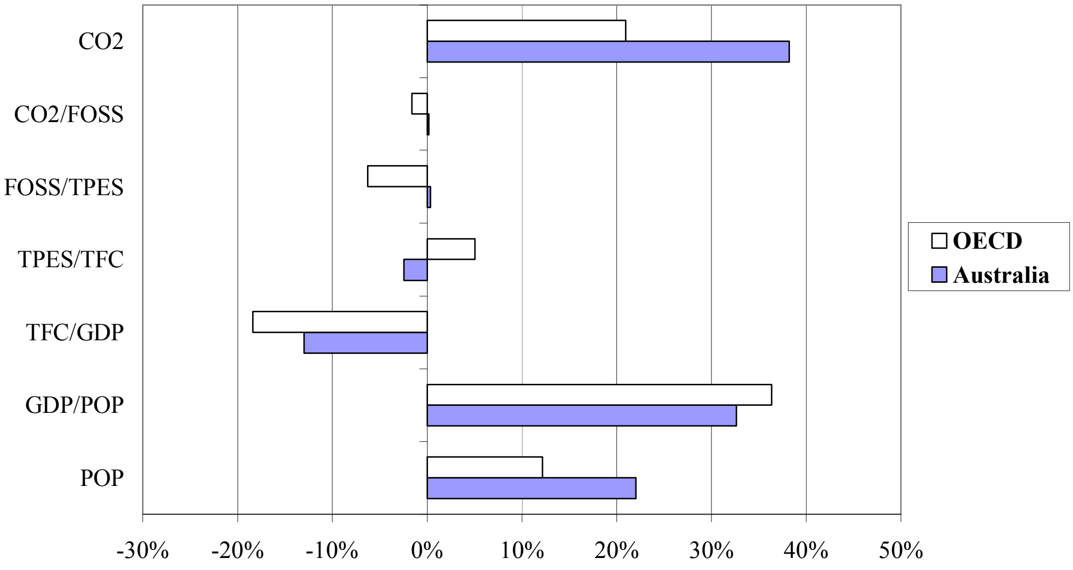
[13] Immigration is the main factor driving population growth in Australia. See Sections 4 and 5.

Figure 7 Contributions to growth in CO_2 emissions, Australia 1982-87, 1987-92 and 1992-97



explained by smaller population growth in the OECD (12% compared to 22%). However, the OECD exhibited a larger increase in GDP per capita, a larger decrease in energy-intensity, a larger increase in the proportion of electricity in final energy consumption (growing from 14.2% to 18.6%) and a decrease in the proportion of energy sourced from fossil fuels. The latter can be explained by greater use of nuclear and hydroelectric power in OECD countries other than Australia. The OECD TPES/TFC result is also influenced by changes in fuel mix leading to changes in aggregate

Figure 8 Contributions to growth in CO_2 emissions, Australia and the OECD 1982-1997

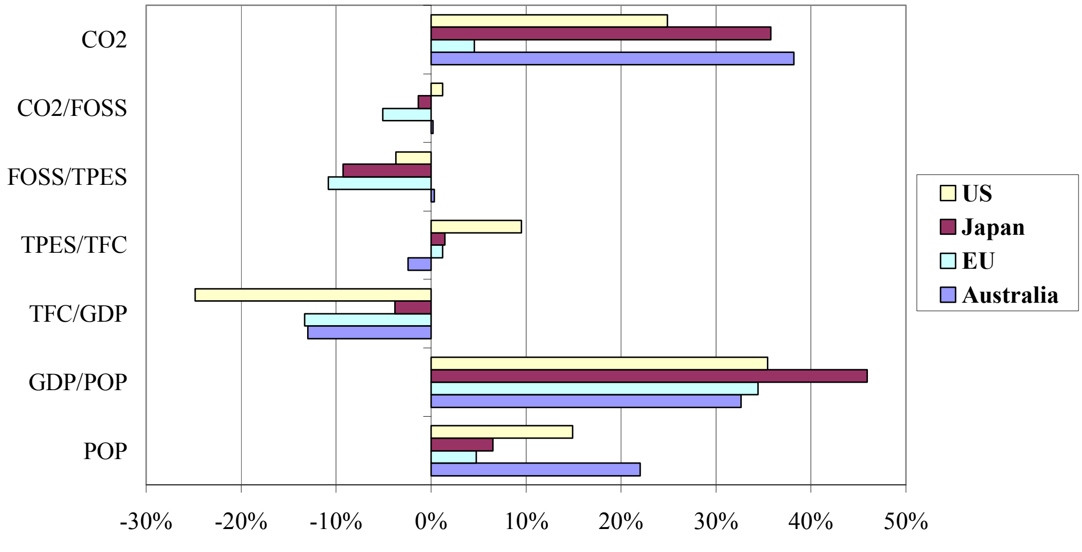


thermal efficiency.[14] The reduction in Australia's TPES/TFC between 1982 to 1997 is due to slower growth in the share of electricity in final consumption and improved thermal efficiency resulting from electricity generation fuel mix changes or improvements in operating efficiency.

Figure 9 compares Australia with the larger economies – Japan, the USA and the European Union. All of these economies have experienced lower population growth and higher GDP/capita growth than Australia. Unlike Australia, these economies have all reduced the proportion of fossil fuels used in energy production. All countries have improved the energy-intensity of economic activity, although Japan lags behind slightly because it had already introduced major restructuring and energy-efficiency measures following the oil shocks of the 1970s and early 1980s. Interestingly, the USA is using an increased proportion of electricity (growing from 14% in 1982 to 18.8% in 1997) and has not improved aggregate thermal efficiency enough to offset the impact on TPES/TFC.[15] As a result of these changes, energy-related CO_2 emissions have increased in all countries, led by Australia (38%) and followed by Japan (36%), the USA (25%) and the EU (5%). The significantly lower growth observed for the EU can be attributed to much smaller population growth, improved efficiency and greater use of nuclear, hydro and gas.[16]

A clearer indication of Australia's relative performance over the period may be gained by comparing Australia with countries that share other similarities. Figure 10

Figure 9 Contributions to growth in CO_2 emissions, Australia, Japan and US 1982-1997



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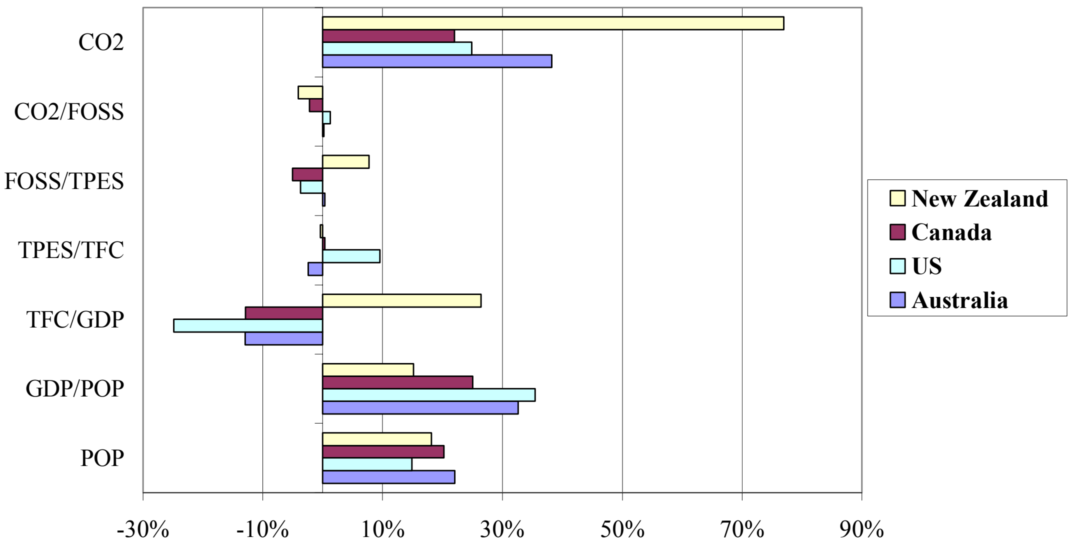
[14] Certain assumptions used by the IEA in determining the notional thermal efficiency of nuclear and hydroelectric power have a large influence on energy use data for those countries deriving a large proportion of energy from these fuels. For instance, for nuclear power the IEA assumes thermal efficiency of 33%. That is, 3 PJ of primary nuclear energy are needed to produce 1 PJ of electricity. Consequently, a shift from certain fossil fuels to nuclear power in electricity generation may lead to an increase in TPES/TFC.

[15] It is unclear whether this is because many improvements in technological and operational efficiency were made prior to 1982, whether the USA did not have the flexibility to make electricity generation fuel mix changes (or had already made them) or whether the USA was generally less efficient.

[16] The reduction in the CO_2-intensity of fossil fuel use is indicative of a shift to gas.

Figure 10 Contributions to growth in CO_2 emissions, Australia, Canada, New Zealand and US 1982-1997



compares Australia with Canada, New Zealand and the USA. These countries have experienced similar levels of population growth between 1982 and 1997, all are English-speaking and all have similar lifestyles. However, Figure 10 illustrates significant variation in fuel mix and energy intensity of economic activity across these countries. New Zealand, particularly, appears to be the odd one out, having experienced lower growth in GDP/capita, a shift to more energy-intensive industries, an increase in the proportion of energy derived from fossil sources[17] and a massive (77%) increase in energy-related CO_2 emissions. Canada and the USA have reduced the use of fossil fuels and reduced the energy intensity of economic activity (other features of the USA's performance have been discussed above). The growth in Australia's emissions is particularly high because population growth has not been offset by improvements to the fuel mix.

Figure 11 presents a comparison between Australia and some of the countries that make up to EU, in addition to Norway. The European countries all experienced significantly lower population growth than Australia and slightly higher growth in GDP/capita. Germany and the United Kingdom were able to restrict (and in the case of Germany, reverse) growth in energy-related CO_2 emissions by changing fuel mix, reducing the use of fossil fuels and improving the energy-intensity of economic activity.[18] Of more interest is the increase in emissions in the Netherlands and Norway. In the latter this can be attributed to exceptionally high growth in GDP/capita and increased own-use of natural gas in the North Sea, leading to higher TPES without affecting TFC.[19] In the Netherlands, the increase can be attributed to a

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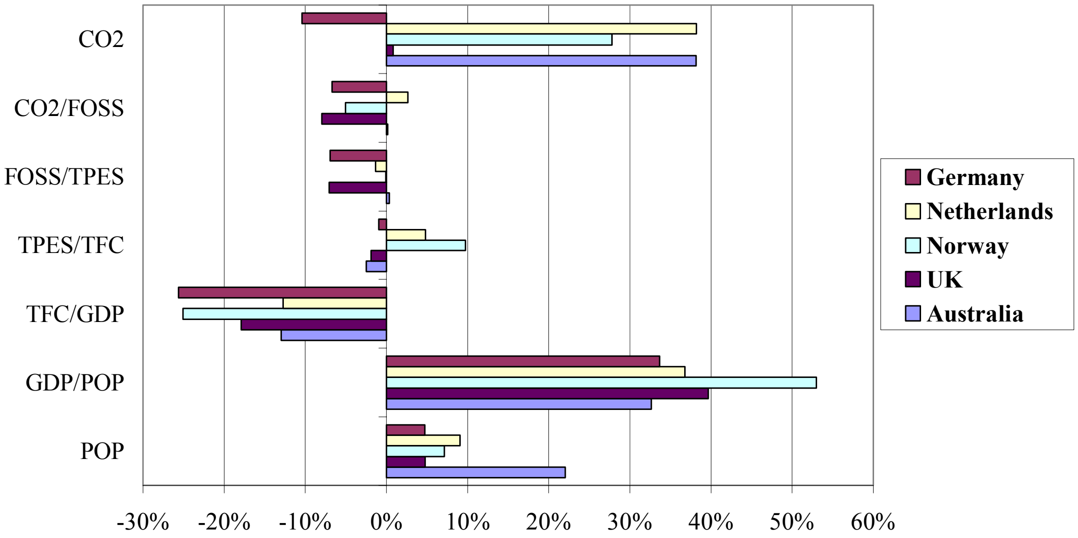
[17] This increase is a result of increased energy use overall, without a similar increase in hydroelectric capacity.

[18] The decrease in fossil fuel use is a result of increased use of nuclear power. The decrease in CO_2 intensity of fossil fuel can be attributed to a shift from coal to North Sea gas in the UK and decommissioning of old East German power stations.

[19] This result is not from decreases in thermal or operating efficiency in electricity generation, or from a higher share of electricity in final consumption, because Norway obtains almost all of its electricity from hydroelectric power. The IEA assumes 100% efficiency and does not allow for changes in the

Figure 11 Contributions to growth in CO_2 emissions, Australia, Germany, Netherlands, Norway and UK 1982-1997



relatively smaller improvement in the energy-intensity of economic activity as a result of structural change, a slightly larger population growth, higher CO_2 intensity of fossil fuels and an increase in electricity's share of final consumption (growing from 10.8% to 13.3%). These factors ensured that the growth in GDP/capita flowed through strongly to an increase in CO_2 emissions. Australia's growth in emissions was almost identical to that of the Netherlands (which experienced the largest increase of the European countries studied) and both countries experienced a similar change in GDP/capita and the energy intensity of economic activity.[20] However, unlike the Netherlands, Australia's growth is population was responsible for the large increase in energy-related CO_2 emissions.

Overall, New Zealand experienced the largest increase in energy-related CO_2 emissions over the period, mainly as a result of increase energy-intensity of economic activity. Australia experienced the highest population growth of all the countries studied and the second-largest increase in energy-related CO_2 emissions. Australia did not improve the energy intensity of economic output, nor shift away from fossil fuels as rapidly as the other countries studied (except New Zealand). In all countries (except New Zealand) the share of electricity in final energy consumption has increased. Unlike most other countries, Australia has improved the thermal efficiency of its electricity generation (while increasing the share of electricity in final consumption) by changing the electricity generation fuel mix and making operational improvements, both of which many other countries improved prior to 1982. Many countries have initiated a shift away from coal towards gas that has reduced the CO_2 intensity of fossil energy. In contrast, Australia lags behind in the use of gas. In addition, most developed countries have reduced the share of fossil fuels in their energy supply.

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notional efficiency of hydroelectric plants. Incidentally, Norway increased its share of electricity in final consumption from 42.5% to 46%, a relatively small increase compared to other countries.

[20] The smaller reduction in energy intensity may be structural – that is, growth in the large petrochemical industry in the Netherlands and the large non-ferrous metals industry in Australia may have offset improvements in the energy intensity of the rest of those country's economies.

In most countries economic growth is the main factor driving higher energy-related greenhouse gas emissions. However, where this is the case most countries have managed to offset the impact of economic growth by reducing energy-intensity and changing the fuel mix. It follows, and is demonstrated by the above analysis, that the faster a country's rate of population growth, the greater the improvements in energy-intensity and fuel mix needed to restrict the growth of greenhouse gas emissions. In the case of Australia, it is clear that population policy decisions have had a marked effect on growth in greenhouse gas emissions.

4. Migration and greenhouse gas emissions

The decomposition analysis of the previous section showed that population growth has made a large contribution to the growth of greenhouse gas emissions in Australia, much more so than in other OECD countries. Australia's rapid population growth is due in part to relatively high rates of immigration.

Climate change is a global environmental problem; the location of the source of emissions is irrelevant to the climate effects of greenhouse gas emissions. The fact that a large part of population growth in Australia is due to immigration rather than natural increase thus has significant implications for assessing the effect of population growth on greenhouse gas emissions. This is because some part of the greenhouse gas emissions for which immigrants to Australia are responsible would have occurred anyway had they not migrated. We therefore need to assess the net impact of migration to Australia on the world's greenhouse gas emissions. The key factor here is the per capita emissions of Australians compared to the per capita emissions of residents in those countries that supply migrants to Australia. We must also take into account the effects on global emissions of emigration from Australia.

Total immigration to Australia by country of origin for the twelve years 1985-86 to 1996-97 is shown in Table 2. Emigration from Australia by country of destination is shown in Table 3 (see Appendix 5 for detailed data sets). Energy emissions per capita for 1995 are also shown for each country. The shares of immigrants and emigrants by country are shown in Figures 12 and 13. A full comparison of per capita emissions would compare *comprehensive* greenhouse gas emissions for all countries rather than the energy component, but comprehensive emissions data are available only for industrialised countries. The latter account for around 45% of immigrants to Australia but receive around 80% of emigrants from Australia. On the other hand, increased immigration to Australia will directly affect energy-related emissions, but will have little impact on the other two principal sources of emissions – agriculture and land-use

Figure 12 Immigration to Australia by country of origin, 1986-97

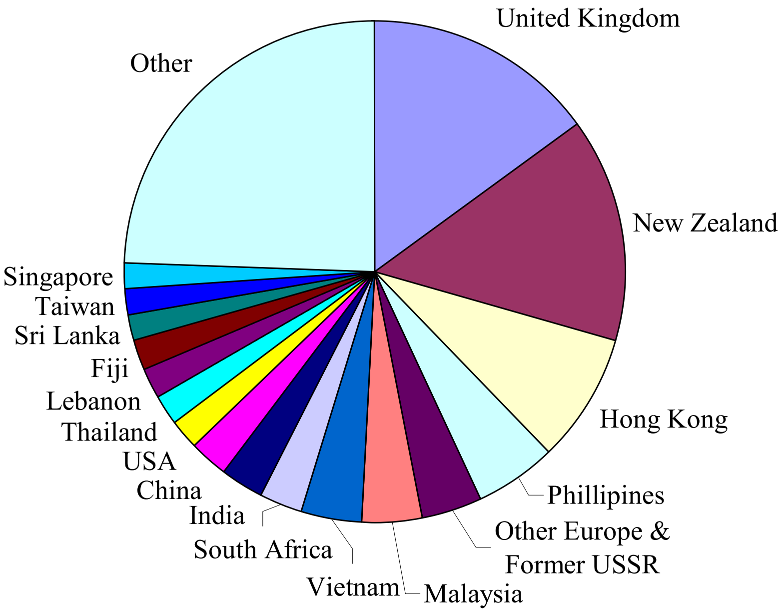


Table 2 Arrivals and average per capita emissions by country of origin

Country of origin	Number 1986-1997	CO_2/capita from energy 1995	CO_2-e/capita comprehensive (bold where available) 1995
United Kingdom	185720	9.64	**11.31**
New Zealand	181100	8.19	**17.13**
Hong Kong	100530	7.11	7.11
Philippines	66400	0.73	0.73
Other Europe & Former USSR[a]	48150	6.60	**11.23**
Malaysia	47950	4.58	4.58
Vietnam	47810	0.30	0.30
South Africa	34990	7.74	7.74
India	34510	0.86	0.86
China[b]	30240	2.51	2.51
United States of America	26060	19.88	**21.21**
Thailand	24780	2.67	2.67
Lebanon	23020	3.35	3.35
Fiji	22120	ne	ne
Sri Lanka	21840	0.34	0.34
Taiwan	20550	7.83	7.83
Singapore	20320	19.66	19.66
Other[c]	303961		
Total	**1240051**	**6.58**	**8.61**

a. The breakdown of countries within this group was not available. Accordingly, per capita emissions from energy are for 'non-OECD Europe' (IEA 1997, p. 48). Comprehensive emissions are a simple average of those of Bulgaria, the Czech Republic, Hungary, Poland, Slovakia and the Ukraine.

b. These figures do not account for 'category jumping'.

c. See Appendix 5 for full breakdown.

change. Accordingly, comparison of energy-related emissions may be more appropriate.

The weighted average of per capita emissions in countries from which immigrants to Australia are drawn and to which emigrants from Australia go are shown at the

Figure 13 Emigration from Australia by country of destination, 1986-97

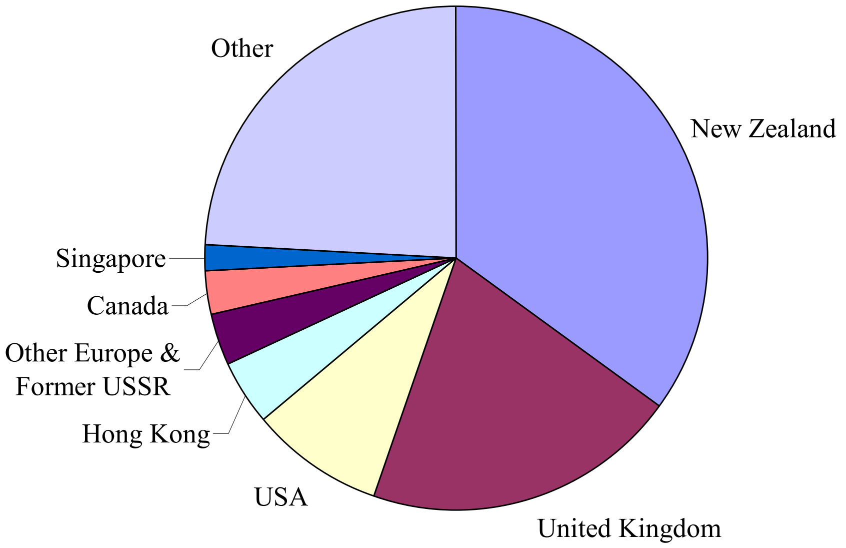


Table 3 Departures and average per capita emissions by country of destination

Country of destination	Number	CO_2/capita from energy	CO_2-e/capita comprehensive (bold where available)
	1986-1997	1995	1995
New Zealand	109550	8.19	**17.13**
United Kingdom	63370	9.64	**11.31**
United States of America	26740	19.88	**21.21**
Hong Kong	12700	7.11	7.11
Other Europe & Former USSR[a]	10860	6.60	**11.23**
Canada	8760	15.90	**20.64**
Singapore	5210	19.66	19.66
Other[b]	75367		
Total	**312557**	**9.47**	**13.67**

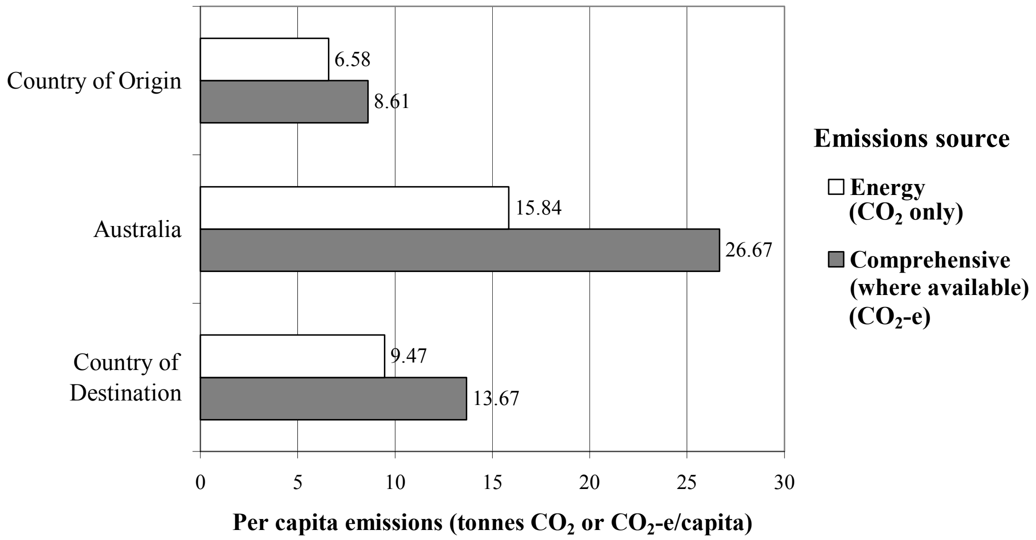
Footnotes as for Table 2.

bottom of Tables 2 and 3. They are compared with per capita emissions for Australia in Figure 14. It is apparent that emissions per person in the countries from which immigrants to Australia are sourced are less than half (42%) of the energy-related emissions for each Australian.

Similarly, the countries to which Australians emigrate have much lower emissions per capita. It is reasonable to use comprehensive emissions data in this case, and they indicate that average emissions in countries of destination are a little over half (51%) of those in Australia. Using energy-related emissions only, average per capita emissions in the countries of destination are 60% of those in Australia.

However, before one can conclude that migration to Australia results in the doubling of emissions of those people, several other factors need to be considered. Some of Australia's emissions are accounted for by exports, and it is reasonable to assume that immigration does not increase Australia's exports (or decrease exports from the countries of origin). On the other hand, immigration does increase Australia's imports and therefore global emissions embodied in those goods; similarly it reduces

Figure 14 Weighted mean per capita greenhouse gas emissions, Australia, countries of origin and countries of destination, 1995



imports into the countries of origin. Thus a full accounting of the effect of migration to Australia must include the effect of immigration on the emissions embodied in exports and imports in both Australia and the countries of origin. When these various factors are accounted for, the per capita emission levels in Figure 14 emerge as an accurate estimate of the change in global emissions associated with migration to Australia (see Appendix 6 for a full discussion).

The question naturally arises of whether immigrants to Australia do actually emit as much as the average Australian resident when they take up residence, or whether they continue with their less emissions-intensive patterns of behaviour. Perhaps the question is better phrased as follows: How much time elapses before immigrants to Australia (or their descendants) reach the average Australian level of emissions? Due to lack of information, no comprehensive answer to this question is possible. However, some light can be shed on it from the ABS *Household Expenditure Survey* (HES) (ABS 1995a). Per capita energy-related emissions can be related to consumption of goods and services, particularly of fuel and power, but also those that require energy inputs.

The HES examines household expenditure on a variety of goods and services, including electricity and transport, in 1993-94. The survey indicates that the average Australian-born household spends slightly less than the average overseas-born household on all expenditure categories except alcoholic beverages and medical care.[21] However, the average overseas-born household is slightly larger than the average Australian-born household (2.77 persons to 2.57). Table 4 reports expenditure per person on energy-intensive consumption goods – fuel and power and transport – for households by country of origin. The average Australian-born household spends $16.63 per week on fuel and power and $89.69 per week on transport (including fuel), compared with $17.13 and $93.74 for the average overseas-born household. Per person, this equates to $6.47 per Australian born resident and $6.18 per overseas-born resident for fuel and power, and $34.90 versus $33.84 for transport. Expenditure on household goods, often energy-intensive products, is $39.12 per week ($15.22 per person) for Australian-born households compared with $40.12 ($14.48 per person) for overseas-born households. These data indicate that overseas-born Australians tend to consume slightly less than Australian-born citizens.

Table 4 Weekly expenditure per person on energy-related goods, 1993-94

Category	**Australian-born**	**Overseas-born**	**Post-1984 arrivals**	**Italian-born**	**Chinese-born**
Fuel and power[a]	$6.47	$6.18	$4.91	$7.53	$4.64
Transport	$34.90	$33.84	$32.80	$48.89	$26.11

a. Not including automotive fuel.
Source: ABS 1995a, pp. 20-21.

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[21] An ‘Australian-born household’ indicates that the reference person, i.e. the head of the household, was born in Australia. Similarly, an ‘overseas-born household’ is one in which the head of the household was born outside Australia.

Examining only those households where the head of the household arrived after 1984 paints a slightly different picture. These households spend substantially less on fuel and power ($4.91 per person) and slightly less on transport ($32.80 per person), one interpretation of which is that over time immigrants adjust their consumption habits towards that of established Australians. Another possible explanation is that pre-1984 immigrants were drawn from a different mix of countries to post-1984 immigrants, and this explains consumption differences. For example, Italian immigrant households spend $7.53 per person on fuel and power and $48.89 per person on transport, compared to Chinese immigrant households where spending is much lower – $4.64 per person on fuel and power and $26.11 per person on transport. Clearly, some of this is due to consumption habits brought from their country of origin, some is due to income levels, and some is a result of naturalisation of consumption habits. It is reasonable to conclude that immigrants to Australia do adopt Australian consumption patterns over time so that their greenhouse gas emissions rise from the levels in their countries of origin to Australian levels.

A further point worth considering is whether the average per capita emissions for a country accurately reflects the per capita emissions of those individuals who emigrate from that country to Australia. Skilled migrants, making up around 45% of the current immigration intake (Birrell and Rapson 1998), are likely to be the more affluent citizens of a country on average, while unskilled family-reunion immigrants or refugees (making up the remainder) are likely to be less affluent.[22] The consumption habits of these individuals may differ markedly from the country average. A similar concern arises for those people emigrating from Australia. However, without detailed information about consumption habits of those individuals, it is difficult to draw any conclusions.

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[22] This is more likely to be true in the case of immigrants from developing countries.

5. Projections of greenhouse gas emissions

While the last section considered the impact of migration on global emissions, this section considers the impact of population growth in Australia on Australia's emissions relative to its Kyoto target. It was shown in Section 3 that historically population growth has made a large impact on Australia's energy-related greenhouse gas emissions. Continued high population growth has been used by the Government to justify the lenient emissions target awarded to Australia under the Kyoto Protocol. This argument implicitly recognises the influence population size has on greenhouse gas emissions but denies that Australia should be responsible for domestic population growth. However, it remains true that immigration policy is a significant determinant of population growth in Australia (for example, see Kippen and McDonald 1998). In addition, European experience indicates that government policies can have a significant impact on fertility rates.

Here the relationship between population growth and growth of greenhouse gas emissions is explored using a number of feasible population scenarios in which rates of immigration and fertility are varied. It will indicate the importance or otherwise of population growth in achieving Australia's emission reduction targets in the first and subsequent commitment periods of the Kyoto Protocol.

5.1 Population scenarios

The Australia Bureau of Statistics (ABS) produces population projection scenarios using a variety of assumptions and some of these scenarios – both published and unpublished – are used in this analysis (ABS 1998b; *pers. comm.* Sue Taylor, ABS). The ABS scenarios include those based on assumed rates of annual net immigration of 0 and 70,000. In addition to these we include a scenario based on a net immigration figure of 140,000 per annum through to 2020, a rate that was almost attained in both 1987-88 and 1988-89 and is at the high end of feasible scenarios.[23] In addition, we allow the fertility rate to vary, taking a value of either 1.6 (low fertility) or 1.75 (high fertility). These values are consistent with recent trends in fertility.[24] Together, these variables give six population growth scenarios through to 2020 as set out in Table 5 below. The population paths under the various scenarios are shown in Figure 15 (and are fully specified in Appendix 7, Table A7.1).

Table 5 Population projection scenarios

Scenario	Net immigration	Fertility rate	Population 2020 (millions)
A1	0	1.6	20.0
A2	0	1.75	20.4
B1	70,000	1.6	22.0
B2	70,000	1.75	22.4
C1	140,000	1.6	23.9
C2	140,000	1.75	24.4

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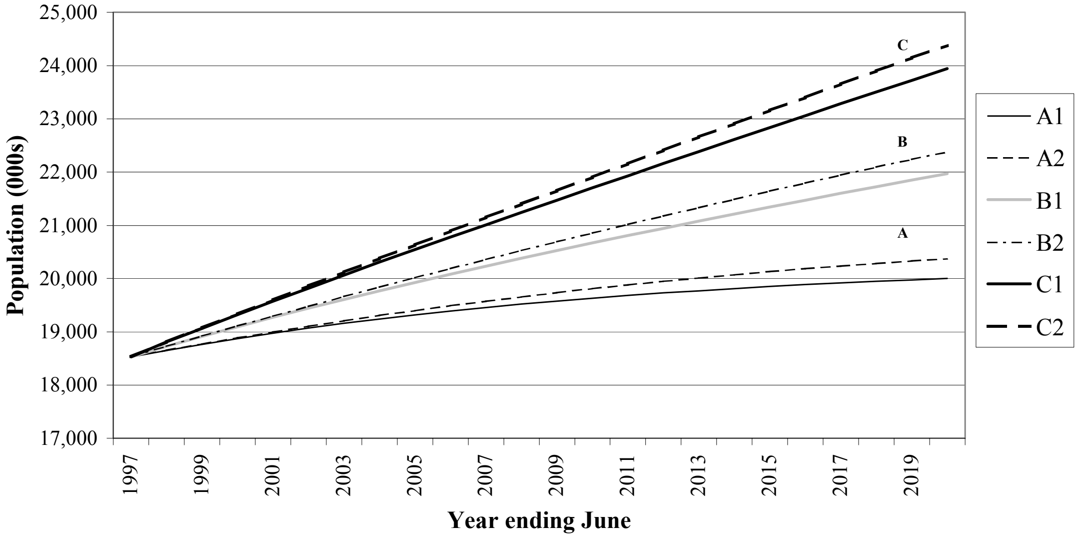
[23] Note that calls for Australia to aim for a population of 50 million within the next century would require levels of net immigration reaching 450,000 per annum, a level that is socially, politically and environmentally infeasible.

[24] Fertility fell from 1.85 in 1994 to 1.80 in 1997 (ABS 1998b; Kippen and McDonald 1998).

Figure 15 Population projections under different fertility and migration scenarios, 1997-2020



5.2 Linking population growth with greenhouse gas emissions

The level of energy-related greenhouse gas emissions in 2020 will depend on the demand for energy and the mix of energy types in the various sectors of the economy. Growth of the various sectors of the economy will in turn be influenced by a range of factors. Some will be influenced by population growth while others will not. For example, growth of the residential and road transport sectors will be directly influenced by population growth, while growth of agriculture and mining, because they are mostly export-oriented, will not. The energy-using sectors in question are:

- agriculture
- mining
- manufacturing
- construction
- commercial (services)
- road passenger transport
- other road transport
- other transport
- residential
- other

The model used in this study is based on one developed by the Australian Bureau of Agricultural and Resource Economics (ABARE) for making projections of energy consumption and production to 2014-15 (Bush *et al.* 1999). The ABARE model is not designed to investigate the impact of different population growth scenarios, and thus incorporates only one population scenario, Scenario B2 in Figure 15 above, i.e.

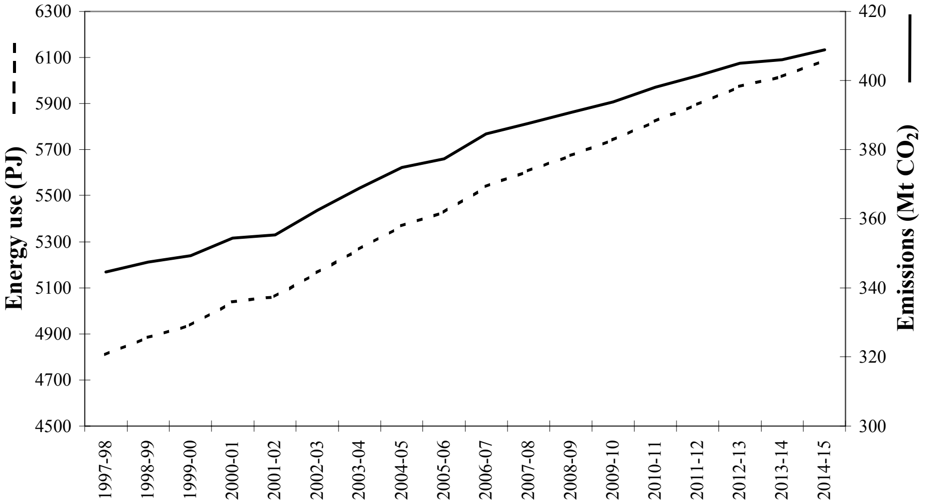
net immigration of 70,000 with a high level of fertility (Bush *et al.* 1999, p. 40). In this study, we modify the ABARE model so that it incorporates a number of population growth scenarios. This has required some 'unpacking' of the ABARE model and the extension of the timeframe by 5 years to 2019-2020. The ABARE model also makes assumptions about the rate of economic growth, assumptions that are adopted in this study.

ABARE uses econometric estimation to determine energy use in the residential, commercial (services) and transport sectors. Energy use in the construction and agricultural sectors is projected according to historical trends (Bush *et al.* 1999, Appendix B). In addition, ABARE includes a number of assumptions about the energy market, including the advent of new major energy-producing or energy-consuming projects, the growth of the National Electricity Market (NEM) and reforms in other market sectors.[25] The ABARE model also depends heavily on a biannual survey of energy consumption by the 5,300 largest energy consumers in Australia (to cover the mining and manufacturing sectors) (Bush *et al.* 1999, p. 37). The survey respondents' implicit assumptions about population and economic growth are embodied in the results of this survey. The energy-use projections estimated by ABARE (using population projection B2) are shown in Figure 16. The same publication also presents fuel mix information sufficient to enable energy use to be converted to greenhouse gas emissions. These are also shown in Figure 16.

5.3 Modelling energy demand under various population scenarios

The ABARE projections have been modified to enable the energy use and greenhouse gas emissions to be examined under a range of population trajectories. However, a number of assumptions are necessary to facilitate modification of the ABARE projections. Each sector of the economy has been modelled separately and these

Figure 16 ABARE's projections of energy use and energy-related CO_2 emissions, 1997-2015



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[25] For example, ABARE makes assumptions about the development of a major gas pipeline from Papua New Guinea to Queensland, the full integration of Queensland into the NEM and the expansion of liquefied natural gas production in Western Australia over the next decade or so (Bush *et al.* 1999, p. 38).

sectors aggregated to produce a whole-of-economy estimate of energy use and emissions dependent on population. The assumptions necessary to generate this model are discussed in detail in Appendix 8. Briefly, population growth is assumed to influence activity in all sectors except mining and agriculture. Demand for the output of these two sectors is assumed to be independent of Australia's domestic population. Energy use in some other sectors – namely, the residential sector, passenger car transport and air travel – is assumed to be directly related to population. Energy use in other sectors is assumed to be influenced by the impact of population growth on GDP. These sectors include the commercial and services sector, construction, road freight and rail transport. Energy use in the manufacturing sector is divided between export-driven and domestic, the latter being influenced by population growth via increasing consumption.

In addition, a number of other parameters are assumed to be given and not influenced by changes in population growth. They include GDP per capita, household income, energy prices, average fuel consumption of vehicles and freight rates.

The factors influencing energy demand in each of the sectors are shown in Table 6 (see Appendix 8 for a full discussion).

Table 6 Summary of assumptions for energy use projections

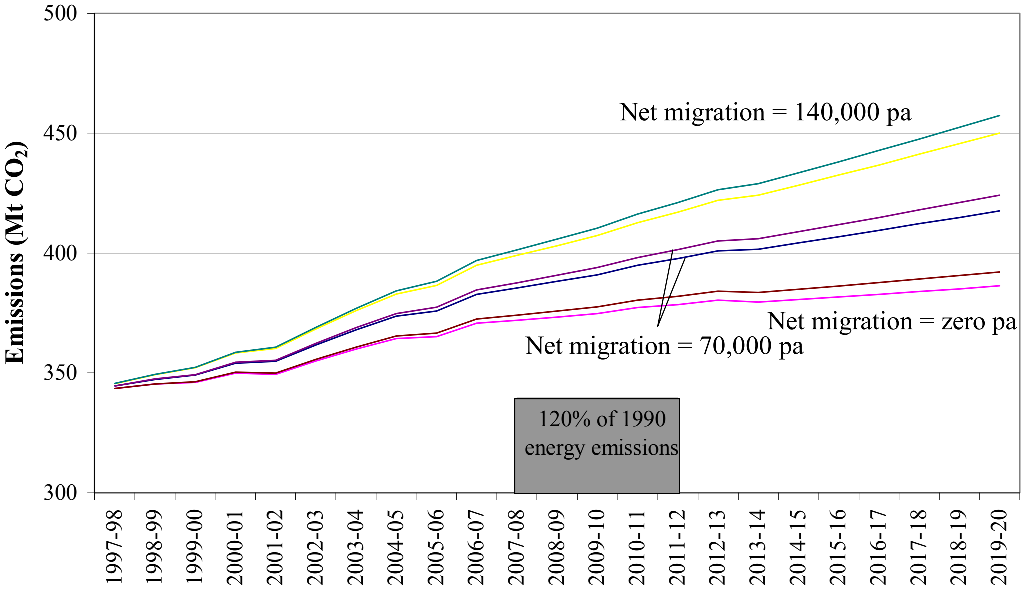
Sector	Energy use depends on:	Influenced by population growth?
Agriculture	Export demand	No
Mining	Export demand	No
Manufacturing	Export demand and domestic demand	Yes (domestic)
Construction	GDP growth	Yes (via GDP/cap)
Commercial	GDP growth	Yes (via GDP/cap)
Road passenger transport	Population, car ownership, travel, fuel consumption	Yes
Other road transport	GDP growth, freight rates	Yes (via GDP/cap)
Other transport	GDP growth, output of goods (Ag, Min. and Man.), and population	Yes
Residential	Population, household income, energy prices	Yes
Other	Same as ABARE	No
Other assumptions		
GDP	GDP/capita is assumed to follow ABARE projections but remain independent of population	Yes (GDP) No (GDP/cap)
Fuel mix	The fuel mix used in each sector listed above follows ABARE projections.	No (within sectors) Yes (combination of sectors)

5.4 Emissions projections under various population scenarios

The results of the analysis of the impact of population growth on greenhouse gas emissions are reported in Figure 17. Depending on Australia's population policy decisions, population growth is expected to lead to total energy-related emissions of between 385 and 455 Mt CO_2 by 2020. These are 37% and 62% above the 1990 level of energy-related emissions, respectively.[26]

These projections of growth in emissions should be compared to Australia's obligation under the 1997 Kyoto Protocol to limit total emissions to 108% of the 1990 level (i.e. 8% above the 1990 level) by the commitment period 2008-2012. However, while the overall target is 108%, declining emissions from land-clearing are expected to allow energy emissions to increase to 120% (and possibly more) of 1990 levels.[27] In Figure 11, the line across the period 2008-2012 shows the level of energy emissions at 120% of 1990. As an interesting aside, in 1997-98 Australia's energy-related emissions were already above 120% of 1990 levels. The projections under the various population scenarios show that during the commitment period energy-related emissions will vary between 133% and 146% of 1990 levels.[28] Under current levels of immigration and fertility, emissions will be around 140% of 1990 levels.

Figure 17 Energy-related CO_2 emissions under various population scenarios, 1997-2020



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[26] Although not shown if Figure 17, if Australia were to decide to increase its population rapidly – for instance, to 50 million in the next 50 years as advocated by some business groups – energy-related emissions would grow to around 600 Mt CO_2 by 2020 (or more than double 1990 levels).

[27] See Hamilton and Vellen (1999). For consistency, the 120% target in Figure 17 is based on ABARE data, which is not entirely consistent with National Greenhouse Gas Inventory data used by Hamilton and Vellen (for example, fuel consumed for international shipping aviation is included in ABARE, but not NGGI). The emissions calculated from ABARE energy data are based on the assumption that all chemical feedstocks and non-energy fuel use lead to emissions (in contrast to the assumptions in Section 2.2). These assumptions are used consistently in these projections, and are included in the base year.

[28] The Government's recent 2% renewables policy in the electricity sector will reduce energy-related emissions by at most 2.5% in 2010.

Looking at the results another way, we can say that each additional 70,000 immigrants arriving annually from now on will lead to additional emissions of 20 Mt CO_2 per year by the end of the commitment period, increasing to 30 Mt CO_2 per year by 2020. (for more detail, see Appendix 9).[29] How big is this? The additional 20 Mt CO_2 per year by around 2010 can be compared with a reduction in emissions of 8-10 Mt CO_2 per year by 2010 expected from the Government's recently announced 2% renewables policy in the electricity sector. Roughly speaking, therefore, one might say that a decision to adopt a policy of high rather than low net immigration would require two or three 2% renewables policies to offset the consequent increase in emissions.

5.5 Contributions to emissions growth

The decomposition analysis presented in Section 3 for historical emissions can be repeated for the emission projections. Certain assumptions used in the projection model fix some of the decomposition variables. For example, growth in GDP/capita is the same under all scenarios. Changes in CO_2/FOSS and FOSS/TPES within each sector follow ABARE estimates, but relative sectoral energy usage is influenced by population. This enables population to influence economy-wide CO_2/FOSS and FOSS/TPES. TPES/TFC is determined by energy losses in conversion (refining, electricity generation and other fuel manufacture) and by fuel mix – namely, the share of electricity in final consumption. It has been assumed that the fuel mix in the electricity generation sector does not depend on the quantity of electricity generated (at least at the margins relevant to these projections) and hence conversion efficiency follows ABARE projections independent of population.[30] However, the influence of population on sectoral shares of final energy consumption will affect the share of electricity in final consumption and hence TPES/TFC.

The decomposition analysis under a number of population trajectories is presented in Figure 18. The figure shows that population growth and increased GDP per capita are the factors driving higher energy-related emissions under all population scenarios. However, reduced energy-intensity of economic activity, improved conversion efficiency (and a lower proportion of electricity in final consumption) and reduced fuel CO_2 intensity almost entirely offset the increase caused by higher GDP per capita. Accordingly, with growth per capita fixed, population is the main driver of increased energy-related emissions.

Comparing the scenarios, apart from population growth most other factors vary relatively little. Interestingly, the energy intensity of economic activity decreases more for higher population growth. This is because increases in population flow directly to increases in GDP, but only influence final consumption of energy in certain

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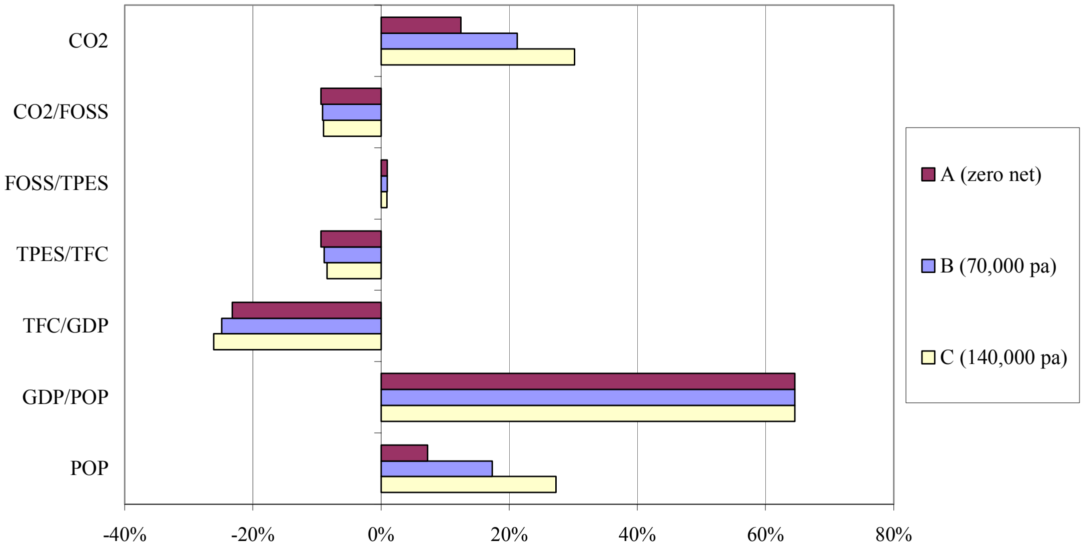
[29] Interestingly, Figure 17 shows that 1997-98 energy-related emissions are already around 120% of 1990 levels. The discrepancy between this result and information presented in the latest NGGI – which shows that energy-related CO_2 emissions have increased by 15% between 1989-90 and 1996-97 (NGGIC 1999b, Table 1-2) – is due to ABARE being one year ahead of the NGGIC. The extra year, 1997-98, was one of rapid growth in energy consumption, with electricity consumption growing around 9% (compared with an average of 5% from 1993-94 to 1997-98). Energy consumption in Queensland and Victoria grew 5.8% and 6.4%, respectively in 1997-98 (Bush *et al.* 1999, pp. 2-3). ABARE indicates that black coal use increased by 6.7% (compared with an average 2.3% in the previous five years) and brown coal by 13% (compared with an average of 2.4% pa over the previous five years, see Bush *et al.* 1999, Table D1). The latter was a result of a 12.6% increase in energy consumption in the Victorian electricity sector (Bush *et al.* 1999, p. 3).

[30] This assumes there are no economies of scale and electricity infrastructure capital is putty-putty.

Figure 18 Contributions to growth in energy-related CO_2 emissions under population projections, 1997-2020 (fertility = 1.6)



sectors of the economy. In contrast, those sectors relatively independent of population growth (mining and agriculture) use proportionally less electricity than those sectors heavily influenced by population,[31] producing slight differences between the scenarios in TPES/TFC and CO_2/FOSS.

Figure 18 helps to illustrate what Australia has to do to restrict emissions if economic growth continues as projected. The principal policy levers available are:

- reduce population growth;
- achieve a greater reduction in CO_2/FOSS by increasing the share of gas in the fuel mix (at the expense of coal);
- displace the use of electricity in final consumption, again by increasing the use of gas, thereby reducing TPES/TFC; and
- reduce the share of energy sourced from fossil fuels by increasing the share of renewables (thereby reducing FOSS/TPES).

Some combination of these is necessary; less emphasis on one option will require more emphasis on the others. As illustrated in Section 3, these are areas where Australia lags behind the rest of the developed world.

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[31] For 2009-10, ABARE predicts that electricity will comprise 15% of energy use in agriculture and mining compared with 44% in the commercial sector and 67% in the residential sector. Although very little electricity is used in transport, population growth favours electricity-intensive sectors. It is worth noting however, that large increases in population will require the construction of new power stations. In all likelihood, these new stations will be more efficient than existing generators, and this will result in an improvement in the average efficiency of electricity generation. The model does not cater for this possibility.

5.6 Concluding comments

The results of the model indicate that various feasible population scenarios have a significant impact on the growth of Australia's greenhouse gas emissions. If fertility remains low, in 2020 we would expect Australia's energy-related emissions to be 450 Mt with a high immigration policy (140,000 per annum) as opposed to 385 Mt under a zero net immigration policy. In other words, a high immigration policy would result in Australia's energy-related emissions being 16% higher than they would be with zero net immigration.

While the two immigration scenarios result in a difference of 65 Mt in Australia's energy-related emissions by 2020, the world's greenhouse gas emissions would increase by less than half of this amount since immigrants to Australia come from countries that have per capita emissions levels less than half of Australia's. While immigration to Australia at the assumed levels would have a significant impact on Australia's emissions, it would not have a significant effect on global emissions because Australia's emissions are only a small share of the world's emissions.

The Federal Government will need to introduce further policies to restrict emissions from the energy sector in order to meet Australia's international obligations under the Kyoto Protocol, especially in the second and subsequent commitment periods. Clearly, population policy could be an important tool for meeting Australia's target. The government could reduce energy-related emissions during the first commitment period by up to 6% of 1990 levels by restricting the immigration intake from now until 2012. Conversely, any increase in the current immigration intake will require more severe restrictions on the economy to control emission-producing activities if Australia is to meet its international targets.

This analysis highlights the importance of incorporating environmental considerations into population policy decisions. The experience of the GST package has shown that the impact of major public policy decisions is not confined to the portfolio of the minister or department responsible for that policy. This is illustrated again in the case of population policy. Clearly, any attempts to increase rapidly Australia's population will produce a sharp increase in greenhouse gas emissions. However, even small increases will make it more costly for Australia to achieve future emission reduction targets.

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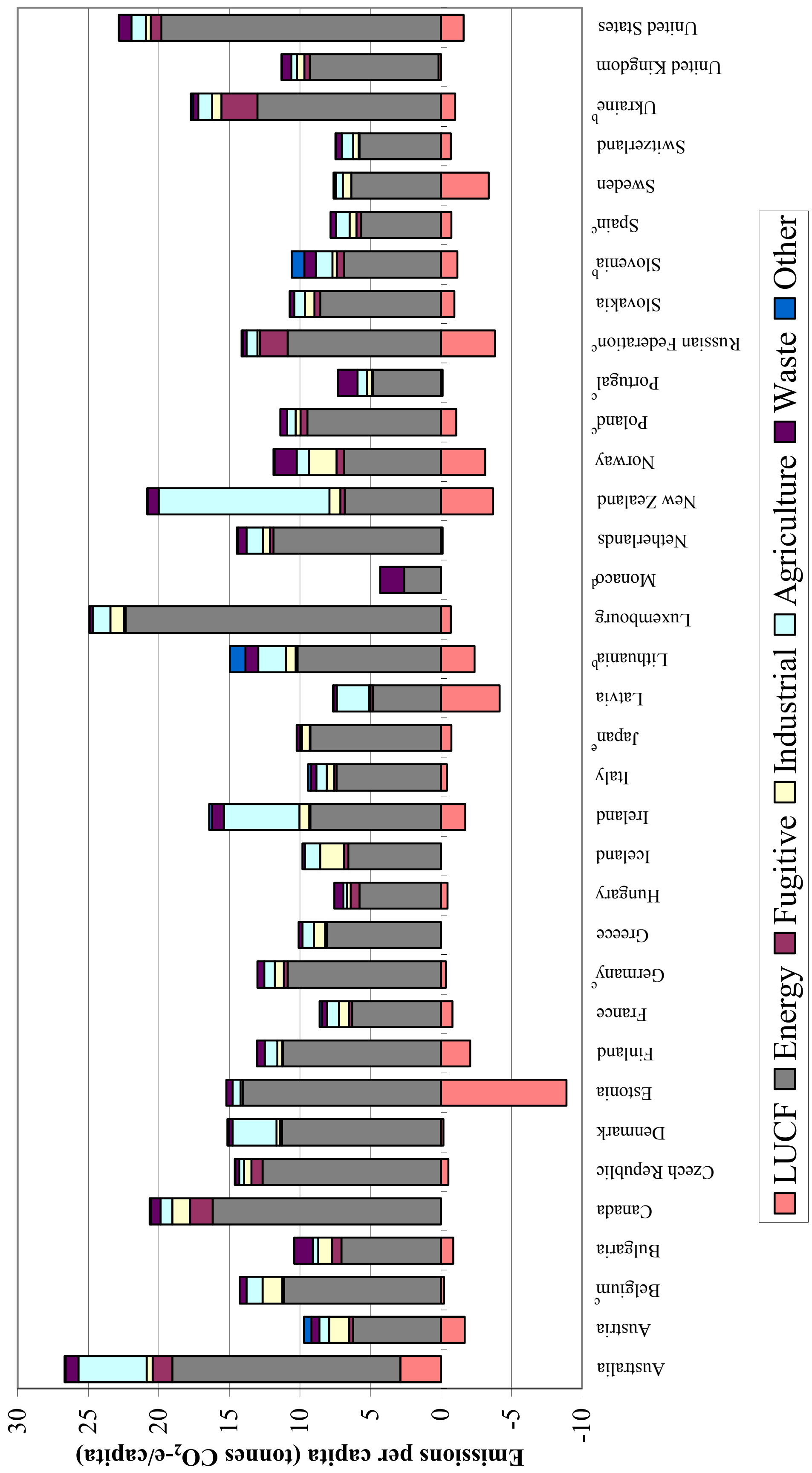
Figure A1.1 Greenhouse gas emissions per capita by source for Annex B countries,



Note: For description of footnotes, refer to Table 1 in Section 2.

Appendix 2 Sectoral emissions data

The table on the following page (Table A2.1) presents sectoral energy use in selected OECD countries. These data are from the IEA's *Energy balances of OECD countries* publication (IEA 1998).

Energy use (in Mtoe) by fuel type is presented for each sector. Fuel used in electricity and heat generation is assigned to the sectors consuming the heat and electricity to determine total direct and indirect sectoral consumption of fossil-based fuels. Energy use has been converted to petajoules (PJ) by using the conversion factor of 41.868 PJ/Mtoe (IEA 1997, p. 58). IPCC default emission factors have been applied to convert consumption of coal, oil and gas to emissions of carbon dioxide (CO_2) (IPCC 1997b, p. 1.6). The percentage of emissions arising from each sector are presented in Figures 2 and 3.

A large part of the petroleum and gas consumed by the chemical and petrochemical industries is classified as feedstock. Not all fuel used in feedstocks is oxidised to CO_2, with some being converted to relatively inert plastics, for example. For this analysis, it has been assumed that natural gas feedstocks are used for the production of ammonia or urea and all carbon is oxidised relatively rapidly. Carbon in petroleum feedstocks is taken to remain unoxidised. Accordingly, energy use presented for the chemical and petrochemical industry has been reduced by the quantity of petroleum fuel consumed in feedstocks, but includes natural gas consumed as feedstocks.

Table A2.1 Sectoral fossil energy use (Mtoe), 1997[a]

		Industry				Transport	Agriculture	Commercial	Residential	Electricity[c]	Heat[c]
		Iron and Steel	Non-ferrous metals	Chemical & Petrochem.[b]	Other Industry						
Australia	Coal	1.41	1.22	0.16	1.28	0.09	0.00	0.07	0.00	35.50	0.00
	Oil	0.04	0.79	0.27	2.37	26.20	1.30	0.29	0.36	0.56	0.00
	Gas	0.47	2.42	1.05	2.71	0.22	0.00	0.99	2.44	3.08	0.00
	Electricity	0.49	2.53	0.37	2.40	0.18	0.23	3.18	3.85	-13.24	0.00
	Heat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Canada	Coal	1.78	0.27	0.00	1.00	0.00	0.00	0.00	0.10	22.96	0.00
	Oil	0.18	0.17	2.06	5.61	46.47	2.88	5.25	3.67	2.39	0.04
	Gas	1.90	0.59	6.83	13.07	5.35	0.56	9.61	13.92	4.26	0.68
	Electricity	0.78	4.22	1.60	11.04	0.37	0.86	10.39	11.60	-40.86	0.00
	Heat	0.00	0.00	0.49	0.25	0.00	0.00	0.01	0.00	0.00	-0.76
Germany	Coal	5.28	0.13	1.45	3.36	0.00	0.07	0.80	1.85	70.42	4.98
	Oil	0.12	0.16	5.05	5.81	63.62	1.74	10.03	24.89	1.13	0.74
	Gas	2.55	0.70	6.01	9.94	0.00	0.25	5.99	22.93	9.00	2.75
	Electricity	2.07	1.48	4.60	9.59	1.45	0.66	8.61	11.25	-39.72	0.00
	Heat	0.00	0.02	0.53	1.44	0.00	0.00	0.00	7.06	0.00	-9.04
Japan	Coal	12.07	0.30	0.76	7.57	0.00	0.00	0.94	0.05	38.15	0.01
	Oil	2.50	1.16	11.08	28.64	90.19	10.68	16.06	18.80	37.30	0.03
	Gas	1.98	0.33	1.49	4.35	0.00	0.00	4.48	8.09	37.06	0.27
	Electricity	7.09	1.67	5.58	21.33	1.87	0.32	19.72	20.95	-78.56	0.04
	Heat	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.03	0.00	-0.44
Netherlands	Coal	1.34	0.00	0.04	0.08	0.00	0.00	0.00	0.01	5.62	0.62
	Oil	0.01	0.00	1.68	0.27	13.69	0.28	0.00	0.10	0.72	0.09
	Gas	0.31	0.10	4.12	3.14	0.00	3.40	0.00	8.47	9.01	1.21
	Electricity	0.20	0.42	1.05	1.66	0.14	0.28	2.20	1.75	-7.70	0.00
	Heat	0.00	0.00	0.00	0.84	0.00	0.18	0.57	0.18	0.00	-1.77
NZ	Coal	0.31	0.00	0.00	0.41	0.00	0.02	0.10	0.03	0.44	0.00
	Oil	0.00	0.00	0.00	0.30	4.51	0.20	0.09	0.05	0.00	0.00
	Gas	0.00	0.00	1.16	0.65	0.02	0.00	0.11	0.11	1.90	0.00

		Industry Iron and Steel	Non-ferrous metals	Chemical & Petrochem.[b]	Other Industry	**Transport**	**Agriculture**	**Commercial**	**Residential**	**Electricity**[c]	**Heat**[c]
NZ cont.	Electricity	0.42	0.00	0.08	0.64	0.00	0.09	0.52	0.96	-2.72	0.00
	Heat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Norway	Coal	0.54	0.01	0.16	0.24	0.00	0.00	0.00	0.00	0.02	0.02
	Oil	0.01	0.05	0.27	0.65	4.54	0.64	0.32	0.32	0.00	0.03
	Gas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
	Electricity	0.61	1.51	0.51	1.38	0.15	0.09	1.74	2.91	-8.91	0.00
	Heat	0.00	0.00	0.01	0.01	0.00	0.00	0.07	0.02	0.00	-0.11
UK	Coal	1.99	0.15	0.55	1.49	0.00	0.00	0.28	2.06	27.37	0.00
	Oil	0.04	0.05	2.11	5.40	49.93	0.78	2.24	3.22	1.70	0.00
	Gas	1.62	0.36	4.08	7.72	0.00	0.11	4.07	26.73	18.83	0.00
	Electricity	0.89	0.45	1.63	6.04	0.67	0.33	7.61	8.98	-26.60	0.00
	Heat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
US	Coal	6.68	0.00	5.77	11.47	0.00	0.00	0.35	1.51	470.34	3.77
	Oil	2.60	0.29	15.85	34.00	550.78	15.74	15.80	30.75	18.35	0.55
	Gas	10.84	6.25	57.21	53.77	17.59	0.00	74.88	115.94	122.63	4.51
	Electricity	6.16	6.77	21.50	58.70	0.34	0.00	86.59	92.15	-272.21	0.00
	Heat	0.17	0.01	3.10	2.10	0.00	0.00	2.21	0.00	0.00	-7.59
OECD	Coal	52.86	2.72	11.29	51.89	0.14	1.62	4.03	20.26	794.93	26.45
	Oil	10.63	4.13	65.65	125.07	1113.07	57.21	80.88	135.01	128.43	4.75
	Gas	27.94	12.13	102.73	134.67	23.57	5.12	114.99	250.43	243.28	16.94
	Electricity	29.86	22.78	49.20	160.12	8.99	6.53	175.00	196.70	-650.93	0.44
	Heat	0.38	0.08	5.16	9.31	0.00	0.29	7.13	21.52	0.00	-47.09
EU	Coal	18.12	0.66	2.68	9.54	0.01	0.12	1.10	6.65	157.11	8.38
	Oil	1.61	1.21	22.27	33.66	291.04	14.29	23.20	63.53	36.56	2.84
	Gas	8.85	2.07	25.13	48.47	0.33	4.22	20.47	93.42	57.86	8.87
	Electricity	8.77	5.16	14.61	45.43	4.91	2.99	41.59	52.14	-177.08	0.36
	Heat	0.01	0.02	0.73	3.70	0.00	0.23	2.79	12.58	0.00	-22.48

Source: IEA 1998, pp. II.17, 47, 53, 71,101, 137, 161, 167, 173, 215, 221.

a. Excludes non-energy use, non-fossil sources (solar, hydro, nuclear, biomass) b. Net of petroleum and oil feedstocks. c. After own-use, distribution losses and exports. Energy use in combined heat and power plants is assigned to electricity and heat in the manner discussed in Section 2.1.

Figure A2.1 Per capita energy-related CO_2 emissions for selected countries by source, 1997

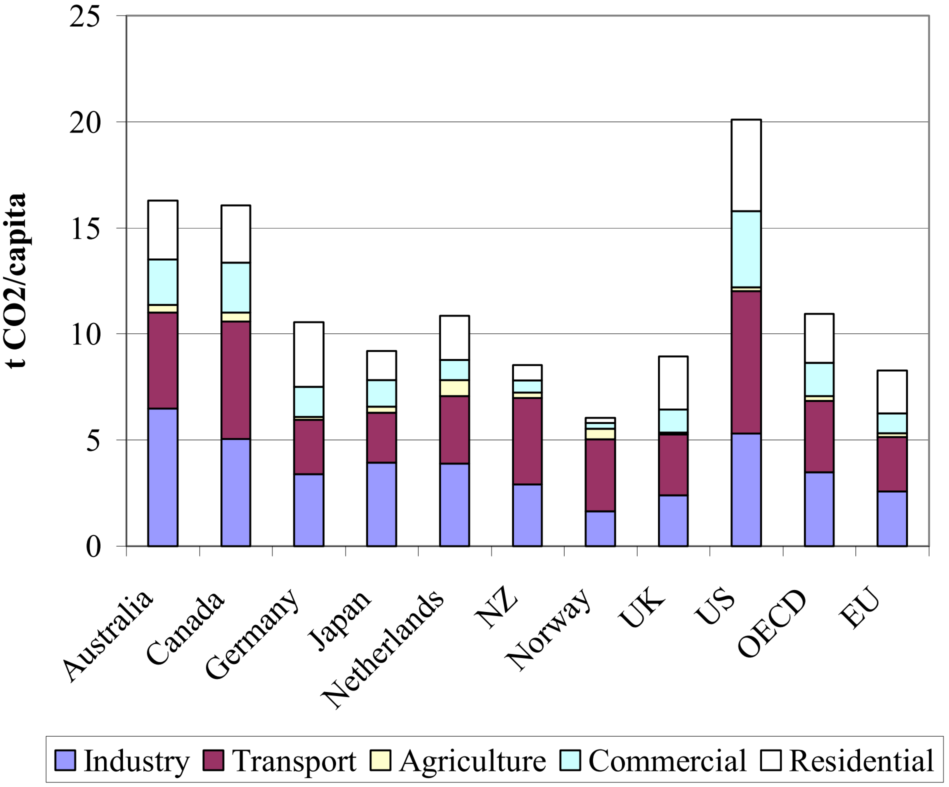
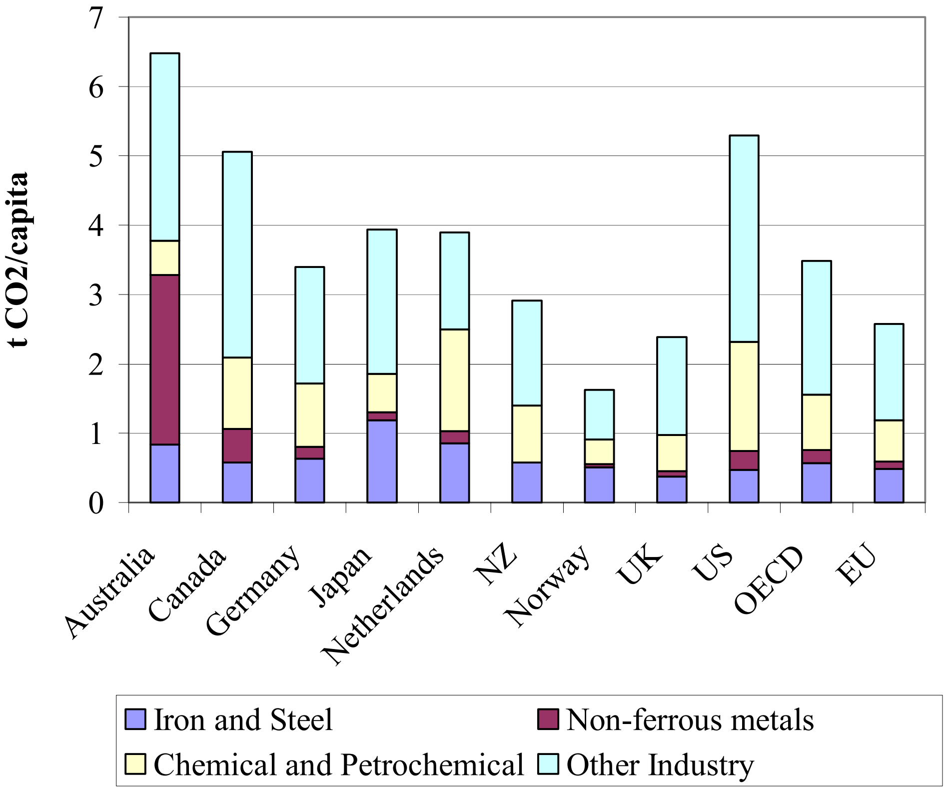


Figure A2.2 Per capita energy-related CO_2 emissions from industry for selected countries, 1997



Appendix 3 Decomposition of energy-related emissions growth

Energy-related CO_2 emissions are given by the following formula:

$$CO_2 = \frac{CO_2}{FOSS} \bullet \frac{FOSS}{TPES} \bullet \frac{TPES}{TFC} \bullet \frac{TFC}{GDP} \bullet \frac{GDP}{POP} \bullet POP$$

where:

CO_2 = energy-related CO_2 emissions (emission factors derived from IPCC 1997b, p. 1.6; energy use from IEA 1998, pp. II.254-259);

FOSS = fossil fuel consumption (measured in PJ) (derived from IEA 1998, pp. II.254-259);

TPES = total primary energy supply (measured in PJ) (derived from IEA 1998, pp. II.260-261);

TFC = total final consumption (measured in PJ) (derived from IEA 1998, pp. II.282-283);

GDP = gross domestic product (measured in inflation-adjusted own currencies) (ANU DX statistics database; IEA 1998, pp. II.312-313; IEA 1997, p. II.13); and

POP = population (ANU DX statistics database; IEA 1998, pp. II.312-313; IEA 1997, p. II.13).

Each factor in the equation can be interpreted as follows:

$\frac{CO_2}{FOSS}$ is the CO_2 intensity of fossil fuel combustion, mainly reflecting the fuel mix;

$\frac{FOSS}{TPES}$ indicates the proportion of total energy obtained from fossil sources;

$\frac{TPES}{TFC}$ represents the amount of primary energy required to deliver energy for final consumption and reflects both conversion efficiency and the fuel mix. The share of electricity in final consumption is the main influence;

$\frac{TFC}{GDP}$ is the energy intensity of economic output, reflecting both efficiency of energy use and economic structure; and

$\frac{GDP}{POP}$ is a measure of economic output per capita.

Changes in energy-related CO_2 emissions between two time periods (t=1 and t=2) can be expressed as follows:

$$\frac{CO_{2\,(t=2)}}{CO_{2\,(t=1)}} = \frac{\frac{CO_2}{FOSS}_{(t\,=\,2)}}{\frac{CO_2}{FOSS}_{(t\,=\,1)}} \bullet \frac{\frac{FOSS}{TPES}_{(t\,=\,2)}}{\frac{FOSS}{TPES}_{(t\,=\,1)}} \bullet \frac{\frac{TPES}{TFC}_{(t\,=\,2)}}{\frac{TPES}{TFC}_{(t\,=\,1)}} \bullet \frac{\frac{TFC}{GDP}_{(t\,=\,2)}}{\frac{TFC}{GDP}_{(t\,=\,1)}} \bullet \frac{\frac{GDP}{POP}_{(t\,=\,2)}}{\frac{GDP}{POP}_{(t\,=\,1)}} \bullet \frac{POP_{(t\,=\,2)}}{POP_{(t\,=\,1)}}$$

Expressing $\frac{CO_{2\,(t=2)}}{CO_{2\,(t=1)}}$ as a percentage gives the CO_2 emissions at t=2 as a percentage of CO_2 emissions at t=1, which is the product of $\frac{CO_2}{FOSS}_{(t\,=\,2)}$ as a percentage of $\frac{CO_2}{FOSS}_{(t\,=\,1)}$ and $\frac{FOSS}{TPES}_{(t\,=\,2)}$ as a percentage of $\frac{FOSS}{TPES}_{(t\,=\,1)}$ and so on. These percentage changes have been presented in Figures 6-11 and 18.

Appendix 4 Data for the decomposition analysis

The following tables present the data used in the decomposition analysis. These data are from IEA's *Energy balances of OECD countries* publication (IEA 1998).

Total energy from fossil fuel sources (FOSS, presented in Table A4.2) was determined by summing the energy derived from each fossil fuel source: coal, gas and oil in Table A4.1. Energy was converted to PJ using the conversion factor 41.868 PJ/Mtoe (IEA 1997, p. 58).

Energy-related CO_2 emissions (CO_2, presented in Table A4.3) were determined by applying IPCC emission factors to energy use by fuel type (IPCC 1997b, p. 1.6) and summing emissions.

The total primary energy supply (TPES, presented in Table A4.4) was derived directly from IEA (1998, pp. II.260-61) and converted to PJ. This represents total energy use and includes energy use from fossil fuel sources (FOSS) in addition to energy from hydro, nuclear, geothermal, solar, biomass, waste etc.

Total final consumption of energy (TFC, presented in Table A4.5) was obtained from IEA (1998, pp. II.282-83) and converted to PJ. TFC represents energy left over after conversion and distribution losses and energy use in the conversion sector.

Tables A4.6 and A4.7 present GDP and population data, respectively. Each factor in the decomposition (CO_2/FOSS, FOSS/TPES, etc.) has been determined using the data presented in Tables A4.1 to A4.7. Changes in these factors are determined according to the formula presented in Appendix 3.

Table A4.8 presents trends in per capita energy-related CO_2 emissions.

Decomposition data

Table A4.1 Consumption of gas, oil and coal, 1982-1997 (Mtoe)

Gas	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Australia	9.6	10.1	10.5	11.2	12.3	12.7	13.1	13.5	14.8	13.9	14.3	14.9	15.6	16.7	16.8	16.9
Canada	44.0	45.3	46.7	49.9	48.0	48.8	53.6	56.2	54.3	55.0	58.3	61.2	64.6	67.1	70.3	70.7
Germany	45.4	47.1	49.2	48.7	49.9	54.4	53.1	55.1	55.0	57.7	56.9	59.7	61.2	67.3	75.2	71.9
Japan	22.7	23.9	32.5	35.0	35.5	36.1	37.6	40.6	43.3	46.5	47.3	47.8	51.2	52.0	56.1	55.0
Netherlands	27.4	29.2	30.8	32.4	32.5	33.6	30.5	31.2	30.8	34.4	33.4	34.3	33.4	34.1	37.5	35.3
New Zealand	1.7	1.9	2.4	3.0	3.6	3.5	3.8	3.9	3.9	4.2	4.5	4.3	4.1	3.8	4.4	4.7
Norway	1.0	1.1	1.0	1.2	2.1	1.5	1.7	1.8	2.0	1.9	3.2	3.4	3.9	3.5	3.6	3.9
UK	40.7	42.4	43.5	46.6	47.2	48.7	46.2	45.7	47.2	50.9	50.7	57.8	60.2	65.1	75.9	76.4
US	430.1	408.0	422.1	411.7	387.9	409.2	425.2	443.9	439.4	459.6	468.7	481.9	491.7	508.5	504.3	508.0
OECD	723.5	711.5	749.3	756.4	736.0	773.8	794.4	828.1	834.3	875.8	890.3	924.2	946.0	992.9	1036.0	1041.4
EU	171.4	179.2	189.3	197.5	200.6	213.1	209.2	216.8	223.3	240.2	238.4	251.9	253.7	274.9	305.3	302.7

Oil	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Australia	30.6	27.8	28.4	27.3	28.0	28.9	29.6	31.4	32.1	30.8	31.5	34.2	34.4	34.4	37.2	35.6
Canada	76.6	70.8	72.1	70.2	72.9	75.7	75.9	80.1	77.6	72.8	74.5	76.1	76.8	77.7	77.5	80.8
Germany	124.1	121.6	121.6	124.2	130.2	127.7	129.2	121.5	126.7	132.5	134.4	135.4	135.3	135.7	138.9	139.3
Japan	213.2	211.4	216.3	203.6	209.3	210.5	228.6	239.8	252.9	253.1	260.6	254.9	268.5	269.6	273.5	271.6
Netherlands	22.5	21.6	21.9	21.1	23.4	23.6	24.5	24.1	24.8	25.6	25.9	25.2	25.9	27.4	26.5	27.6
New Zealand	4.0	3.9	4.0	4.2	3.6	4.0	3.9	4.3	4.3	4.3	4.7	4.8	5.3	5.7	6.1	6.3
Norway	7.9	8.0	8.4	8.4	9.2	9.3	8.1	9.2	8.6	9.1	8.1	8.5	7.7	8.0	8.3	8.4
UK	76.9	72.6	88.2	78.9	78.3	76.6	81.1	82.3	82.6	83.5	85.2	84.6	86.4	84.5	84.7	82.5
US	720.2	716.6	736.3	736.8	763.9	779.9	805.1	806.0	770.4	754.5	770.1	786.4	806.2	805.8	832.5	854.5
OECD	1764.7	1729.4	1764.6	1744.6	1797.1	1826.8	1884.4	1914.2	1902.9	1907.0	1953.6	1975.6	2023.6	2039.7	2097.7	2131.3
EU	547.5	529.6	532.3	525.0	537.3	539.5	549.4	551.3	555.2	573.3	577.7	573.4	576.8	585.9	598.2	598.4

Coal	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Australia	28.6	28.0	29.3	30.2	29.6	31.9	31.9	35.0	35.0	36.3	36.9	37.6	37.1	37.5	40.7	42.4
Canada	23.0	24.3	26.7	25.8	23.9	25.7	27.5	27.6	24.5	25.6	26.2	24.1	24.9	25.4	25.9	27.4
Germany	140.4	140.2	144.5	145.2	140.4	138.4	136.9	135.9	128.5	114.7	104.4	98.2	95.7	91.0	90.1	86.3
Japan	64.3	61.8	69.6	73.0	69.0	66.8	73.6	73.3	74.0	76.6	75.2	76.8	78.8	82.6	84.6	86.5
Netherlands	3.7	5.2	6.6	6.6	6.6	6.8	8.1	8.1	8.9	8.1	7.9	8.1	8.8	9.2	9.3	9.2
New Zealand	1.0	1.1	1.1	1.0	0.9	1.0	1.2	1.2	1.1	1.1	1.2	1.1	1.0	1.2	1.3	1.4
Norway	1.0	0.9	1.2	1.2	1.0	1.0	1.0	1.0	0.9	0.8	0.8	0.9	1.0	1.0	1.0	1.0
UK	64.0	64.8	46.8	62.0	65.6	68.7	66.0	62.9	64.0	63.5	59.6	52.4	49.2	48.4	44.4	40.0
US	370.5	388.2	409.7	425.7	412.8	437.1	454.1	460.5	456.7	450.0	452.9	475.2	473.4	475.3	497.5	513.3
OECD	948.8	966.2	999.6	1047.9	1021.7	1055.1	1071.1	1075.0	1046.0	1025.3	1006.9	1010.6	1003.5	1008.1	1043.0	1052.3
EU	301.1	300.5	292.2	314.8	306.6	309.5	302.6	304.1	300.1	288.1	266.3	246.3	244.8	239.8	234.3	222.9

Note: 1 Mtoe = 41.868 PJ
Source: IEA 1998, pp. II.254-259

Table A4.2 Energy from fossil sources, 1982-1997 (PJ)

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Australia	2880	2760	2855	2879	2923	3073	3125	3344	3429	3391	3463	3628	3645	3711	3964	3972
Canada	6010	5877	6091	6109	6064	6288	6576	6860	6548	6421	6656	6757	6961	7125	7271	7492
Germany	12975	12934	13200	13318	13421	13420	13364	13081	12988	12766	12379	12279	12232	12310	12736	12456
Japan	12568	12439	13330	13043	13139	13124	14226	14809	15499	15750	16040	15888	16682	16922	17343	17295
Netherlands	2243	2343	2484	2515	2616	2680	2638	2656	2700	2850	2812	2831	2850	2960	3066	3020
New Zealand	280	285	309	344	340	356	371	393	390	399	433	426	432	449	490	517
Norway	414	420	440	450	518	494	453	500	477	493	508	535	530	523	538	557
UK	7601	7527	7468	7852	8002	8124	8092	7993	8116	8285	8185	8152	8197	8290	8585	8327
US	63668	63336	65650	65907	65503	68082	70525	71614	69767	69672	70830	72995	74160	74929	76799	78535
OECD	143900	142651	147102	148584	148833	153060	157001	159821	158393	159435	161226	163722	166345	169174	174868	176891
EU	42707	42257	42446	43428	43734	44467	44431	44892	45158	46121	45318	44866	45022	46075	47634	47056

Table A4.3 Energy-related CO_2 emissions, 1982-1997 (kt)

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Australia	228187	218813	226599	228725	230636	243316	246882	265343	270532	269781	275162	287262	287648	291985	313191	315355
Canada	424273	415230	432061	430408	426480	443776	463074	481872	457573	449136	464414	467742	480878	491493	500353	517408
Germany	1038551	1034335	1056340	1065764	1067575	1062586	1057861	1035377	1021461	989942	952581	937456	930653	927622	951996	930281
Japan	948114	935559	1001553	982847	985432	981763	1066453	1105732	1154105	1172556	1191430	1181885	1238353	1258810	1288336	1287495
Netherlands	146440	153867	164289	165561	172702	176689	177084	177894	182077	189579	187425	188447	191120	198871	204272	202393
New Zealand	19926	20245	21668	23634	22812	24223	25307	26769	26532	26862	29329	28724	29340	30839	33441	35267
Norway	29982	30205	31935	32617	36725	35388	32239	35540	33708	34768	34991	36920	36352	36147	37120	38315
UK	581054	575508	552596	593171	607193	618010	614679	604794	613768	622940	611994	597852	596349	599017	609201	586036
US	4644616	4652776	4830636	4871658	4845263	5040150	5221496	5293728	5160754	5134242	5214074	5382615	5457789	5503854	5662443	5799940
OECD	10769120	10704933	11032101	11181659	11186536	11497730	11782186	11965916	11830976	11858059	11958365	12118636	12285114	12461667	12875823	13026252
EU	3243527	3205741	3204316	3291904	3303627	3350828	3343925	3373458	3384216	3430190	3352178	3291266	3299853	3356397	3442785	3391734

Source: IEA 1998, pp. II.254-259, IPCC 1997b, p. 1.6

Table A4.4 Total primary energy supply, 1982-1997 (PJ)

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Australia	3096	2970	3061	3094	3128	3276	3335	3561	3649	3616	3674	3873	3885	3957	4234	4255
Canada	7589	7530	7920	8096	8237	8513	8873	9045	8780	8772	8975	9237	9571	9711	9837	9964
Germany	14097	14099	14640	15125	15116	15240	15347	15098	14894	14547	14283	14155	14100	14230	14707	14540
Japan	14214	14242	15323	15367	15552	15739	16814	17463	18372	18781	19117	19292	20217	20810	21367	21558
Netherlands	2299	2400	2536	2580	2675	2737	2714	2733	2788	2936	2908	2935	2956	3071	3181	3136
New Zealand	408	421	450	480	484	503	525	569	593	601	631	630	628	646	685	698
Norway	753	782	821	851	909	904	862	913	898	922	939	993	981	985	989	1014
UK	8097	8088	8071	8533	8679	8783	8848	8865	8922	9158	9142	9246	9300	9401	9758	9545
US	70679	70767	73807	74597	74657	77841	80909	82135	80624	81158	82709	84629	86184	87492	89603	90527
OECD	161762	162039	168849	172543	174213	179872	185245	189048	188196	190469	192925	196265	199594	203696	210167	212167
EU	48174	48447	49839	51836	52604	53618	54240	55368	55616	56896	56356	56301	56492	57750	59715	59502

Source: IEA 1998, pp. II.260-61

Table A4.5 Total final consumption of energy, 1982-1997 (PJ)

	1982	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Australia	2008	1938	2016	2105	2111	2161	2259	2354	2431	2415	2440	2534	2597	2687	2775	2828
Canada	6000	5922	6122	6335	6352	6459	6758	6915	6742	6663	6823	7008	7222	7419	7715	7851
Germany	9824	9946	10293	10620	10746	10813	10763	10454	10352	10201	9970	9965	9878	10040	10367	10230
Japan	9534	9722	10310	10315	10484	10790	11438	11877	12329	12699	12865	12914	13395	13827	14107	14254
Netherlands	1868	1948	2023	2077	2119	2171	2106	2101	2176	2325	2274	2286	2283	2379	2482	2432
New Zealand	303	310	340	347	350	366	382	395	415	420	431	443	468	492	509	520
Norway	659	676	720	745	752	775	764	754	754	745	739	756	780	801	814	810
UK	5479	5473	5491	5730	5922	6008	6116	6061	6083	6300	6270	6356	6407	6380	6753	6582
US	51748	51084	54035	53538	53660	55478	57902	56176	55008	54714	54877	56031	57334	58302	60435	60510
OECD	117088	116776	122368	123153	124313	128081	132115	131524	130709	131827	132742	134798	137356	140438	145266	146178
EU	34515	34781	35598	36568	37247	37983	38417	38700	38943	40017	39865	39793	39997	40750	42225	42118

Source: IEA 1998, pp. II.282-283

Table A4.6 Gross Domestic Product, 1982-1997 (in inflation-adjusted own currencies)

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Australia (1990A$mill)	280397	283223	304552	317412	323686	338294	351306	365892	370318	365373	374872	389347	410313	426510	441098	453908
Canada (1986C$mill)	425970	439448	467167	489437	505666	526730	552958	566486	565155	555052	559305	571722	594990	608835	617795	640080
Germany[a] (1991DMmill)	2233545	2279378	2348559	2403866	2464486	2506038	2597535	2687898	2774776	2853600	2916400	2881900	2960200	3013800	3054500	3127172
Japan (1990¥bill)	308927	316101	328483	342950	352880	367556	390325	409184	429986	446315	450924	452282	455197	461456	477837	480193
Netherlands (1990NLGmill)	409320	416320	430010	443250	455460	461900	473980	496160	516550	528280	538980	543090	560590	573260	591970	610647
New Zealand (91/92NZ$mill)	62983	64558	70058	71190	71970	72130	73717	73405	73639	71921	72320	75999	80150	82343	84084	85673
Norway (1990NOKmill)	576755	597194	632257	665243	689059	703050	702261	708727	722705	745227	769576	790619	834039	863814	909351	945590
UK (1990£mill)	425252	440888	451131	468071	488122	511615	537215	548940	551118	540308	537448	548622	572301	587912	601720	622276
US (1992US$mill)	4620300	4803700	5140125	5323550	5487731	5649450	5865200	6062081	6136325	6079426	6244425	6389550	6610725	6742050	6928378	7189614
OECD (1991=100)	75	77	80.7	83.5	86	88.9	92.8	96.2	99	100	101.9	103.1	106.1	108.4	111.4	114.7
EU (1991=100)	78.5	79.8	81.6	83.7	86.1	88.6	92.3	95.6	98.5	100	101	100.4	103.3	105.9	107.7	110.5

a. Own-currency used for Germany from 1991 onwards. For 1982-1990, the aggregate of West German and East German GDP (in 1991US$ and converted to 1991DM) has been used.

Source: ANU DX statistics database.

Table A4.7 Population, 1982-1997 (millions)

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Australia	15.18	15.39	15.58	15.79	16.02	16.26	16.53	16.81	17.07	17.28	17.5	17.67	17.86	18.07	18.31	18.53
Canada	25.20	25.46	25.7	25.94	26.2	26.55	26.9	27.38	27.79	28.12	28.54	28.95	29.26	29.62	29.97	30.29
Germany	78.34	78.12	77.85	77.67	77.69	77.72	78.12	78.68	79.36	79.98	80.59	81.18	81.42	81.66	81.88	82.05
Japan	118.45	119.26	120.02	120.75	121.49	122.09	122.61	123.12	123.54	123.92	124.32	124.67	124.96	125.57	125.86	126.17
Netherlands	14.31	14.37	14.42	14.49	14.57	14.66	14.76	14.85	14.95	15.07	15.18	15.29	15.38	15.46	15.52	15.61
New Zealand	3.18	3.23	3.26	3.27	3.28	3.3	3.32	3.33	3.36	3.48	3.51	3.55	3.6	3.66	3.71	3.76
Norway	4.12	4.13	4.14	4.15	4.17	4.19	4.21	4.23	4.24	4.26	4.29	4.31	4.34	4.36	4.38	4.41
UK	56.318	56.377	56.506	56.685	56.852	57.009	57.158	57.358	57.561	57.808	58.007	58.293	58.395	58.606	58.782	59.01
US	232.188	234.307	236.348	238.466	240.651	242.804	245.021	247.432	249.911	252.643	255.407	258.12	260.682	263.168	265.557	266.79
OECD (IEA)	975.39	983.16	990.56	997.99	1005.52	1012.97	1020.84	1029.15	1038	1046.6	1055.37	1063.87	1071.81	1080.26	1087.67	1093.88
EU (IEA)	357.24	357.79	358.29	358.9	359.64	360.39	361.51	362.9	364.53	366.23	367.99	369.72	370.99	372.1	373.13	374.15

Source: ANU DX statistics database. IEA 1998, p. II.312, IEA 1997, p. II.13

Table A4.8 Trends in per capita emissions, 1982-1997 (kg/capita)

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Australia	15028	14218	14544	14485	14397	14964	14935	15785	15848	15612	15724	16257	16106	16159	17105	17019
Canada	16835	16309	16812	16592	16278	16715	17215	17599	16465	15972	16272	16157	16435	16593	16695	17082
Germany	13257	13240	13569	13722	13741	13672	13541	13159	12871	12377	11820	11548	11430	11359	11627	11338
Japan	8004	7845	8345	8140	8111	8041	8698	8981	9342	9462	9584	9480	9910	10025	10236	10204
Netherlands	10231	10708	11393	11426	11853	12052	11998	11979	12179	12580	12347	12325	12427	12864	13162	12966
New Zealand	6260	6268	6647	7228	6955	7340	7622	8039	7897	7719	8356	8091	8150	8426	9014	9380
Norway	7286	7314	7714	7860	8807	8446	7658	8402	7950	8162	8156	8566	8376	8290	8475	8688
UK	10317	10208	9779	10464	10680	10841	10754	10544	10663	10776	10550	10256	10212	10221	10364	9931
US	20004	19858	20439	20429	20134	20758	21310	21395	20650	20322	20415	20853	20937	20914	21323	21740
OECD	11041	10888	11137	11204	11125	11351	11542	11627	11398	11330	11331	11391	11462	11536	11838	11908
EU	9079	8960	8943	9172	9186	9298	9250	9296	9284	9366	9109	8902	8895	9020	9227	9065

Table A4.9 Electricity use in final energy consumption, 1982 and 1997

	1982	1997	Change
Australia	15.6%	19.6%	25.8%
Canada	18.7%	21.8%	16.8%
Germany	14.4%	16.3%	12.9%
Japan	19.4%	23.1%	19.0%
Netherlands	10.8%	13.3%	22.2%
New Zealand	25.4%	21.8%	-14.3%
Norway	42.5%	46.0%	8.3%
UK	14.8%	16.9%	14.5%
US	14.0%	18.8%	34.6%
OECD	14.2%	18.6%	30.8%
EU	14.8%	17.6%	18.9%

Source: IEA 1998, pp. II.17,47,53,71,101,137,161,167,173,215,221; IEA 1996, p. 236

Note: due to rounding some of the percentage changes may appear slightly incorrect.

Appendix 5 Immigration and emigration data

The follow tables present data on the number and countries of origin and destination of all immigrants and emigrants (permanent arrivals and departures) from 1985-86 to 1996-97 (obtained from ABS). Information on per capita emissions from energy has been obtained from the International Energy Agency (IEA 1997, pp. 48-57). Comprehensive emissions per capita for most developed countries are presented in Section 2. Comprehensive emissions are not available for most other countries.

Table A5.1 Arrivals and average per capita emissions by country of origin

Country of origin	**Number** 1986-1997	**CO_2/capita from energy** 1995	**CO_2-e/capita comprehensive (bold where available)** 1995
United Kingdom	185720	9.64	**11.31**
New Zealand	181100	8.19	**17.13**
Hong Kong	100530	7.11	7.11
Philippines	66400	0.73	0.73
Other Europe & Former USSR[a]	48150	6.60	**11.23**
Malaysia	47950	4.58	4.58
Vietnam	47810	0.30	0.30
South Africa	34990	7.74	7.74
India	34510	0.86	0.86
China	30240	2.51	2.51
United States of America	26060	19.88	**21.21**
Thailand	24780	2.67	2.67
Lebanon	23020	3.35	3.35
Fiji	22120	ne	ne
Sri Lanka	21840	0.34	0.34
Taiwan	20550	7.83	7.83
Singapore	20320	19.66	19.66
Indonesia	18980	1.17	1.17
Other Americas[b]	17640	2.11	2.11
Former Yugoslav Republic of Serbia and Montenegro	17520	3.77	3.77
Ireland	15750	9.73	**14.68**
Other Southern Asia[c]	15040	1.22	1.22
Former USSR & Baltic States[d]	15035	8.48	**10.30**
Other Africa[e]	14880	0.98	0.98
Germany	14500	10.83	**12.63**
Canada	14280	15.90	**20.64**
Turkey	14190	2.60	2.60
Korea	12450	7.87	7.87
Chile	9240	2.96	2.96
Other Southeast Asia[c]	8940	1.22	1.22
Greece	7930	7.33	**10.08**
Italy	7360	7.40	**9.00**
Japan	7310	9.17	**9.48**
Bosnia and Herzegovina	7120	1.05	1.05
Austria	5900	7.45	**8.01**
Iraq	5875	3.57	3.57
Iran	5470	3.63	3.63
Papua New Guinea	4960	ne	ne
Other Oceania & Antarctica	4760	ne	ne

Country of origin	**Number** 1986-1997	**CO_2/capita from energy** 1995	**CO_2-e/capita comprehensive (bold where available)** 1995
Switzerland	4640	5.93	**6.74**
France	4480	6.23	**7.78**
Netherlands	4450	11.57	**14.36**
Croatia	4040	3.46	3.46
Argentina	3710	3.70	3.70
Israel	3670	9.22	9.22
Sweden	3650	6.35	**4.21**
Syria	3600	2.79	2.79
Jordan	3590	3.00	3.00
Denmark	3490	11.58	**14.94**
Saudi Arabia	2870	11.96	11.96
United Arab Emirates	2690	30.72	30.72
Zimbabwe	2680	1.45	1.45
Former Yugoslav Republic of Macedonia (FYROM)	1810	4.29	4.29
Brazil	1620	1.81	1.81
Kuwait	1465	25.24	25.24
Other Northeast Asia[c]	1055	1.22	1.22
Belgium	1005	11.50	**14.06**
Norway	940	7.84	**8.74**
Bahrain	855	22.86	22.86
Finland	835	10.65	**11.00**
New Caledonia	623	ne	ne
Oman	478	4.74	4.74
Qatar	287	30.16	30.16
Slovenia	274	6.73	**9.42**
Yemen	21	0.57	0.57
Gaza Strip and West Bank	3	ne	ne
Total	**1240051**	**6.58**	**8.61**

a. A breakdown of countries within this group was not available. Accordingly, per capita emissions from energy are for ‘non-OECD Europe’ (IEA 1997, p. 48). Comprehensive emissions are a simple average of those of Bulgaria, the Czech Republic, Hungary, Poland, Slovakia and the Ukraine.

b. Per capita emissions from energy are those for ‘Latin America’ (IEA 1997, p. 48).

c. A breakdown of countries within this group was not available. Accordingly, average per capita emissions from energy for Asia (IEA 1997, p.48).

d. Average per capita energy-related emissions for the Former USSR are used. Comprehensive per capita emissions for the Russian Federation are used.

e. Per capita emissions from energy are those for ‘Africa’ (IEA 1997, p. 48).

Table A5.2 Departures and average per capita emissions by country of destination

Country of destination	Number	CO_2/capita from energy	CO_2-e/capita comprehensive (bold where available)
	1986-1997	1995	1995
New Zealand	109550	8.19	**17.13**
United Kingdom	63370	9.64	**11.31**
United States of America	26740	19.88	**21.21**
Hong Kong	12700	7.11	7.11
Other Europe & Former USSR[a]	10860	6.60	**11.23**
Canada	8760	15.90	**20.64**
Singapore	5210	19.66	19.66
Greece	4770	7.33	**10.08**
Ireland	4580	9.73	**14.68**
Italy	4160	7.40	**9.00**
Indonesia	3395	1.17	1.17
Other Oceania & Antarctica	3270	ne	ne
Malaysia	3250	4.58	4.58
Germany	3190	10.83	**12.63**
Netherlands	3050	11.57	**14.36**
Papua New Guinea	3020	ne	ne
Japan	2515	9.17	**9.48**
China	2432	2.51	2.51
France	2320	6.23	**7.78**
Thailand	2120	2.67	2.67
Philippines	2035	0.73	0.73
Switzerland	1980	5.93	**6.74**
Lebanon	1905	3.35	3.35
Other Americas[b]	1730	2.11	2.11
Chile	1630	2.96	2.96
Taiwan	1610	7.83	7.83
South Africa	1535	7.74	7.74
Sweden	1315	6.35	**4.21**
Vietnam	1308	0.30	0.30
Israel	1265	9.22	9.22
Denmark	1205	11.58	**14.94**
Korea	1200	7.87	7.87
Fiji	1090	ne	ne
United Arab Emirates	1046	30.72	30.72
Other Southeast Asia[c]	1003	1.22	1.22
Turkey	975	2.60	2.60
Argentina	890	3.70	3.70
Other Africa[e]	860	0.98	0.98
Saudi Arabia	838	11.96	11.96
Croatia	800	3.46	3.46
Former Yugoslav Republic of Serbia and Montenegro	800	3.77	3.77
Austria	735	7.45	**8.01**
India	645	0.86	0.86
Finland	445	10.65	**11.00**
Former Yugoslav Republic of Macedonia (FYROM)	430	4.29	4.29
Bahrain	406	22.86	22.86
Norway	388	7.84	**8.74**
Belgium	358	11.50	**14.06**

Country of destination	**Number** 1986-1997	**CO_2/capita from energy** 1995	**CO_2-e/capita comprehensive (bold where available)** 1995
Former USSR & Baltic States[d]	341	8.48	**10.30**
Brazil	323	1.81	1.81
Other Southern Asia[c]	272	1.22	1.22
Oman	267	4.74	4.74
New Caledonia	251	ne	ne
Sri Lanka	223	0.34	0.34
Kuwait	201	25.24	25.24
Zimbabwe	192	1.45	1.45
Iran	159	3.63	3.63
Syria	135	2.79	2.79
Jordan	116	3.00	3.00
Other Northeast Asia[c]	97	1.22	1.22
Bosnia and Herzegovina	94	1.05	1.05
Qatar	90	30.16	30.16
Slovenia	89	6.73	**9.42**
Iraq	12	3.57	3.57
Yemen	6	0.57	0.57
Gaza Strip and West Bank	0	ne	ne
Total	**312557**	**9.47**	**13.67**

Footnotes as for Table 2.

Appendix 6 Immigration, emissions and exports

Section 4 compares the average per capita energy-related greenhouse gas emissions of immigrants to Australia with that of Australians. However, using these per capita emission levels to estimate the change in global emissions attributable to the migration of a person from the country of origin to Australia requires more careful consideration. In particular, if Australian emissions are due to export activity, and exports are unaffected by immigration, then increases in domestic population through immigration will not add to emissions. In this case, immigrants to Australia from a low-emissions country will not increase Australian or global emissions. Accordingly, it does not follow from the results of Section 4 that when an immigrant leaves their country of origin and settles in Australia global emissions increase by the difference between per capita emissions in the country of origin and the average Australian level. (This feature is modelled in Section 5 of the paper, where Australia's energy-related emissions are projected to 2020, by excluding emissions from export sectors.)

The analysis in Section 4 excludes emissions from agriculture and land-use change and forestry (plus waste). This is because population size is assumed to have no influence on the export-driven agricultural sector (which is also responsible for much land clearing and forestry). The analysis should also, but does not yet, exclude energy-related emissions generated in the production of exports.

The energy emissions associated with Australia's exports have been estimated at 56 Mt CO_2 or around 3t CO_2/person in 1989-90 (BIE 1995). If this has not changed appreciably per capita since 1989/90 then Australia's relevant per capita emissions fall to around 12.8t/capita (net of exports). In other words, an extra person would generate an extra 12.8 t CO_2.

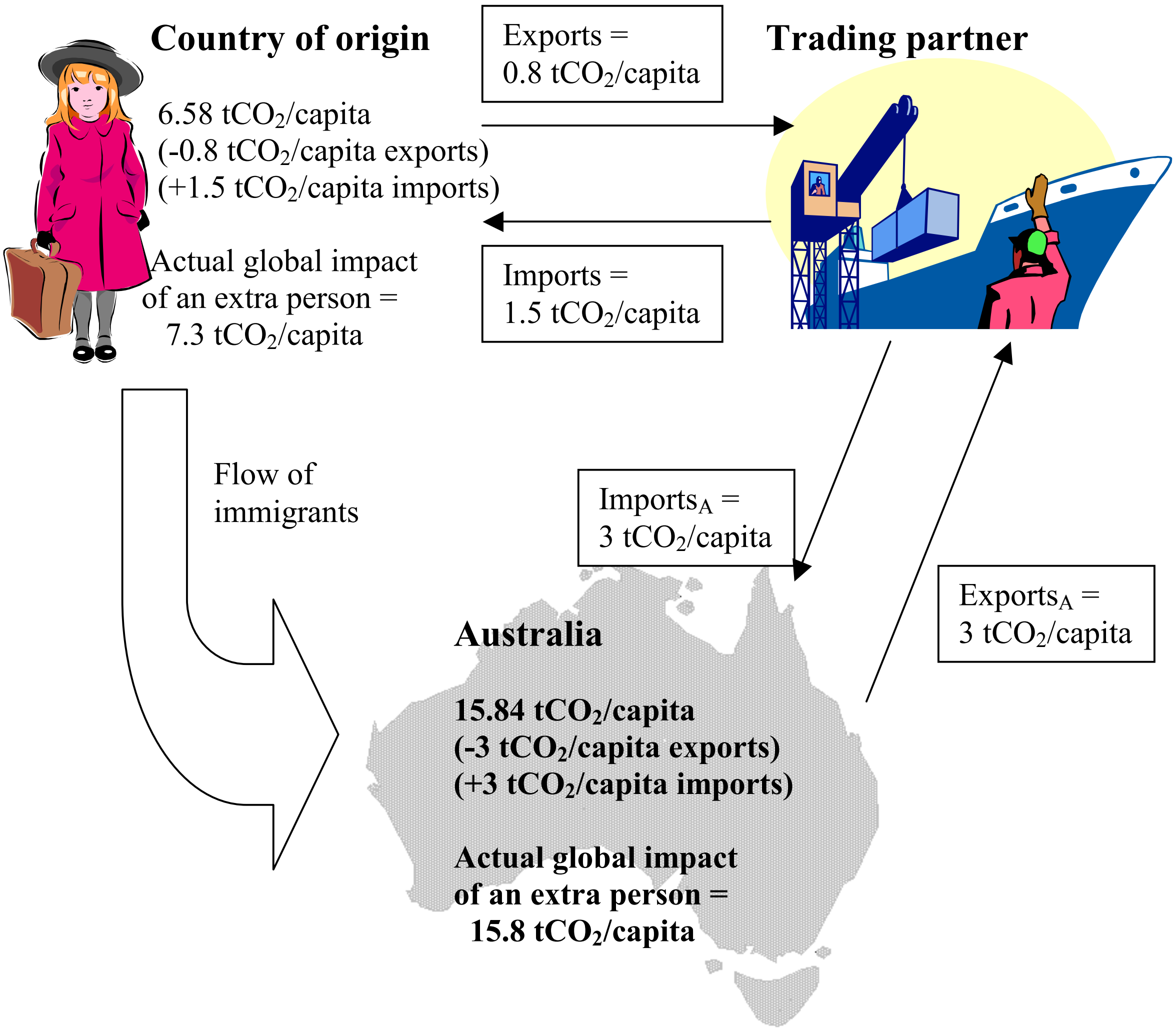
To be consistent, average per capita emissions for the countries of origin of immigrants to Australia should be adjusted similarly. This is, when an immigrant leaves their country of origin they do not affect export-related emissions in that country. Accordingly, the average per capita emissions of immigrants to Australia, whilst in their countries of origin, should be reduced.

Putting it another way, when a person leaves their country of origin the marginal change in emissions is less than the average, and when that person arrives in Australia their marginal impact on Australia's emissions is less than the average.

But the issue does not stop there. While it is reasonable to assume that exports are not affected by emigration and immigration, it is reasonable to assume that imports will be affected because they are demand-driven. The analysis should account for emissions associated with the production of goods imported into Australia and the countries of origin. We have data for Australia. Demand for imports by Australians generates 53 Mt CO_2 of energy-related emissions globally, again around 3t CO_2 per person (1989-90 data) (BIE 1995). Immigration will increase imports to Australia and induce a fall in imports to the immigrants' countries of origin.

Accordingly, the net impact of immigration to Australia on global emissions depends on changing levels of consumption (of energy-using goods and services) as immigrants move from their country of origin to Australia. If immigrants consume at a level similar to that of Australians and not at the levels in their countries of origin (examined in the discussion of the Household Expenditure Survey in Section 4) then global consumption and emissions will be higher.

Thus per capita emissions in Australia and the countries of origin should exclude emissions from exports but include emissions from imports. In all likelihood, on a per capita basis the emissions from imports to Australia will be higher than average emissions from imports to countries from which Australia draws immigrants. Similarly, on a per capita basis Australia probably exports more emissions-intensive products. The consequences, in terms of global emissions are presented in the figure where for simplicity the world is divided into three countries – the country of origin of immigrants to Australia, the trading partners of Australia and the countries of origin, and Australia. Actual per capita emissions attributable to exports and imports are included for Australia. In the absence of data, we have assumed for illustrative purposes only that the emissions embodied in exports from the country of origin amount to 0.8 t/capita and emissions embodied in imports to the country of origin amount to 1.5 t/capita (i.e. half of the Australian figure).



The greenhouse gas emissions of the average additional immigrant to Australia in their country of origin which their consumption is responsible for are given by

$E_o - X_o + M_o$

where

E_o = greenhouse gas emissions within country per capita,

X_o = emissions from the manufacture etc. of exports per capita,

M_o = emissions occurring outside country but attributable to imports per capita.

The greenhouse gas emissions attributable to the consumption of the average additional Australian are given by

$E_A - X_A + M_A$

where

E_A = greenhouse gas emissions within Australia per capita,

X_A = emissions from the manufacture etc. of exports per capita,

M_A = emissions occurring outside Australia but attributable to imports to Australia per capita.

Therefore, the value of $\frac{E_A - X_A + M_A}{E_o - X_o + M_o}$ represents the factor by which emissions per person increase when an immigrant moves to Australia from their country of origin (assuming their consumption habits change to those of the average Australian).

Appendix 7 Projections of greenhouse gas emissions

Table A7.1 Population projections (thousands)

	Low fertility = 1.6			High fertility = 1.75		
Net migration	0	70,000	140,000	0	70,000	140,000
Scenario	**A1**	**B1**	**C1**	**A2**	**B2**	**C2**
1997	18532.2	18532.2	18532.2	18532.2	18532.2	18532.2
1998	18650.7	18729.5	18808.3	18653.8	18732.6	18811.4
1999	18763.5	18914.6	19065.7	18772.2	18923.1	19074.0
2000	18870.6	19095.4	19320.2	18886.4	19111.3	19336.2
2001	18971.9	19271.6	19571.3	18997.0	19297.1	19597.2
2002	19067.3	19443.4	19819.5	19103.7	19480.5	19857.3
2003	19157.2	19610.5	20063.8	19206.4	19661.5	20116.6
2004	19240.2	19773.0	20305.8	19305.1	19839.9	20374.7
2005	19317.7	19931.0	20544.3	19399.8	20015.9	20632.0
2006	19389.4	20084.3	20779.2	19490.5	20189.4	20888.3
2007	19455.7	20233.7	21011.7	19576.7	20360.0	21143.3
2008	19518.0	20380.5	21243.0	19658.7	20528.0	21397.3
2009	19576.3	20524.7	21473.1	19736.6	20693.4	21650.2
2010	19630.9	20666.5	21702.1	19810.6	20856.5	21902.4
2011	19681.7	20806.0	21930.3	19880.7	21017.3	22153.9
2012	19729.2	20943.4	22157.6	19947.5	21176.0	22404.5
2013	19773.5	21078.8	22384.1	20010.9	21332.7	22654.5
2014	19814.8	21212.3	22609.8	20071.3	21487.7	22904.1
2015	19853.1	21344.0	22834.9	20128.7	21640.9	23153.1
2016	19888.7	21473.8	23058.9	20183.3	21792.3	23401.3
2017	19921.4	21601.6	23281.8	20235.1	21941.9	23648.7
2018	19951.3	21727.3	23503.3	20284.2	22089.6	23895.0
2019	19978.1	21850.7	23723.3	20330.3	22235.2	24140.1
2020	20001.7	21971.5	23941.3	20373.4	22378.4	24383.4

Appendix 8 Projection model assumptions

The assumptions and equations used in the emission projections are detailed below. Energy use and emissions for each sector have been modelled separately, and then aggregated.

Agriculture and mining

The agricultural and mining sectors are assumed to be largely independent of population size. That is, it has been assumed that mining projects do not depend on domestic population to be viable and the prices received for the output of the mining and agricultural sector are determined by international factors. Australia is a price-taker for agricultural and mineral output and any produce that is not sold domestically can be exported. Energy use in these sectors is assumed to directly follow ABARE's projections based on historical trends and fuel and electricity survey data. Fuel use in the production of bitumen, lubricants, solvents and greases has been assumed to be independent of population and therefore is projected to follow ABARE's estimates. Accordingly energy use in mining and agriculture is given by:

$$E_t = E(ABARE)_t,$$

where $E(ABARE)_t$ = energy use by sector at time t according to ABARE projections.

Manufacturing

The manufacturing sector is slightly more complex. Energy use in manufacturing depends on both export-driven demand and domestic demand. The export-driven component has been modelled as for the mining and agricultural sectors. Domestic demand has been modelled on the assumption that demand for manufactured products per person follows the levels implicit in ABARE projections. In this exercise it is assumed that the energy-intensity of exports and domestically-consumed manufactured goods are the same.

$$E_t = Export.prop \bullet E(ABARE)_t + (1 - Export.prop) \bullet \frac{E(ABARE)_t}{Pop(ABARE)_t} \bullet Pop_t$$

Exports as a proportion of total production are based on 1994-1998 value of exports compared to total manufacturing sales (ABS 1995b, 1996a, 1996b, 1997, 1998a, 1999a, 1999b). It is assumed the energy used to produce a dollar of manufacturing exports is the same as the proportion used to produce a dollar of domestic goods.

Construction

ABARE has assumed the construction sector grows in accordance with historical trends (Bush *et al.* 1999, p. 67). The model defined here assumes that energy use in construction (closely linked to construction activity) is more closely related to economic activity. Accordingly, energy use in construction has been assumed to follow the relationship between real GDP and construction implicit in ABARE projections. Accordingly, energy use is given by:

$$E_t = \frac{E(ABARE)_t}{GDP(ABARE)_t} \bullet GDP_t$$

Commercial, services and government

Energy use in the commercial sector is estimated by ABARE with an econometric model. This model has been applied here but modified to include commercial sectors covered by the ABARE survey (Bush *et al.* 1999, p. 68). Energy use is given by:

$$\begin{aligned} \ln E_t &= -2.33 + 0.67 \ln GDP_t - 0.01T + 0.70 \ln E_{t-1} \\ &\quad (-2.46)\ (3.31) \qquad (-2.39)\ \ (6.83) \end{aligned}$$

where GDP is given in 1989-90 billion dollars, E_{t-1} is energy use in the sector in the previous year and T is a time trend, where T = 1, 2, 3,….

Residential

The residential sector model used by ABARE has been used here, assuming ABARE's projections of energy prices and household disposable incomes are realised (Bush *et al.* 1999, pp. 68-69). Quarterly energy consumption per person is given as follows:

$$\ln E_t = -0.19 - 0.16 \ln P_t + 0.12 \ln Y_t + 0.31 \ln E_{t-4} + 0.36 \ln E_{t-1} + 0.05 D_1 + 0.20 D_2 + 0.30 D_3$$

where P is an index of energy costs, Y is per person disposable income and D_1, D_2 and D_3 are seasonal dummy variables.

As indicated above, it has been assumed that energy costs and per person disposable incomes are independent of population size (as are seasonal dummy variables). Accordingly, per person energy consumption is given by ABARE's projections, and annual energy consumption in this sector is given by:

$$E_t = \frac{E(ABARE)_t}{Pop(ABARE)_t} \bullet Pop_t$$

Road transport

The road transport sector has been modelled in accordance with the Bureau of Transport Economics' CARMOD and TRUCKMOD models (BTCE 1995, pp. 35-39; BTCE 1996a, App. VII, App. VIII). It has been assumed that population changes will not have a significant impact on average fleet fuel efficiency and, accordingly, efficiency has been assumed to follow BTE projections (BTCE 1996a, Table II.3). Other assumptions are as used by the BTE. Passenger car fuel consumption is given by:

$$E_t = \frac{0.516}{(1 + 7.65e^{-0.0896T})} \bullet Pop_t \bullet 15{,}500 \bullet AFC_t \bullet AED_t,$$

where AFC is average fuel consumption (BTCE 1996a, Table II.3), AED is average energy density of fuel mix (MJ/L) which is assumed to follow BTCE fuel mix projections (BTCE 1996a, Table II.7). T is a time trend, given as 0, 1, 2, 3, … where T=1 in 1944-45. Average total kilometres per vehicle are taken to be 15,500 kilometres per annum (BTCE 1996b, p. 95).

Travel by other road vehicles is given by:

$$\ln TOTFRT = -4.46 + 1.058 \ln GDP_t - 0.923 \ln RROADLH_t,$$

where TOTFRT is total freight in billion tonne-kilometres, GDP is real GDP in $billion 1989-90 dollars and RROADLH represents real long-haul freight rates. These are taken to drop 15% between 1992-93 and 2014-15 (BTCE 1995, p. 38) and continuing to decrease at a similar rate thereafter.

Tonne-kilometre freight task has been assigned to each class of commercial vehicle, comprising light commercial vehicles (LCVs), rigid trucks and articulated trucks. According to BTCE assumptions, LCV task is assumed to grow at 5.8% per year, rigid trucks at 3% per year and articulated trucks the remainder of the growth given by the above formula.

Average loads for each class of vehicle are applied to convert tonne-kilometres to total kilometres by vehicle class (BTCE 1995, Table VIII.4). This is multiplied by average fuel consumption (BTCE 1995, Table VIII.5) to determine total fuel consumption. Average fuel energy density (as determined from BTCE 1996a, Table II.13-15) is then applied to determine energy use in the transport sector. Energy use can be given as follows, where each vehicle class is summed:

$$E_t = \Sigma(\frac{FRT_t}{AL_t} \bullet AFC_t) \bullet AED_t,$$

where FRT is tonne-kilometres of freight for each class of vehicles, AL is average load and AFC average fuel consumption. AED is the average energy density.

Other transport

Energy use in other transport sectors (water, rail and air) has been modelled according to assumptions about the factors that drive demand in each sector but based on ABARE projections. For example, variations (from ABARE projections) in water transport energy use have been assumed to be dependent on changes in the output of the agricultural, mining and manufacturing sectors. Variations in rail transport demand have been assumed to be dependent on GDP. Variations in air transport energy use are assumed to depend on changes in population. This enables trends in per capita air travel to be incorporated into the model since these are incorporated into the ABARE projections on which this model is based. Energy use is given by:

$$E_t = \frac{E(ABARERail)_t}{GDP(ABARE)_t} \bullet GDP_t + \frac{E(ABARESea)_t}{Output(basic)_t} \bullet Output_t + \frac{E(ABAREAir)_t}{Pop(ABARE)_t} \bullet Pop_t$$

where Output is based on the value of goods produced by the agricultural, mining and manufacturing sectors. Under Output (basic) sectors grow according to the rate from

1987-1996. Output_t varies with changes in manufacturing output (discussed for the model of energy use in the manufacturing sector).

Electricity generation

Fuel use in electricity generation is derived from fuel use in other sectors. It has been assumed that there are no economies of scale in electricity generation at the margin relevant to this analysis and fuel mix in the electricity generation sector is independent of capacity. Accordingly, electricity use is given by:

$$E_t = \frac{E(ABAREelect.)_t}{E(ABAREag,min,man,comm,res)_t} \bullet E(ag,min,man,comm,res)_t$$

Other assumptions

An important assumption has been made that although population growth leads to increases in GDP, it is not projected to lead to an increase in GDP/capita. Accordingly, GDP/capita is assumed to follow ABARE projections independent of population. That is:

$$GDP_t = \frac{GDP(ABARE)_t}{Pop(ABARE)_t} \bullet Pop_t$$

Another important assumption is that the fuel mix in any sector is not influenced by the energy use in that sector. That is, a 10% drop in fuel use in the manufacturing sector leads to a 10% drop in each electricity use, gas use, coal use, petroleum use etc. and does not change the mix from one fuel to another.

Appendix 9 Projections of energy-related emissions

Table A9.1 Emission projections under each scenario, 1997-2020 (Mt CO_2)

	Low fertility = 1.6			High fertility = 1.75		
Net migration	0	70,000	140,000	0	70,000	140,000
Scenario	**A1**	**B1**	**C1**	**A2**	**B2**	**C2**
1996-97	331	331	331	331	331	331
1997-98	343	345	346	344	345	346
1998-99	345	347	349	345	347	349
1999-00	346	349	352	346	349	352
2000-01	350	354	358	350	354	359
2001-02	349	355	360	350	355	361
2002-03	355	362	368	356	362	369
2003-04	360	368	376	361	369	377
2004-05	364	374	383	365	375	384
2005-06	365	376	387	367	377	388
2006-07	371	383	395	372	385	397
2007-08	372	385	399	374	388	401
2008-09	373	388	403	376	391	406
2009-10	375	391	407	377	394	410
2010-11	377	395	413	380	398	416
2011-12	379	398	417	382	401	421
2012-13	380	401	422	384	405	426
2013-14	380	402	424	384	406	429
2014-15	381	404	428	385	409	433
2015-16	382	407	432	386	412	438
2016-17	383	409	437	388	415	443
2017-18	384	412	441	389	418	448
2018-19	385	415	445	391	421	452
2019-20	386	418	450	392	424	457

Discussion papers available from the Australia Institute

1. Kirby, M., *Trash Fights Back*, Speeches at the public launch of The Australia Institute, 4 May 1994
2. Quiggin, J., *Does Privatisation Pay?* September 1994
3. Wilkenfeld, G., Hamilton, C. and Saddler, H., *Australia's Greenhouse Strategy: Can the future be rescued?* February 1995
4. Hamilton, C. and Quiggin, J., *The Privatisation of CSL,* June 1995
5. Dargavel, J., O'Shaughnessy, P. and Hamilton, C., *Logging and Water,* November 1995
6. The Australia Institute, *Citizens in the Marketplace: The implications of competition policy for citizenship*, March 1996
7. Jamieson House Employment Group, *Redistributing Work: Solutions to the paradox of overwork and unemployment in Australia*, June 1996
8. The Australia Institute, *What Should Government Do? Auditing the Audit Report*, Papers from a conference held at the Australian National University, July 1996
9. Hamilton, C., *Mining in Kakadu: Lessons from Coronation Hill* July 1996
10. Hamilton, C., Hundloe, T. and Quiggin, J., *Ecological Tax Reform in Australia,* April 1997
11. Wensing, E. and Sheehan, J., *Native Title: Implications for land management* April 1997
12. Hamilton, C. and Saddler, H., *The Genuine Progress Indicator for Australia* (summary version) July 1997
13. Hundloe, T. and Hamilton, C., *Koalas & Tourism: An economic evaluation* July 1997
14. Hamilton, C. and Saddler, H., *The Genuine Progress Indicator: A new index of changes in well-being for Australia* October 1997
15. Hamilton, C. and Quiggin, J., *Economic Analysis of Greenhouse Policy: A layperson's guide to the perils of economic modelling* December 1997
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