POPULATION POLICY AND ENVIRONMENTAL DEGRADATION: SOURCES AND TRENDS IN GREENHOUSE GAS EMISSIONS

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The impact of population growth on the state of the environment has become a subject of vigorous public debate and has led to a number of official reports. This paper is the first systematic analysis of the implications of population growth in Australia on one of the most important environmental problems, the emission of greenhouse gases that are associated with climate change. This is especially important since Australia has signed up to international emission reduction obligations under the 1997 Kyoto Protocol.

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. Some 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. 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:

$$I = P*A*T$$

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 difficult 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.[2] It has four parts. The first part 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 comprehensively for emissions from all sources and sinks as reported by the various parties to the United Nations.

The second part employs a disaggregated IPAT formula to decompose 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.

The third part 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 1986-1997 in countries which provide immigrants to Australia and countries to which Australians emigrate.

The fourth part 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 scenarios. The analysis illustrates the potential contribution of population policies, including immigration, to meeting emission reduction obligations under the Kyoto Protocol.

GREENHOUSE GAS EMISSIONS IN DEVELOPED COUNTRIES

Notions of fairness and justice underpin international negotiations to reduce greenhouse gas emissions since it is generally held that nations that have contributed more to the problem of climate change should do more to solve it.

One of the most important principles referred to internationally is that of polluter pays. The usual 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.

Due to measurement complexities, perceptions of emissions per capita have to date been based on energy emissions alone, and on this basis it is widely believed that the USA has the world's highest emissions per capita. However, the provisions of the United Nations Framework Convention on Climate Change (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.

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 sectoral breakdown of per capita emissions for selected Annex B countries. The emissions data presented in Table 1 represent carbon dioxide-equivalent (CO_2-e) emissions of the three main greenhouse gases — carbon dioxide (CO_2), methane (CH_4)

and nitrous oxide (N_2O). Several other points should be made about the data in Table 1:[3]

- 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. Although potent greenhouse gases, the contribution made by these gases to total CO_2-e emissions is relatively small.
- The analysis excludes emissions from international bunkers (fuel used in international shipping and aviation) because they are not included in national inventories. Greenhouse gas precursor gases (such as CO and NO_x) are also excluded.

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

	Energy		Industry	Agri-culture	Waste	LUCF	Other	Total	Popu-lation 1995 (millions)	Per capita emissions (t CO_2-e/ capita)
	Fuel com-bustion	Fugitive[f]								
Australia	291.8	25.6	7.5	87.4	16.4	51.9	1.6	481.9	18.1	26.7
Austria	50.1	2.5	11.5	5.4	4.6	-13.6	4.1	64.6	8.1	8.0
Belgium[c]	112.8	1.0	14.3	11.5	5.0	-2.1	0.1	142.6	10.1	14.1
Bulgaria	59.3	5.6	8.2	3.4	11.0	-7.5	0.1	80.0	8.4	9.5
Canada	479.0	48.2	36.3	25.0	19.5	0.0	3.3	611.3	29.6	20.6
Czech Republic	130.4	8.5	5.2	3.5	3.0	-5.5	0.3	145.4	10.3	14.1
Denmark	58.9	0.7	1.3	16.2	1.6	-1.0	0.5	78.1	5.2	14.9
Estonia	20.9	0.0	0.2	0.8	0.7	-13.3	0.0	9.4	1.5	6.3
Finland	57.3	0.1	1.8	4.6	2.8	-10.5	0.1	56.2	5.1	11.0
France	365.8	14.3	40.8	48.9	19.2	-46.8	9.9	452.1	58.1	7.8
Germany[e]	885.1	24.6	50.3	61.5	39.9	-30.0	0.0	1,031.4	81.7	12.6
Greece	84.8	1.0	8.3	8.4	2.8	0.0	0.0	105.3	10.5	10.1
Hungary	59.0	6.6	2.3	3.1	6.1	-4.8	0.0	72.2	10.2	7.1
Iceland	1.8	0.1	0.5	0.3	0.04	0.0	0.01	2.7	0.3	9.8
Ireland	33.3	0.2	2.6	19.3	3.0	-6.2	0.8	52.8	3.6	14.7
Italy	425.2	10.1	29.3	41.8	21.7	-24.5	12.4	516.0	57.3	9.0
Japan[e]	1,162.1	3.6	68.7	20.7	28.5	-94.6	1.5	1,190.4	125.6	9.5
Latvia	12.2	0.5	0.1	5.8	0.6	-10.5	0.04	8.8	2.5	3.5
Lithuania[b]	37.8	0.6	2.6	7.2	3.5	-8.9	4.09	46.8	3.7	12.6
Luxembourg	9.2	0.04	0.4	0.5	0.1	-0.3	0.01	9.9	0.4	24.2
Monaco[d]	0.1	0.0	0.0	0.0	0.05	0.0	0.0	0.1	0.03	4.3
Netherlands	183.7	3.6	7.6	18.3	9.1	-1.7	1.5	222.1	15.5	14.4
New Zealand	25.0	1.2	2.7	44.3	2.8	-13.5	0.2	62.7	3.7	17.1
Norway	29.9	2.4	8.5	3.9	6.8	-13.6	0.3	38.1	4.4	8.7
Poland[c]	365.2	18.9	13.8	22.9	18.0	-42.0	0.2	396.9	38.6	10.3
Portugal[c]	47.9	0.3	4.0	6.3	13.8	-1.2	0.3	71.4	9.9	7.2
Russian Fed[c]	1,607.3	297.2	24.4	114.5	41.0	-568.0	10.0	1,526.4	148.2	10.3
Slovakia	46.0	2.3	3.4	4.2	1.5	-5.1	0.2	52.4	5.4	9.8
Slovenia[b]	13.6	1.1	0.6	2.4	1.6	-2.3	1.8	18.8	2.0	9.4
Spain[c]	221.6	13.4	18.9	37.6	15.3	-29.0	0.0	277.9	39.2	7.1
Sweden	56.3	0.02	5.2	4.2	1.3	-30.0	0.3	37.2	8.8	4.2
Switzerland	41.0	0.3	2.7	5.8	2.9	-5.1	0.1	47.7	7.1	6.7
Ukraine[b]	671.2	130.8	33.7	50.5	19.7	-52.0	7.3	861.1	51.6	16.7
United Kingdom	533.8	23.9	28.9	26.2	38.4	10.0	1.5	662.8	58.6	11.3
United States	5,206.4	202.5	96.4	268.2	236.4	-428.0	0.0	5,582.0	263.2	21.2
Total	13,385.3	851.4	543.0	984.6	598.3	1,409.5	62.3	15,015.4	1,106.4	13.6

[a] Main gases (CO_2, CH_4, N_2O), excluding bunkers and non-CO_2 emissions from LUCF. Mt indicates mega-tonnes or million metric tonnes. CO2-e stands for carbon dioxide equivalent. LUCF stands for land-use Change and Forestry.

[b] 1990 data. [c] 1994 data. [d] 1996 data. [e] Combination of 1994 and 1995 data. [f] releases during production.

Source: See Footnote 2

- Several Annex B countries did not report 1995 emissions information to the UNFCCC. Emissions data for these countries from earlier years have been used.
- A number of countries did not report emissions and removals for some sectors, particularly Land-Use Change and Forestry (LUCF). Australia was the only country to report the Forest and Grassland Conversion (F&GC) subsector of LUCF separately.

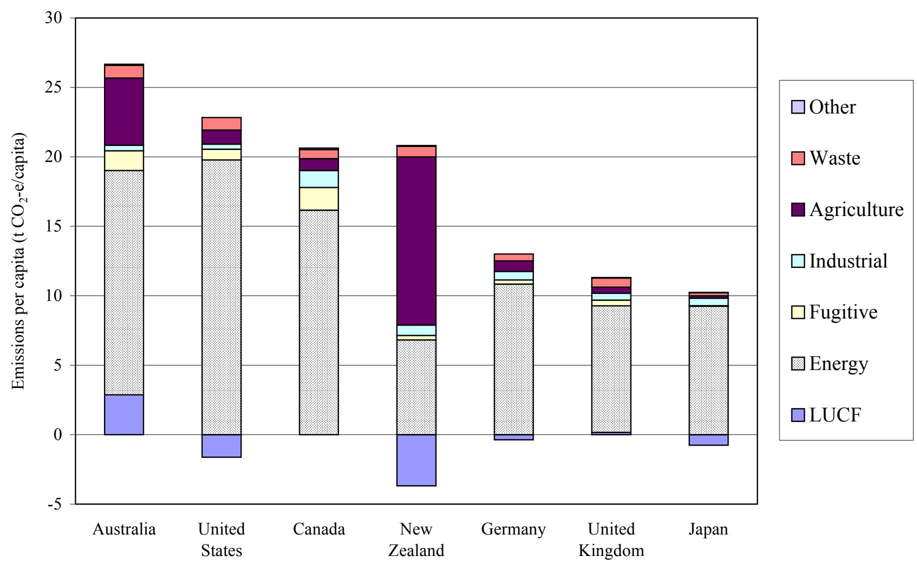
Despite these omissions and inconsistencies, the data reported in Table 1 present a robust and reasonably accurate picture of comprehensive emissions from Annex B countries in 1995.

It is apparent from Table 1 that, 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 per cent higher than emissions per person in the USA (21.2 tonnes).

While the USA has higher energy 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 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

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



Source: Table 1
Note: For those countries where the LUCF sector is a net sink (eg. New Zealand), the block of sequestered emission below the zero line in the figure must be subtracted from the emissions above the line to obtain net emissions per capita.

emissions per capita of 14 to 15 tonnes. Luxembourg's very high emissions are due to the presence of a large steel plant and 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.

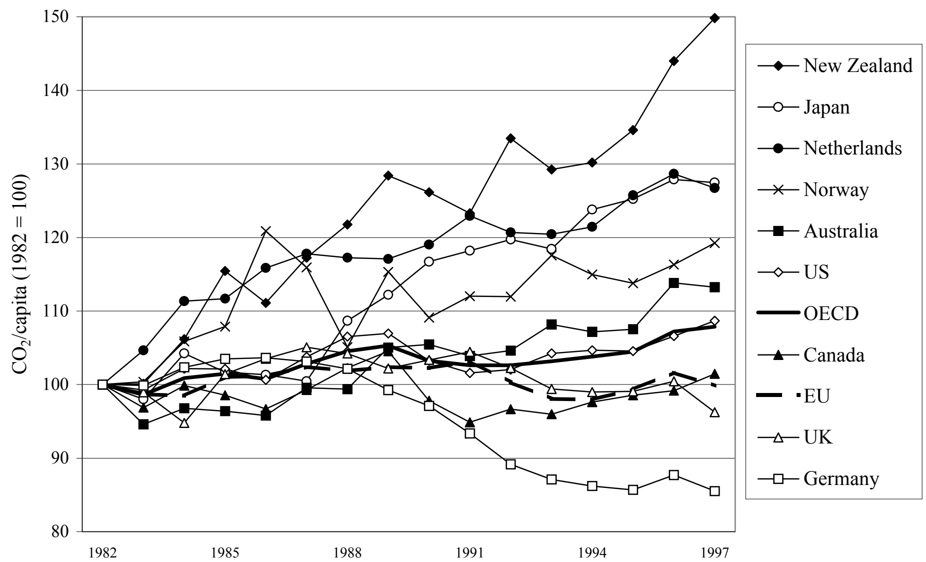
DETERMINANTS OF EMISSIONS GROWTH IN AUSTRALIA AND OTHER OECD COUNTRIES

Although providing an informative snapshot of each country's particular circumstances, the previous section provides no information on trends in emissions. An analysis of 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. 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 derived from International Energy Agency publications[6] and are set out in detail in Turton and Hamilton.[7]

Trends in energy-intensity and per capita emissions

Figure 2 shows changes in energy-related CO_2 emissions per capita from 1982 to 1997 for a number of industrialised coun-

Figure 2: Trends in per capita energy-related CO_2 emissions, 1982-1997



tries, as well as for the OECD and the European Union as a whole. New Zealand stands out as the worst performer, and there is strong evidence that the New Zealand economy became significantly more energy-intensive over this period. Japan and the Netherlands also exhibit a significant increase in energy-related per capita emissions, rising almost 30 per cent in each country. Germany, the United Kingdom, Canada and the European Union as a whole have contained growth of their per capita emissions. While Norway is one of the better performers in energy-intensity (that is energy used per unit of GDP), it is not a good performer in terms of per capita emissions. Australia's per capita emissions increased slightly more than the OECD average and the US.

Decomposition analysis

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

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

where:

CO_2	=	energy-related CO_2 emissions (measured in mega-tonnes (Mt);
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);
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 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.

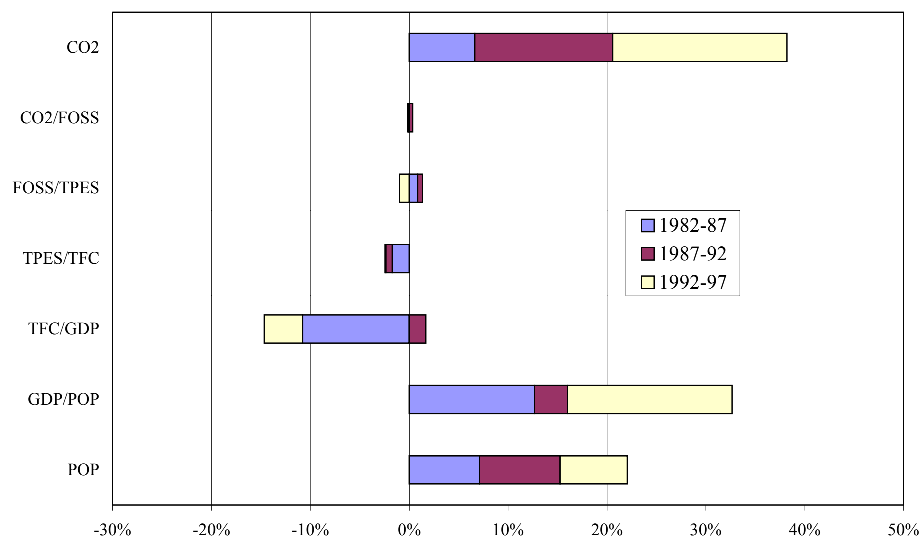
A change in any factor will influence energy-related CO_2 emissions. Similarly, changes in CO_2 emissions between two years can be explained by the changes in the above factors. The equation presented above has been used to decompose growth of energy-related CO_2 emissions between 1982 and 1997.[10]

Figure 3 shows changes in the decomposition variables for Australia between 1982 and 1997 and the three five-year periods. Over the whole period, energy-related CO_2 emissions grew by 38 per cent. This growth can be explained by the large increase in population and GDP per capita, somewhat offset by lower energy use per unit of GDP (TFC/GDP) and slightly improved conversion efficiency or fuel mix changes (TPES/TFC).

Looking at the three five-year periods, 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 lower immigration levels in the later period. Growth in GDP per capita was particularly low between 1987-92, principally because of 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 a growing 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 per cent, 13.1 per cent and 14.6 per cent for each period (compounding to 38 per cent).

How does the growth of energy-related CO_2 emissions in Australia compare with other developed countries? Figure 4 presents a comparison between Australia and the OECD as a whole. Over the 1982-97 period, OECD emissions grew 21 per cent, or a little more than

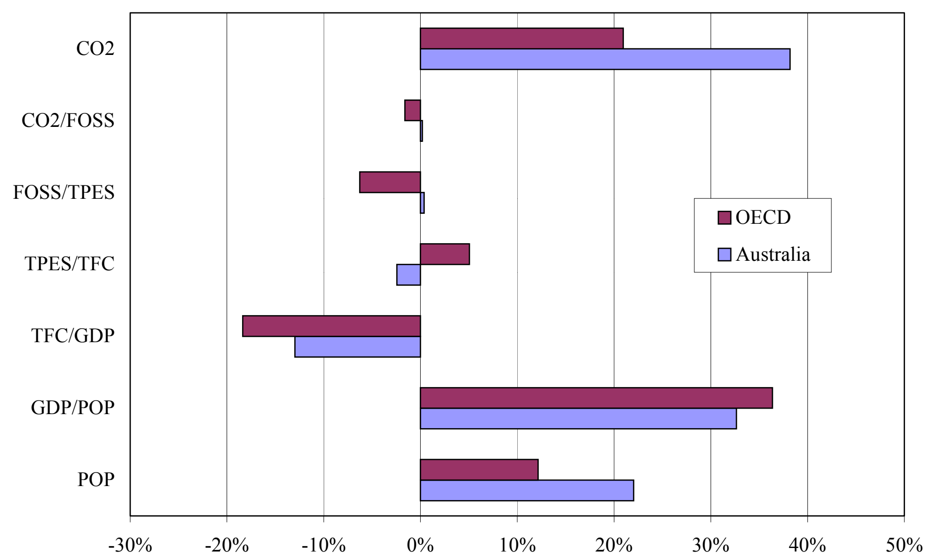
Figure 3: Contributions to growth in CO_2 emissions, Australia 1982-87, 1987-92 and 1992-97



half the growth of Australia's emissions. Much of this difference can be explained by smaller population growth in the OECD (12 per cent compared to 22 per cent). However, the OECD exhibited a larger increase in GDP per capita, a larger decrease in energy- intensity, an increased proportion of electricity in final energy consumption and a decrease in the proportion of energy sourced from fossil fuels. The latter can be explained by higher use of nuclear and hydro-electric power in OECD countries other than Australia. The higher TPES/TFC for the OECD may also be due to changes in fuel mix affecting aggregate thermal efficiency. 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 5 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 energy-efficiency measures following the oil shocks of the 1970s and early 1980s and changed the structure of its economy. Interestingly, the USA is using an increased proportion of electricity but has not improved aggregate thermal efficiency enough to offset the impact of increased electricity use on TPES/TFC. As a result of these changes, energy-related CO_2 emissions have increased in all countries, led by Australia (38 per cent) and followed by Japan (36 per cent), the USA (25 per cent) and

Figure 4: Contributions to growth in CO_2 emissions, Australia and the OECD, 1982-97



the EU (5 per cent). The significantly lower growth observed for the EU can be attributed to much lower population growth, improved efficiency and greater use of nuclear, hydro and gas.[11]

A clearer indication of Australia's relative performance over the period may be gained by comparing Australia with countries that share other similarities. Figure 6 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 6 illustrates significant variations in fuel mix and energy intensity of economic activity. New Zealand, particularly, appears to be the odd one out, having experienced lower growth in GDP/capita, increasing energy-intensity of economic activity (TFC/GDP), an increase in the proportion of energy derived from fossil sources[12] and a massive (77 per cent) 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. The growth in Australia's emissions is particularly high because population growth has not been offset by improvements to the fuel mix.

Overall, Australia experienced the highest population growth of all the industrialised countries and the second-largest increase in energy-related CO_2 emissions. Australia did not improve its energy intensity of economic output, nor shift away from fossil fuels as rapidly as the other countries studied. Unlike many other countries, Australia has improved the thermal efficiency of its electricity generation (while increasing the share of electricity in final consumption), by

Figure 5: Contributions to growth in CO_2 emissions, Australia, EU, Japan and the US, 1982-1997

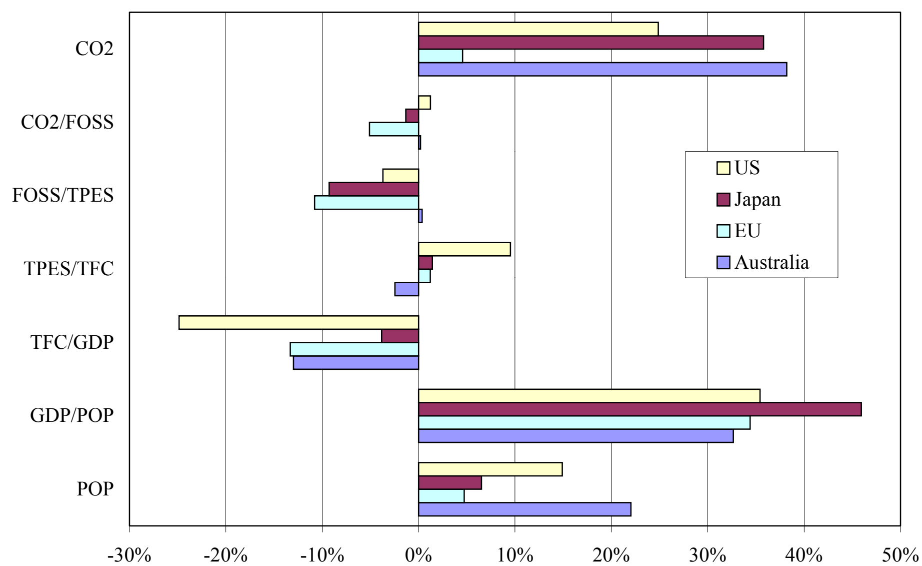
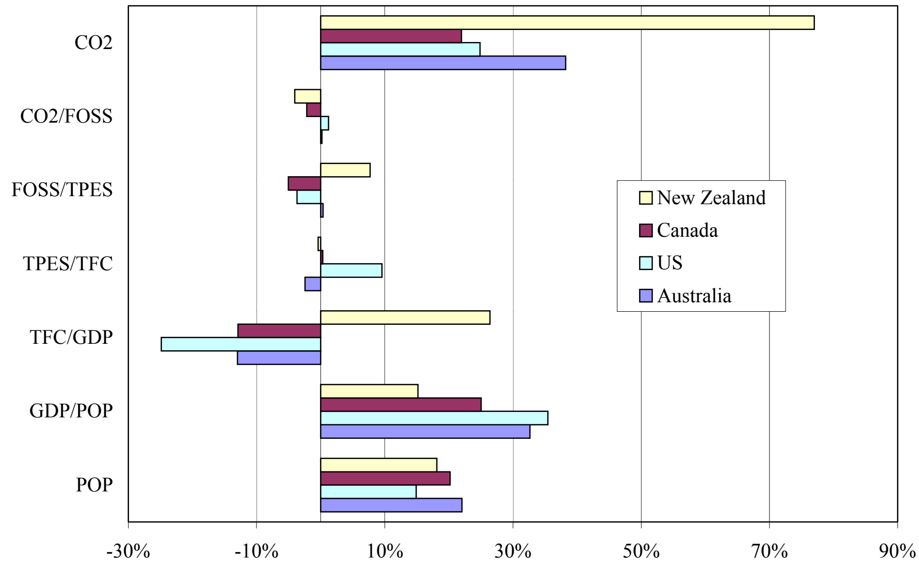


Figure 6: Contributions to growth in CO_2 emissions, Australia, Canada, New Zealand and US, 1982-1997



changing the electricity generation fuel mix and making operational improvements, both of which many other countries improved prior to 1982. Many other countries have initiated a shift away from coal towards petroleum and gas that has also reduced the CO_2 intensity of fossil energy. In contrast, Australia lags behind in the proportion of energy obtained from natural gas. Clearly, Australia's population policy decisions have had a marked effect on the growth of its greenhouse gas emissions.

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.

Permanent immigration to Australia by country of origin for the twelve years 1985-86 to 1996-97 is shown in Table 2. Permanent emigration from Australia by country of destination is shown in Table 3.[13] Energy emissions per capita for 1995 are also shown for each country. The shares of immigrants and emigrants by country are shown in Figures 7 and 8. 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 per cent of immigrants to Australia but receive around 80 per cent of emigrants from

Table 2: Permanent arrivals, 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	185,720	9.64	**11.31**
New Zealand	181,100	8.19	**17.13**
Hong Kong	100,530	7.11	7.11
Philippines	66,400	0.73	0.73
Other Europe & Former USSR[a]	48,150	6.6	**11.23**
Malaysia	47,950	4.58	4.58
Vietnam	47,810	0.3	0.3
South Africa	34,990	7.74	7.74
India	34,510	0.86	0.86
China[b]	30,240	2.51	2.51
United States of America	26,060	19.88	**21.21**
Thailand	24,780	2.67	2.67
Lebanon	23,020	3.35	3.35
Fiji	22,120	ne	ne
Sri Lanka	21,840	0.34	0.34
Taiwan	20,550	7.83	7.83
Singapore	20,320	19.66	19.66
Other	303,961		
Total	1,240,051	6.58	8.61

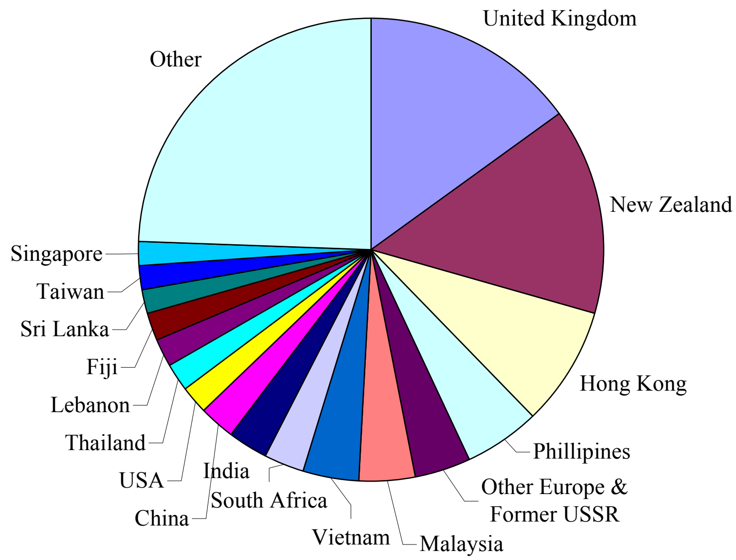
[a] Breakdown of countries within this group was not available. Accordingly, per capita emissions from energy are for 'non-OECD Europe' (IEA 1997, p. 48). Comprehensive emissions are a simple average of those of Bulgaria, the Czech Republic, Hungary, Poland, Slovakia and the Ukraine.
[b] These figures do not account for 'category jumping'.
Source: See Footnote 2

Table 3: Permanent departures, average per capita emissions by country of destination

County of destination	Number 1986-1997	CO_2/capita from energy 1995	CO_2-e/capita comprehensive (bold where available) 1995
New Zealand	190,550	8.19	**17.13**
United Kingdom	63,370	9.64	**11.31**
United States of America	26,740	19.88	**21.21**
Hong Kong	12,700	7.11	7.11
Other Europe & Former USSR[a]	10,860	6.6	**11.23**
Canada	8,760	15.9	**20.64**
Singapore	5,210	19.66	19.66
Other[b]	75,367		
Total	312,557	9.47	13.67

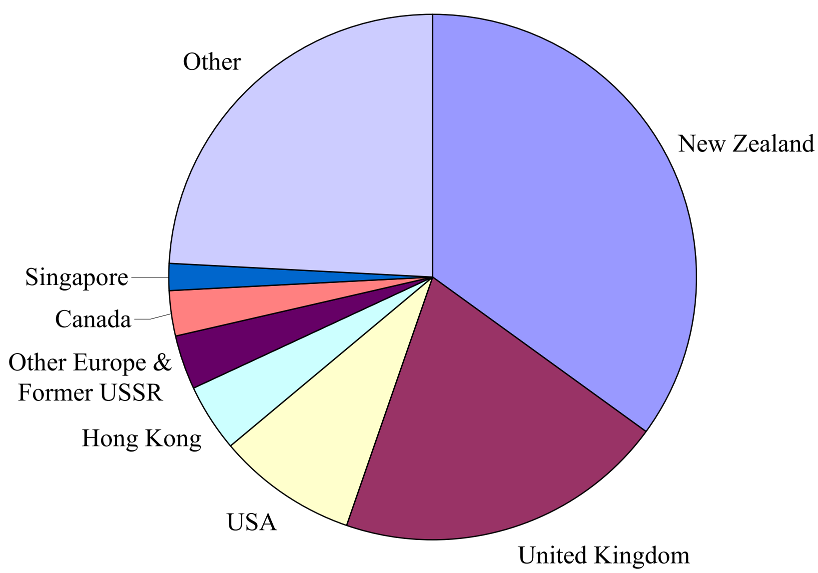
Notes and Source: See Table 2

Figure 7: Immigration to Australia by country of origin, 1986-97



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 change. Accord-

Figure 8: Emigration from Australia by country of destination, 1986-97



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

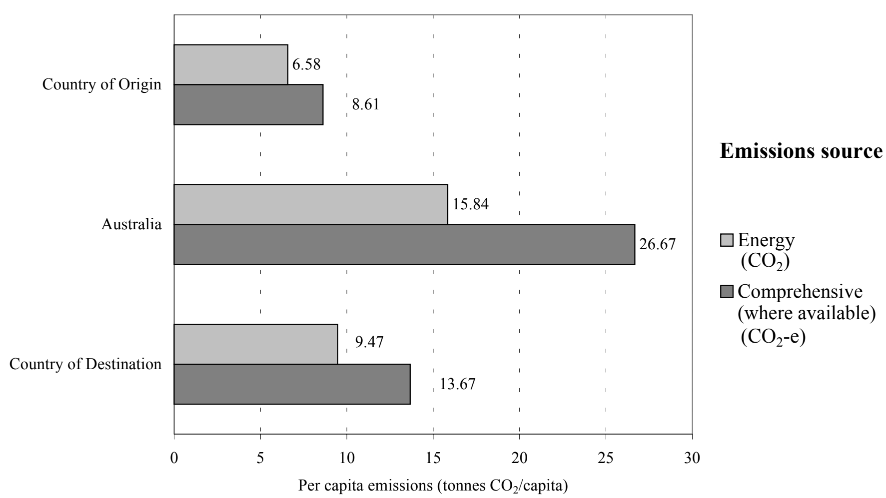
The weighted average of per capita emissions for immigrants to Australia and emigrants from Australia are each shown at the bottom of Tables 2 and 3. They are compared with per capita emissions for Australia in Figure 9. It is apparent that emissions per person in the countries from which immigrants to Australia are sourced are less than half (42 per cent) 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 per cent) of those in Australia. Using energy-related emissions only, average per capita emissions in the countries of destination are 60 per cent 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 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 9 emerge as an accurate estimate of the change in global emissions associated with migration to Australia.[14]

The question naturally arises of whether immigrants to Australia do actually emit as much as the average Australian resident when they take up residence,

Figure 9: Weighted mean per capita CO_2 emissions, Australia, countries of origin and countries of destination, 1995



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).[16] Per capita energy-related emissions are closely associated with consumption of goods and services, particularly of fuel and power, but also those that require large 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.[17] 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. While the situation has some interesting variations, overall overseas-born Australians tend to consume only slightly less of these goods than Australian-born citizens.

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 household where spending is much less — $4.64 per person on fuel and power and $26.11 per person on transport. Clearly, some of this difference 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 per cent of the current immigration intake,[18] are likely to be the more affluent citizens of a country on average, while unskilled family-reunion immigrants or

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: See Footnote 2

refugees (making up the remainder) are likely to be less affluent. 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.

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 above (on the determinants of emissions growth) 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.[19] 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.

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.[20] 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 at the high end of feasible scenarios.[21] In addition, we allow the fertility rate to vary, taking a value of either 1.6 (low fertility) or 1.75 (high fertility). Together, these variables give six population growth scenarios through to 2020 as set out in Table 5. The population paths under the various scenarios are shown in Figure 10.

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

Table 5: Population projection scenarios

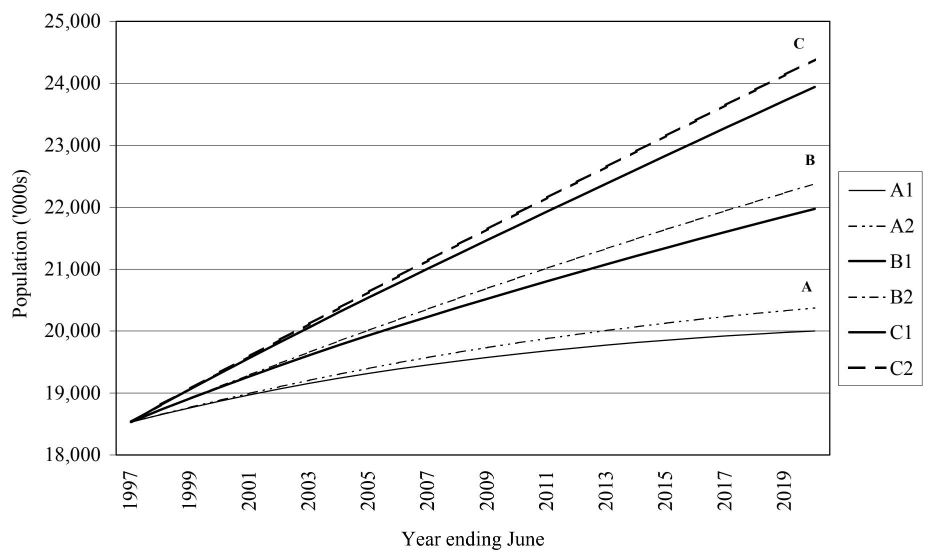
Net immigration	Fertility rate	
	1.6	1.75
0	A1	A2
70,000	B1	B2
140,000	C1	C2

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, and 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.[22] The ABARE model is not designed to investigate the impact of different population growth scenarios, and thus incorporates only one scenario, described as Scenario B2 in Figure 10, that is net immigration of 70,000 with a high level of fertility.[23] 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.[24] 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. The ABARE model also depends heavily on a biannual survey of energy consumption by

Figure 10: Population under different fertility and migration scenarios, 1997-2020



the 5,300 largest energy consumers in Australia (to cover the mining and manufacturing sectors).[25] The survey respondents' implicit assumptions about population and economic growth are embodied in the results of this survey.

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 sectors are then aggregated to produce a whole-of-economy estimate of energy use and emissions dependent on population.[26]

Briefly, population 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. The factors influencing energy demand in each of the sectors are shown in Table 6.

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.

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 11. Depending on Australia's population policy decisions, population growth is expected to lead to total energy-related

Table 6: Summary of assumptions for energy use projections

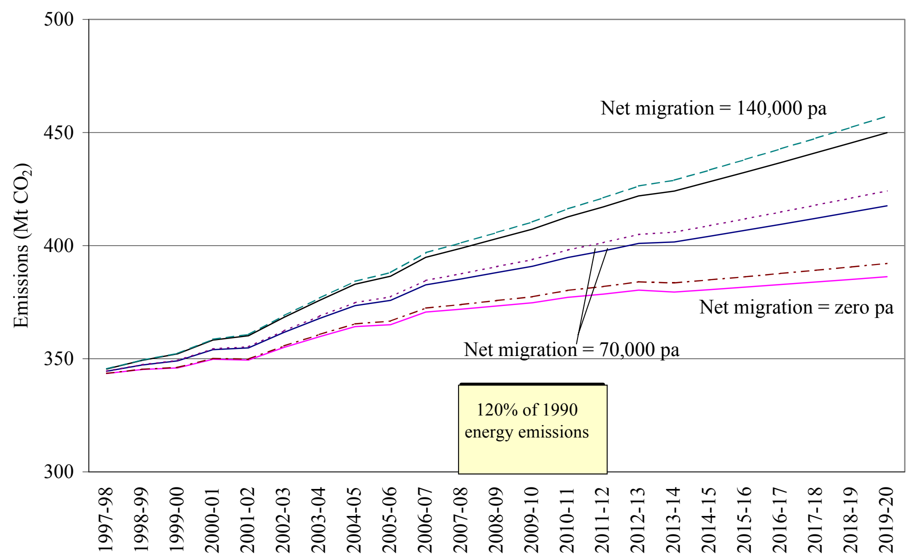
Sector	Energy use depends on:	Influenced by population growth?
Agriculture	Export demand	No
Mining	Export demand	No
Manufacturing	Export demand and domestic demand	Yes (domestic)
Construction	GDP growth	Yes (via GDP/cap)
Commercial	GDP growth	Yes (via GDP/cap)
Road passenger transport	Population, car 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)

emissions of between 385 and 455 Mt CO_2 by 2020. These are 37 per cent and 62 per cent above the 1990 level of energy-related emissions, respectively. At the extreme, 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).

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

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. 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 per cent renewables policy in the electricity

Figure 11: Energy-related CO_2 emissions under various population scenarios, 1997-2020



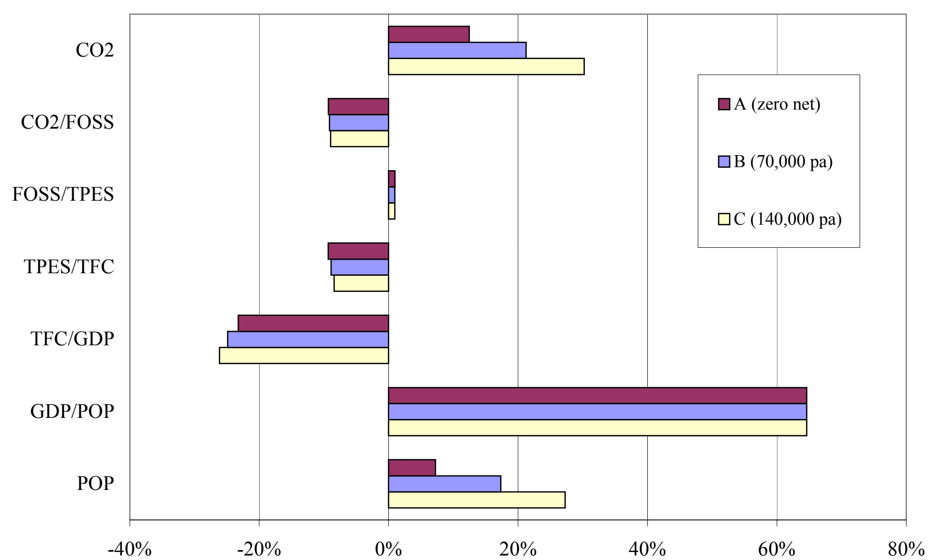
sector. Roughly speaking, therefore, one might say that a decision to adopt a policy of high rather than low net immigration would require two or three two per cent renewables policies to offset the consequent increase in emissions.

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 population scenarios. Changes in CO_2/FOSS and FOSS/TPES within each sector are given, but relative sectoral energy usage is influenced by population. This enables population to have some influence on economy-wide emissions per unit of fossil fuel used (CO_2/FOSS) and the share of fossil fuel in energy supply (FOSS/TPES). 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 projections independent of population. 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 12. The figure shows that population growth and increased GDP per capita are the factors driving increased energy-related emissions under all population projections. However, reduced energy-intensity of economic activity (TFC/GDP), improved conversion efficiency (TPES/TFC) and reduced CO_2 intensity of fossil fuels (CO_2/FOSS) 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-

Figure 12: Contributions to growth in energy-related CO_2 emissions under population projections, 1997-2020 (fertility = 1.6)



related emissions. Figure 12 helps to illustrate what Australia must do to restrict emissions if economic growth continues as projected. The principal policy options 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.

SOME POLICY IMPLICATIONS

The results of the model indicate that various feasible population scenarios have significantly different impacts 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 per cent 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 six per cent 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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5 *Key world energy statistics*, International Energy Agency, Paris, 1997

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7 Turton and Hamilton, op.cit.

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9 IEA, 1998, op. cit.

10 For more discussion of the method and the data see Turton and Hamilton, op. cit., Appendices 3 and 4.

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

12 This increase is probably a result of increased energy use overall, without a similar increase in hydroelectric capacity.

13 More detailed data sets are reported in Turton and Hamilton, op. cit., Appendix 5.

14 See ibid., Appendix 6 for more detail on the arguments and the evidence for this statement. One key fact is that the greenhouse gas emissions embodied in Australia's exports are about the same as the emissions embodied in Australia's imports — 56 Mt compared to 53 Mt, or around 3 tonnes/capita in 1989-90 — according to the Bureau of Industry Economics, *Greenhouse Gas Abatement and Burden Sharing*, Research Report 66, Australian Government Publishing Service, Canberra, 1995, p. 21

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27 See C. Hamilton and L. Vellen, 'Land-use change in Australia and the Kyoto Protocol', *Environmental Science and Policy* 2, 1999, pp. 145-152. For consistency, the 120% target in Figure 11 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 and aviation is included in ABARE, but not NGGI).

THE END