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Comparison of emission sources and emission trends among OECD countries

A report prepared for

the Australian Academy of Technological Sciences and Engineering

by

Clive Hamilton
Executive Director
The Australia Institute

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Abbreviations

CH4	methane
CO2	carbon dioxide
N2O	nitrous oxide
t	metric tons
TFC	total final consumption (of energy)
TJ	terajoule
toe	tonnes of oil equivalent
TPES	total primary energy supply

Summary

This study is an analysis of the structure and causes of greenhouse gas emissions in Australia compared to a number of other OECD countries. While most of the detailed analysis refers to energy-related carbon dioxide emissions, some important results emerge from a comparison of total emissions derived from a number of national greenhouse gas inventories. Total emissions include carbon dioxide (from both energy and non-energy related sources), methane and nitrous oxide.

The principal result to emerge from the statistical analysis is that Australia's emissions of greenhouse gases are very high compared to other OECD countries. Total emissions per unit of GDP in 1990 were 1.92 tonnes of CO_2 equivalent per US$1000 of GDP. The equivalent figure for the USA was 1.04 and for Canada 0.99.

Australia's relatively poor position has become substantially worse over the last two decades. Over the 1987-1992 period, Australia's energy-related CO_2 emissions grew much more than the OECD average -- more than 13 per cent compared to less than 5 per cent for the OECD as a whole. Decomposition analysis reveals that the growth in emissions in Australia has been due principally to population growth and growth in output per capita. Economic growth was also high in OECD countries but the effect on emissions was offset by a large fall in fuel consumption per unit of output.

Contrary to the usual view that Australia has high emissions partly because of the dispersion of its population, the contribution of the transport sector to Australian emissions is a little below the OECD average. In addition, the belief that Australia is disproportionately dependent on energy-intensive industry is not borne out by the figures. While the non-ferrous metals sector in Australia accounts for a much larger share of industrial CO_2 emissions than in the other countries reported, the other countries have a much larger share due to the energy-intensive chemicals industry.

Australia's very high level of emissions per unit of GDP is in large measure due to the high level of CO_2 emissions arising from continued land clearing. In addition, methane emissions in Australia are very high by comparison with other OECD countries. The contribution of fuel combustion to total CO_2 emissions is relatively low in Australia (although Australia's CO_2 emissions from fuel combustion are high by OECD standards).

The results of this study suggest that equal policy emphasis should be placed on non-energy emissions. An end to land clearing and changes to livestock farming methods could have a large impact on emissions over time. The importance of land-use policies could be substantially enhanced by faster establishment of forest plantations.

I Introduction[1]

Australia's greenhouse response strategy is influenced by perceptions about the mix and sources of origin of emitting activities. It is often argued, for example, that the Australian economy is exceptional in its dependence of fossil fuel-intensive industries. This report provides a numerical analysis of the structure of greenhouse gas emissions in Australia compared to some other OECD countries.

The countries selected for comparison with Australia are Canada, USA, Germany, United Kingdom, Japan, Netherlands and OECD countries as a whole. These will be referred to as the study countries. They have been selected because they cover a broad range of characteristics that are relevant for comparative purposes. Due to lack of time and data, it has not been possible to compare Australia with developing countries.

Detailed comparison of Australian emissions with those of the study countries (by industry sector and over time) is possible in the case of energy-related CO_2 emissions because of the ready availability of energy data supplied over many years by the International Energy Agency of the OECD. Most of the analysis in this report is therefore confined to energy-related CO_2 emissions. Data for non-energy related CO_2 emissions and other greenhouse gas emissions (methane and nitrous oxide in particular) are much more difficult to obtain. It is necessary to rely on various national inventories. For comparisons of total emissions we have been able to draw on inventories for Australia, Canada, Germany, USA and Norway. As more national inventories become available, more comprehensive comparisons will become possible.

Section 2 of this report compares the sectoral composition of Australia's greenhouse gas emissions with those of some OECD countries. Section 3 examines and compares emissions (both energy-related and total) per capita and per unit of GDP, including trends in these ratios over time. Section 4 reports the results of a decomposition analysis of the factors behind changes in energy-related CO_2 emissions over time. The last section draws some conclusions and points to some of the implications of the statistical analysis for greenhouse policy.

Analysis of greenhouse gas emissions is very sensitive to the accuracy of the data employed. In the case of energy-related CO_2 emissions we can have considerable confidence that the emissions data are reasonably accurate. This is because the International Energy Agency has been collecting national figures for OECD countries for many years and because the CO_2 emissions from the various fossil fuels are well-known and fixed.

In the cases of the other greenhouse gases and non-energy related carbon dioxide the situation is quite different. Carbon emissions from changes in land use and forestry are quite uncertain and fraught with measurement difficulties. There is also a great deal of uncertainty about emissions of methane and nitrous oxide from various sources including enteric fermentation in cattle and emissions from waste sites. There remains

[1] Research assistance from Rebecca Rodgers is gratefully acknowledged. Dr Hugh Saddler has provided invaluable advice on the energy statistics.

some uncertainty in converting measures of methane and nitrous oxide emissions into CO_2 equivalents through the application of global warming potentials. In comparing total emissions, therefore, one must be aware of potential differences in treating and measuring emissions in various national inventories.

II Total emissions and sectoral composition of emissions

Table 1 shows the energy-related CO_2 emissions by sector for a selection of OECD countries for 1992. They have been calculated from energy consumption statistics combined with emissions factors applied to each type of fossil fuel. Chart 1 shows the shares of the major economic sectors in total energy-related CO_2 emissions for some of the study countries. Chart 2 breaks down the emissions from the industry sector into four major emitting sub-sectors -- iron and steel, non-ferrous metals, chemicals and other. It is not possible to show this industry breakdown for the USA (and thus for the OECD as a whole) due to lack of data.

Table 1 CO_2 emissions by sector for selected OECD countries, 1992 (Mt CO_2) (a)

	Australia	OECD	Canada	USA	Germany	UK	Japan	Nether-lands
Industry (b)	101.15	3519.06	143.19	1516.27	345.99	170.06	530.01	66.3
Iron and steel	11.56		18.19		63.39	24.73	134.08	8.13
Non-ferrous metals	38.78		13.27		16.65	6.63	10.46	2.92
Chemicals	10.42		40.64		115.77	47.5	130.25	38.53
Other industry	40.39		71.09		150.18	91.2	255.31	16.72
Transport	72.63	2955.33	136.94	1529.12	199.23	148.7	272.83	35.54
Agriculture	5.98	171.52	12.47	46.43	15.64	5.48	22.29	9.24
Services	30.85	1343.39	59.39	799.05	131.81	78.12	77.63	13.05
Residential	44.76	1965.49	70.41	975.43	216.92	151.52	158.62	29.23
Total	255.37	9954.79	422.4	4866.3	909.59	553.88	1061.38	153.36

a. Energy-related CO2 emissions
only
b. Breakdown of industry not available for USA and thus
OECD.
Source: Energy data from IEA , *Energy Balances of OECD Countries 1991-1992* (OECD, 1994). Emissions factors are from Federal Environment Ministry, *Environment Policy: Climate Protection in Germany,* National Report of the Federal Republic of Germany (1993?), Table 3.18. The factors used are; coal 94 t/TJ; crude oil 74 t/TJ; petroleum products 75 t/TJ; gas 56 t/TJ

Chart 1 CO2 emissions by sector in selected OECD countries, 1992 (%)

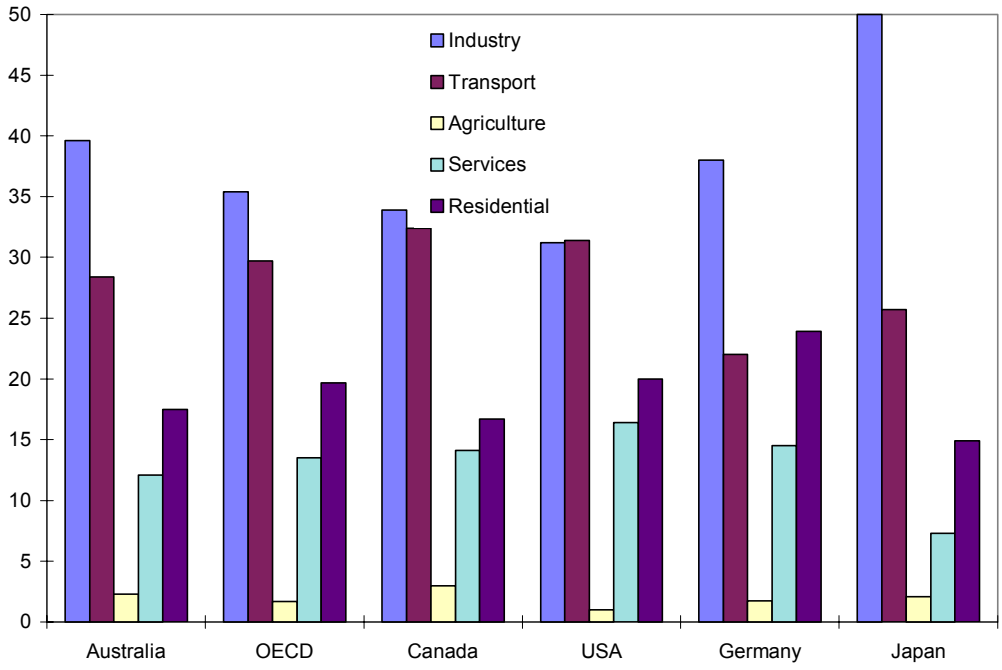
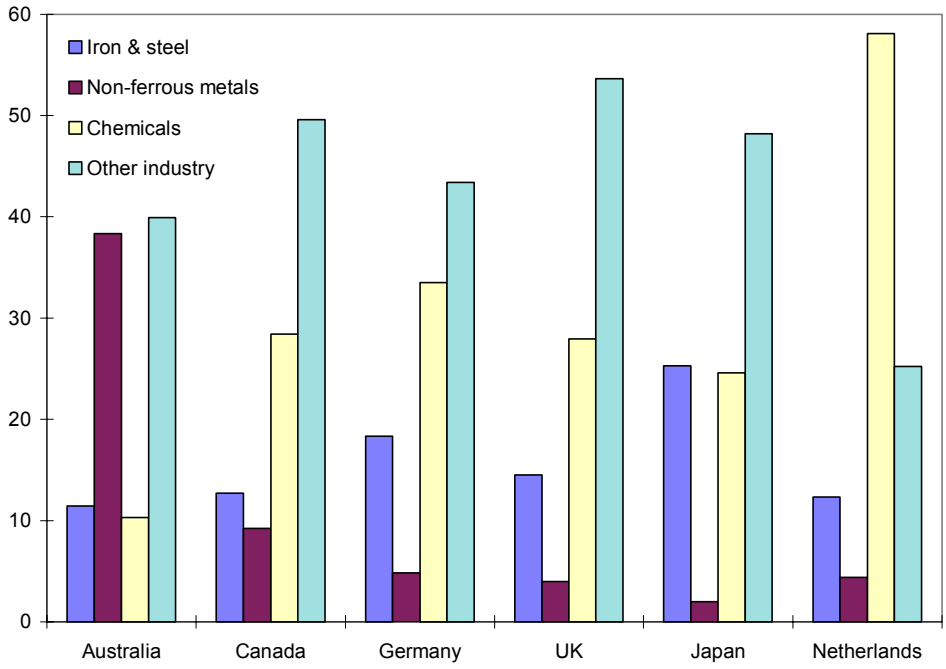


Chart 2 Industry CO2 emissions by sub-sector in selected OECD countries, 1992 (%)



The following observations can be made from Charts 1 and 2 with respect to energy-related CO_2 emissions:

- the sectoral composition of Australia's emissions is close to the OECD average, although the share of industry is slightly higher. Japan's industry share is atypically high;

- the contribution of the transport sector to Australian emissions is a little below the OECD average. This is contrary to the usual view that Australia is particularly dependent on transport;

- within the industry sector, the composition of emissions in Australia seems to be atypical. The non-ferrous metals sector in Australia accounts for a much larger share than in the other countries reported. The other countries, however, have a much larger share due to the chemicals industry; and

- the share of 'other industry' is approximately the same as in other countries so that the share of energy-intensive industries in emissions is not disproportionately high in Australia.

The energy-related CO_2 emissions of Table 1 have been calculated by applying emissions factors to the consumption of the various fossil fuels used. The factors used are 94 t/TJ (3.92 t/toe) for coal (an average of grades), 74 t/TJ (3.10 t/toe) for crude oil, 75 t/TJ (3.14 t/toe) for petroleum products and 56 t/TJ (2.34 t/toe) for natural gas. In calculating emissions for each sector it was necessary to attribute to each sector the emissions due to that sector's electricity consumption. To do this it was first necessary to calculate the emissions from the electricity sectors in each of the study countries. Table 2 reports the mean CO_2 emissions from the electricity sectors in each country. High-emissions countries like Australia depend heavily on high-emitting fuels, especially coal. Canada's mean emissions are low because of its heavy dependence on hydroelectric and nuclear power. Japan depends on nuclear power and, among its fossil fuels, relies heavily on gas.

Turning now to total greenhouse gas emissions including non-energy related CO_2 emissions and emissions of other gases (methane and nitrous oxide), we can examine the composition of total emissions by greenhouse gas and by source of origin. Full details of emissions in the countries for which data are available (Australia, Canada, Germany, USA and Norway) are contained in Appendix Table A1. Table 3 summarises Appendix Table A1 showing major sources of total emissions.

Table 2 Average CO_2 emissions per unit of electricity production in selected OECD countries, 1992 (t CO_2/toe electricity)

Australia	11.18
OECD	6.35
Canada	2.79
USA	7.83
Germany	8.72
Japan	4.78
United Kingdom	8.24
Netherlands	6.46

Table 3 Total emissions by major source in selected OECD countries, 1990 (CO_2 equivalents)

	Australia	**Canada**	**Germany**	**USA**	**Norway**
Total net emissions	*568366*	*565530*	*1221010*	*5723159*	*44863*
All energy	305222	468940	1054900	5181606	29153
Industrial processes	7652	41227	53950	76230	8759
Solvents	0	0	0	0	0
Agriculture	86625	24190	64800	240203	3555
Land use change & forestry	139652	1088	0	0	0
Waste	29215	30085	47360	225120	3396

Note: CH_4 and N_2O are converted to Global Warming Potentials using the factors 21 and 290 respectively, as per the Australian inventory (Department of Environment, Sport and Territories, *National Greenhouse Gas Inventory, 1988 and 1990* (Australia, 1994), Table 4).
Source: Appendix Table A1

Chart 3 shows the sources of origin of total emissions by sector while Chart 4 shows the shares of the three greenhouse gases in total emissions in 1990. It is apparent from the charts that:

- the contribution of the energy sectors to total emissions in Australia is low by comparison with the other countries, while the contributions of land use change and forestry and the agricultural industries are very high by comparison; and

- the share of CO_2 in total emissions is relatively low in Australia while our share of methane emissions (CH_4) is high. This is due to the relative importance of the pastoral industry.

Chart 3 Total emissions by sector of origin for selected OECD countries, 1990 (%)

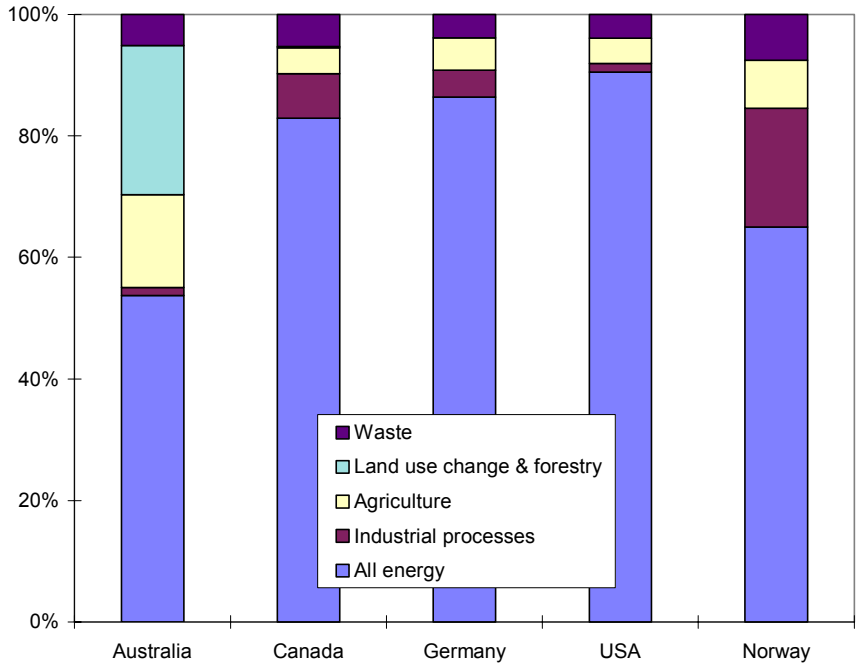
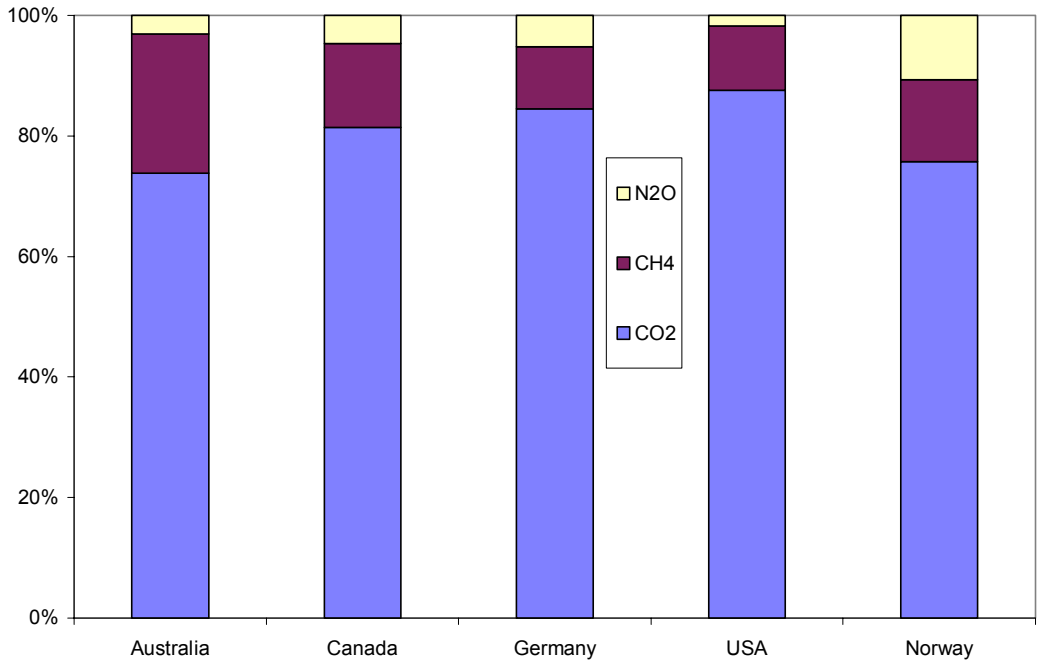


Chart 4 Total emissions by greenhouse gas for selected OECD countries, 1990 (%)



III Emissions per capita and per unit of output

In this section we present and examine the data on emissions per capita and per unit of GDP, including trends in these variables, for several OECD countries. Once again the data on energy-related CO_2 emissions are more accurate and more complete than data on other greenhouse gases. Table 4 presents some basic comparative data on total primary energy supplies (TPES) and energy-related CO_2 emissions for the study countries. Charts 5 and 6 show comparisons of TPES and CO_2 emissions per capita and TPES and CO_2 emissions per unit of GDP respectively. Table 4 and Charts 5 and 6 indicate the following:

- Australia's energy-related CO_2 emissions *per capita* are significantly higher than the OECD average, but they are lower than those of the USA and Canada. We will see, however, that this is no longer the case when account is taken of all emissions;

- Australia's energy-related emissions *per unit of GDP* are 66 per cent higher than the OECD average and higher than those of the USA and Canada, usually seen as high-emissions countries.

Australia's high level of emissions per unit of GDP is in part due to a higher level of energy consumption per capita and a higher level of emissions per unit of energy consumed (3.07 t CO_2/toe for Australia compared to 2.42 t CO2/toe for the OECD).

Table 4 Energy consumption and energy-related CO_2 emissions for selected countries, 1992

	Australia	OECD	Canada	USA	Germany	UK	Japan	Nether-lands
TPES (Mtoe)	88.8	4196.3	216.3	1984.1	340.3	216.2	451.1	68.8
CO2 emissions (Mt CO2) (a)	272.6	10169.0	443.3	4917.1	913.3	577.2	1099.3	165.7
TPES/capita (toe/person)	5.06	4.84	7.88	7.78	4.22	3.74	3.63	4.53
TPES/GDP (toe/US$1000)	0.30	0.23	0.38	0.34	0.19	0.21	0.12	0.23
CO2/capita (t CO2/person)	15.55	11.73	16.16	19.28	11.34	9.98	8.84	10.92
CO2/GDP (t CO2/US$1000)	0.93	0.56	0.79	0.83	0.51	0.55	0.30	0.54

Sources: TPES and CO_2 emissions data are from IEA, *Climate Change Policy Initiatives 1994 Update* (OECD, 1994). GDP figures are from World Bank, *World Tables 1994*

Chart 5 TPES and CO2 emissions per capita in selected OECD countries, 1992

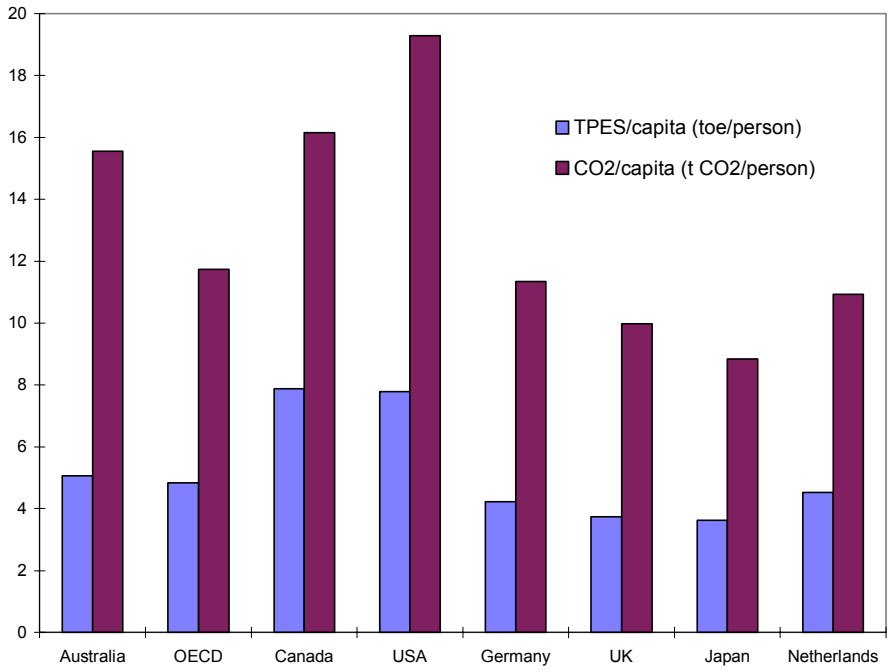
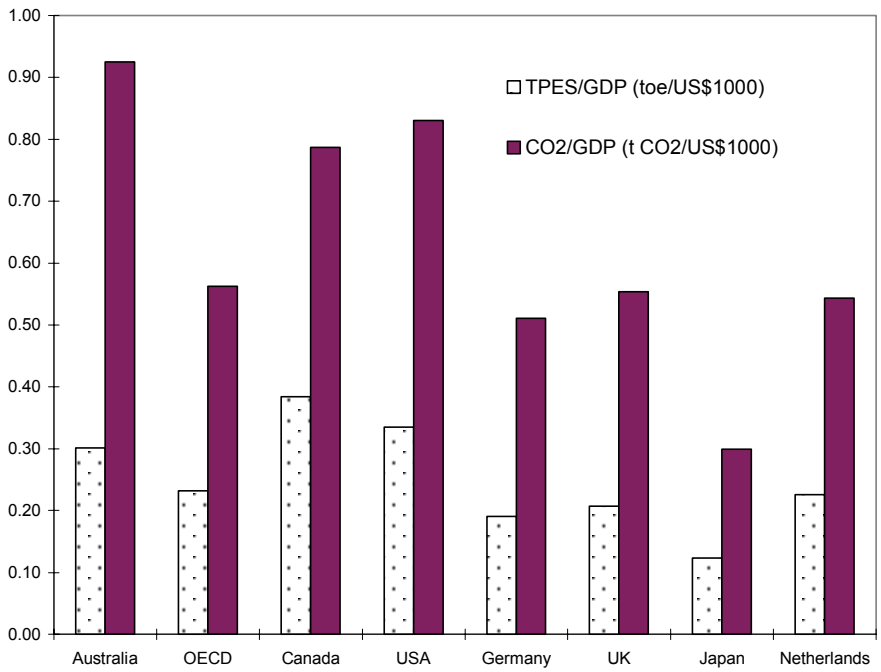


Chart 6 TPES and CO2 emissions per unit of GDP in selected countries, 1992



Trends in energy consumption are a useful guide to the emissions-intensity of an economy. Table 5 shows total primary energy supply (TPES) per capita and per unit of GDP for a number of OECD countries over the period 1970-1992. Chart 7 shows the trends in TPES per unit of GDP over the period.

Table 5 TPES per capita and per unit of GDP for selected OECD countries, 1970-1992

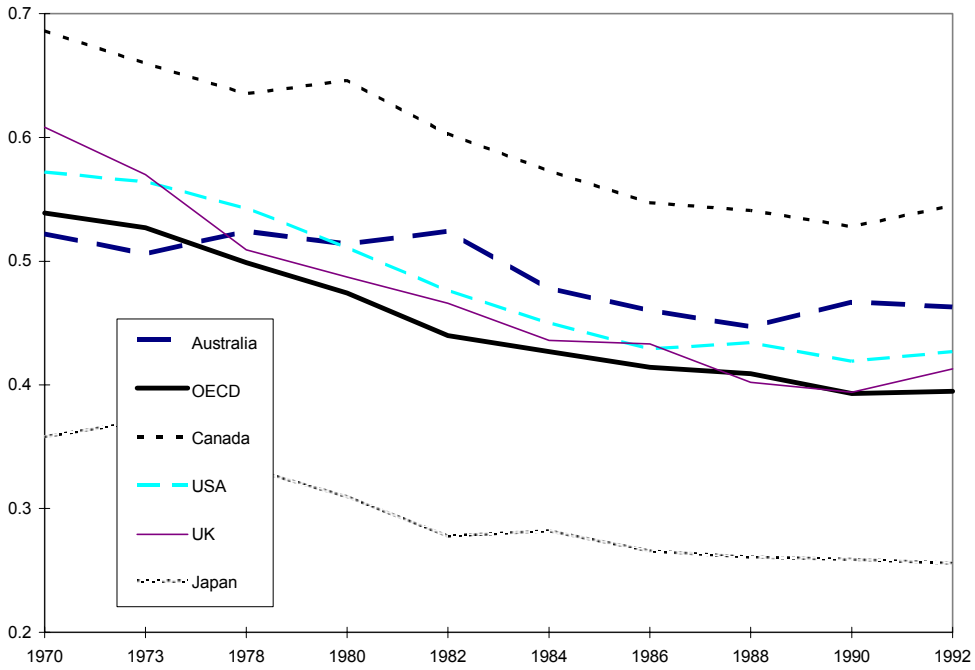
TPES/capita (toe/person)

	1970	1973	1978	1980	1982	1984	1986	1988	1990	1992
Australia	4.00	4.27	4.68	4.79	4.87	4.70	4.69	4.83	5.17	5.06
OECD	4.18	4.62	4.78	4.66	4.33	4.46	4.54	4.76	4.79	4.84
Canada	6.19	6.94	7.71	8.08	7.40	7.60	7.74	8.17	7.95	7.88
USA	7.53	8.13	8.42	7.91	7.22	7.40	7.33	7.80	7.68	7.78
Germany	3.92	4.28	4.54	4.59	4.28	4.47	4.64	4.68	4.46	4.22
UK	3.73	3.93	3.73	3.57	3.43	3.41	3.64	3.69	3.69	3.74
Japan	2.48	2.98	2.96	2.97	2.78	3.01	3.02	3.24	3.50	3.63
Netherlands	3.78	4.65	4.70	4.60	3.83	4.18	4.36	4.35	4.41	4.53
TPES/GDP (toe/1985 US$1000)										
Australia	0.522	0.506	0.524	0.514	0.524	0.478	0.460	0.447	0.467	0.463
OECD	0.539	0.527	0.499	0.474	0.440	0.427	0.414	0.409	0.393	0.395
Canada	0.686	0.660	0.635	0.646	0.603	0.573	0.547	0.541	0.528	0.545
USA	0.572	0.564	0.543	0.511	0.476	0.450	0.429	0.434	0.419	0.427
UK	0.608	0.570	0.509	0.487	0.466	0.436	0.433	0.402	0.394	0.413
Japan	0.358	0.371	0.333	0.310	0.278	0.282	0.266	0.261	0.259	0.256
Netherlands	0.539	0.606	0.555	0.534	0.459	0.483	0.483	0.470	0.443	0.446

Note: GDP figures for Germany not available
Source: IEA, *Energy Balances of OECD Countries 1991-92* (OECD 1994)

Whereas in the early 1970s Australia's energy consumption per unit of GDP was lower than the OECD average, now it is significantly higher. It is higher than that of the USA, generally seen as one of the most energy-intensive economies. In per capita terms, while energy consumption increased by 16 per cent in the OECD, it increased by 27 per cent in Australia. It is thus apparent that Australia's energy consumption per unit of economic activity is higher than the OECD average because it has not declined as quickly over the 20 years to 1992. In the late 1980s and early 1990s, while energy consumption per unit of GDP contined to fall in the OECD as a whole, it was static or rising in Australia.

Chart 7 TPES per unit of GDP for selected OECD countries, 1970-1992 (toe/1985US$1000)



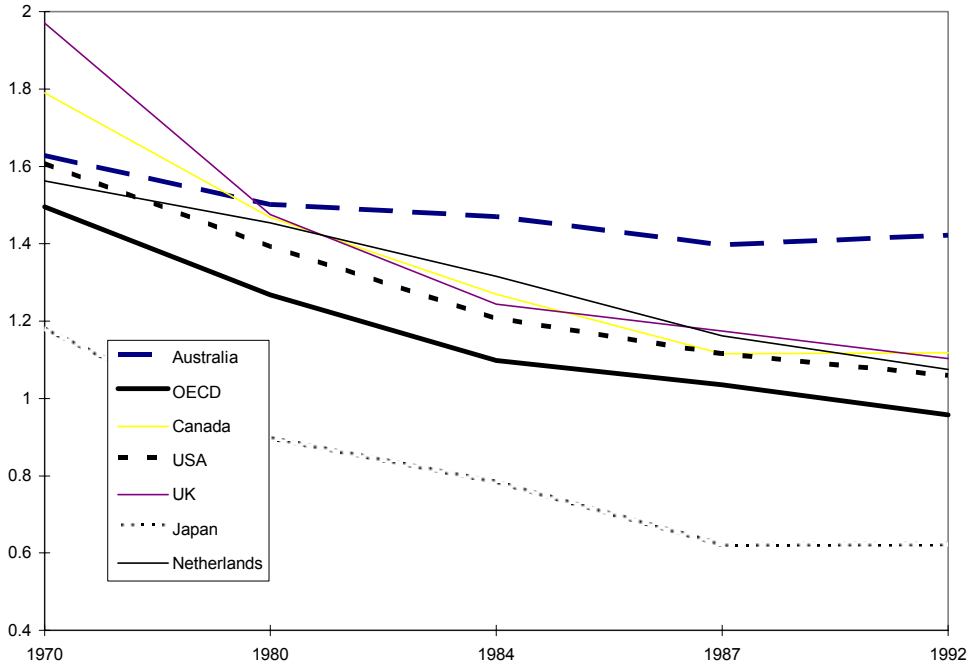
Next we examine energy-related CO_2 emissions per unit of GDP over the period 1970-1992. The detailed figures are contained in Table 6 and the trends are summarised in Chart 8. (Note that the time axis is not at a consistent scale.)

Table 6 Energy-related CO_2 emissions per unit of GDP for selected OECD countries, 1970-1992 (t CO_2/1985 US$1000)

	1970	1980	1984	1987	1992
Australia	1.63	1.50	1.47	1.40	1.42
OECD	1.49	1.27	1.10	1.04	0.96
Canada	1.79	1.47	1.27	1.12	1.12
USA	1.61	1.39	1.21	1.12	1.06
UK	1.97	1.48	1.24	1.17	1.10
Japan	1.18	0.90	0.78	0.62	0.62
Netherlands	1.56	1.45	1.32	1.16	1.07

Source: same as Table 1.

Chart 8 Energy-related CO2 emissions per unit of GDP for selected OECD countries, 1970-1992 (t CO2/1985US$1000)



Between 1970 and 1992 Australia's energy-related CO_2 emissions per unit of GDP fell by 13 per cent while those of all OECD countries fell by 36 per cent. In the USA emissions per unit of GDP fell by 34 per cent and in Canada by 38 per cent over the 22 year period. Australia has thus had a very poor performance in this regard.

Turning to total emissions, that is including non-energy related CO_2 emissions and emissions of methane and nitrous oxide, we can combine the data in Appendix Table A1 drawn from various national inventories with figures on population and GDP in each country. Table 7 shows total emissions by source in 1990 for the countries for which data are available. Table 8 shows total emissions by greenhouse gas. Drawing on these tables, Chart 9 shows total emissions per unit of GDP by source while Chart 10 shows total emissions per unit of GDP by greenhouse gas. The results are remarkable. They show that Australia's total emissions per unit of output are very high, standing at 1.92 tonnes of CO_2 equivalent per US$1000 of GDP. For the USA the figure is 1.04 and for Canada 0.99. The reasons for Australia's very high figure can be seen from Chart 9. There are three main factors:

- Australia's relatively high level of non-energy related CO_2 emissions due to land clearing;
- Australia's high level of methane emissions as a result of the large share of the livestock industry in the national economy. Australia's methane emissions per unit of GDP are three times higher than the other countries reported; and
- Australia's high level of energy-related CO_2 emissions per unit of output.

Table 7 Total emissions per unit of GDP by source for selected OECD countries, 1990 (t CO_2/US$1000)

	Australia	Canada	Germany	USA	Norway
Total net emissions	1.92	0.99	0.81	1.04	0.43
All energy	1.03	0.82	0.70	0.94	0.28
Industrial processes	0.03	0.07	0.04	0.01	0.08
Agriculture	0.29	0.04	0.04	0.04	0.03
Land use change & forestry	0.47	0.00	0.00	0.00	0.00
Waste	0.10	0.05	0.03	0.04	0.03

Table 8 Total emissions per unit of GDP by greenhouse gas for selected OECD countries, 1990 (t CO_2/US$1000)

	Australia	**Canada**	**Germany**	**USA**	**Norway**
CO2	1.42	0.81	0.69	0.91	0.32
CH4	0.44	0.14	0.08	0.11	0.06
N2O	0.06	0.05	0.04	0.02	0.05
Total	1.92	0.99	0.81	1.04	0.43

Chart 9 Total emissions per unit of GDP by source in selected countries, 1990 (t CO2 equivalent/US$1000)

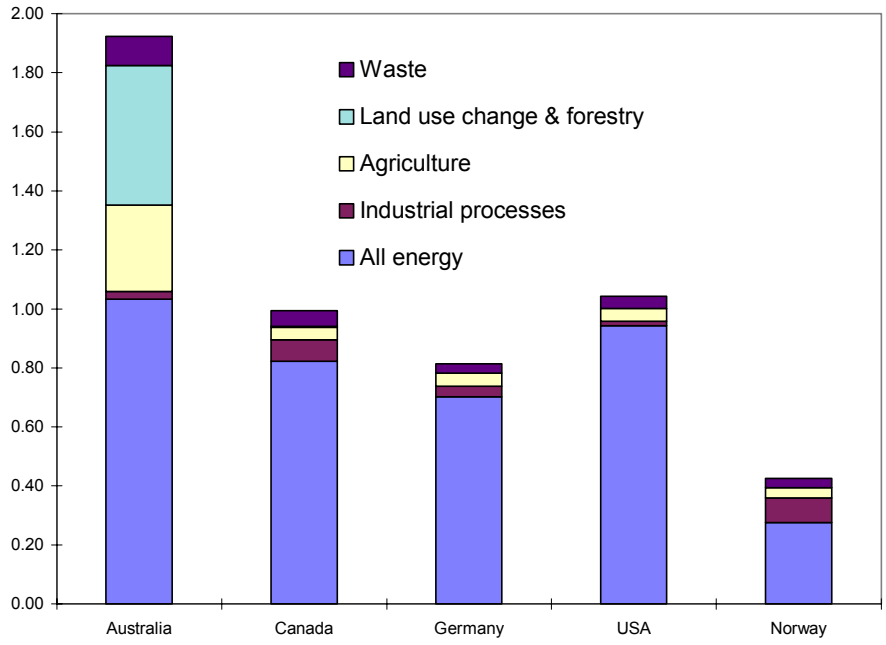
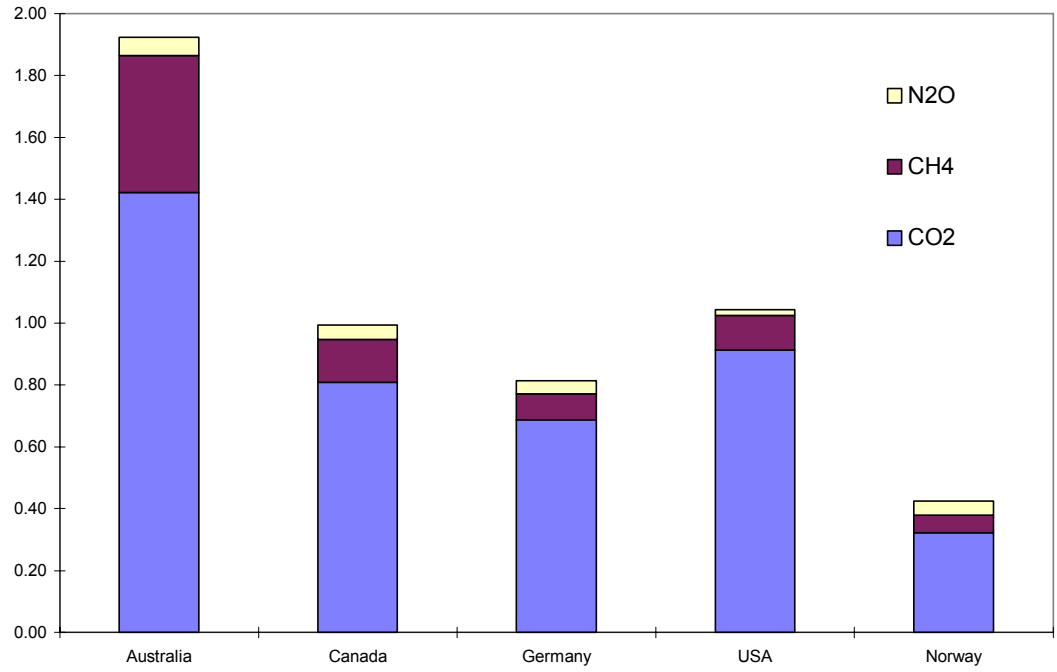


Chart 10 Total emissions per unit of GDP by greenhouse gas in selected countries, 1990 (t CO2 equivalent/US$1000)



IV Decomposition analysis

We have seen that Australia's emissions of greenhouse gases have grown faster than in most other OECD countries. The growth of emissions can be broken down statistically to determine which factors are causing emissions growth and which are reducing emissions. In the case of energy-related CO_2 emissions, we can break down emissions in each year as follows:

CO_2 = CO2 FOSS TPES TFC GDP POP
FOSS TPES TFC GDP POP

where:

CO_2 = energy-related CO_2 emissions

FOSS = fossil fuel consumption

TPES = total primary energy supply

TFC = total final consumption of energy

GDP = gross domestic product

POP = population.

The factors can be defined and interpreted as follows:

CO_2/FOSS is the CO_2 intensity of fossil fuel combustion, reflecting both efficiency of combustion and the mix of fuels;

FOSS/TPES is the fossil fuel intensity of total energy consumption;

TPES/TFC is the ratio of primary to final energy, a measure of the efficiency of the energy industry in converting and delivering energy supplies[2] (i.e. mainly accounting for energy losses (waste heat) in electricity generation);

TFC/GDP is the energy intensity of economic activity, a factor that reflects both energy efficiency and changes in the structure of the economy;

GDP/POP is a measure of economic activity per capita.

By looking at the percentage changes in the variables between two years, we can calculate the contributions of each of the factors to the change in CO_2 emissions. The method of carrying out this calculation is described in Appendix 2.

Chart 11 compares the decomposition of changes in Australia's energy-related CO_2 emissions with those of the OECD for the period 1987-1992. Charts 12 and 13 show the decompositions for other OECD countries. Note that the scale is not the same in each of the charts. Note also that the percentage changes over a period are sensitive to the choice of end-years as consumption of fuels fluctuates with the business cycle.

Several observations can be made from the charts. Firstly, Australia's CO_2 emissions grew much more than the OECD average over the 1987-1992 period -- more than 13 per cent compared to less than 5 per cent for the OECD as a whole. Among the study countries only Japan had a higher growth of emissions. The growth in emissions in Australia was due principally to growth in population and growth in output per capita. Emissions due to growth in output per capita grew much faster in the OECD generally, but this effect was offset by a large fall in fuel consumption per unit of output (TFC/GDP), something that did not occur in Australia. The fall in fuel consumption per unit of output in the OECD could be due to greater energy efficiency.

Chart 14 shows the decomposition of changes in CO2 emissions in Australia and the OECD for the period 1980-87. Emissions grew by 15 per cent in Australia but fell by 2 per cent in the OECD as a whole. The difference appears to be due to a much larger increase in CO_2 emissions per unit of fossil fuels used in Australia and greater population growth in Australia. Both Australia and the OECD experienced large declines in fuel consumption per unit of GDP.

[2] Note that this estimate (TPES/TFC) will tend to be high in economies that have high FOSS/TPES because renewable energy sources are assumed to be 100% efficient whereas fossil fuels and nuclear power are between 30 and 50 per cent efficient.

Chart 11 CO2 decomposition, Australia and the OECD, 1987-1992 (%)

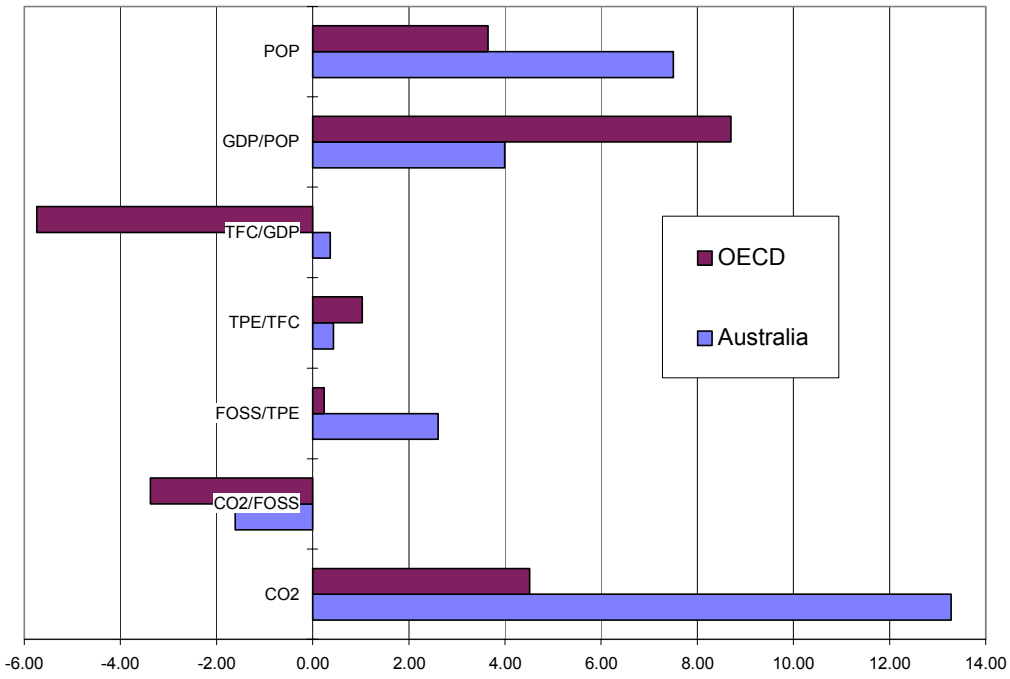


Chart 12 CO2 decomposition, Canada, USA and UK, 1987-1992 (%)

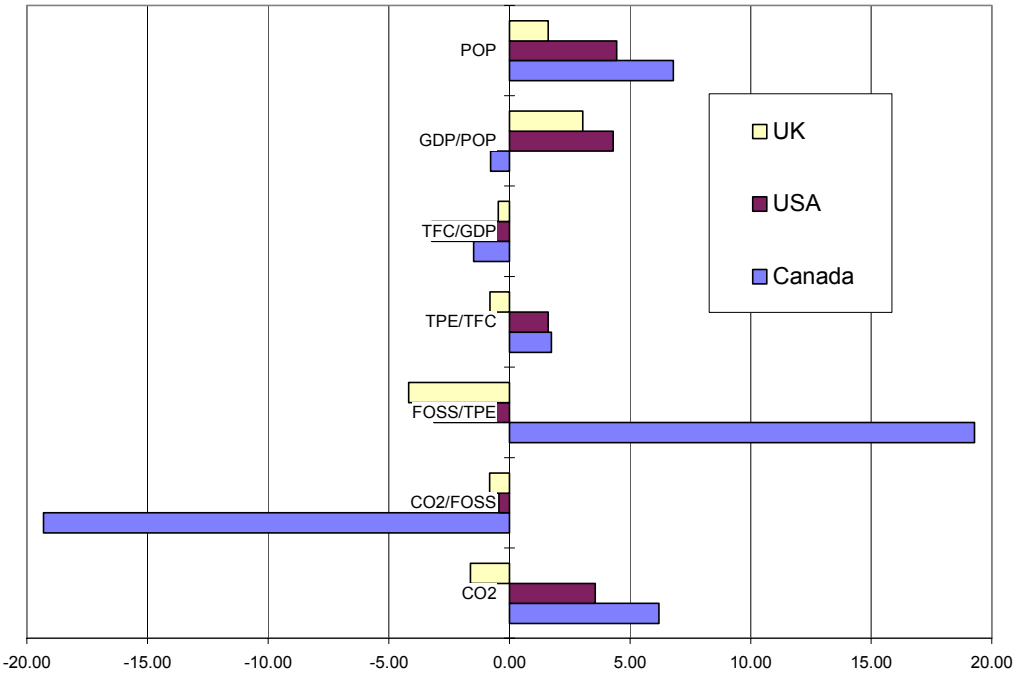


Chart 13 CO2 decomposition, Japan and the Netherlands, 1987-1992 (%)

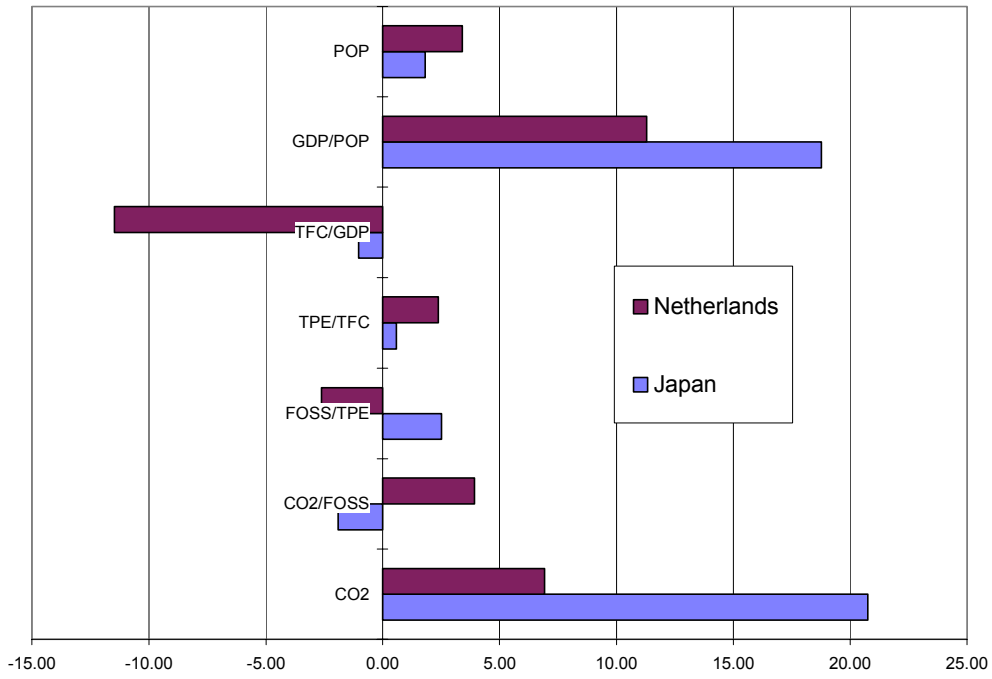
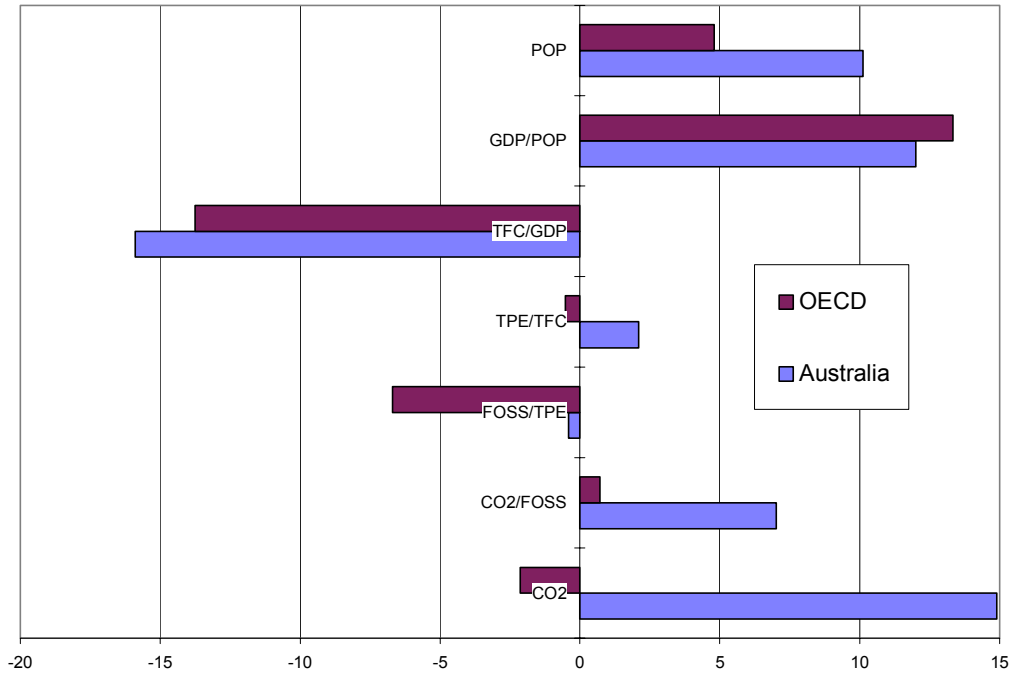


Chart 14 CO2 decomposition, Australia and the OECD, 1980-87 (%)



V Conclusions and some policy implications

The principal result to emerge from the statistical analysis of this study is that, however one looks at it, Australia's emissions of greenhouse gases are very high by OECD standards. Total emissions per unit of GDP are especially high, almost twice as high as the USA and Canada, countries considered to have high-emissions economies.

Australia's poor position appears to have become substantially worse over the last two decades. Over the 1987-1992 period, Australia's energy-related CO_2 emissions grew much more than the OECD average -- more than 13 per cent compared to less than 5 per cent for the OECD. The growth in emissions in Australia was due principally to growth in population and growth in output per capita. Economic growth was also high in OECD countries but the effect on emissions was offset by a large fall in fuel consumption per unit of output. Although Australia's energy consumption per unit of economic activity has declined over the last 20 years, it has not declined as fast as in the OECD as a whole -- Australia's CO_2 emissions per unit of GDP fell by 13 per cent while for the OECD it fell by 36 per cent. If current trends continue Australia's relative position will deteriorate further.

There are several important results relating to the industrial structure of emissions that have major implications for the formulation of greenhouse gas abatement policies. They include the following:

- contrary to the usual view that Australia has high emissions partly because of the dispersion of its population, the contribution of the transport sector to Australian emissions is a little below the OECD average;

- the non-ferrous metals sector in Australia accounts for a much larger share of industrial CO_2 emissions than in the other countries reported. The other countries, however, have a much larger share due to the chemicals industry; and

- over all, the share of energy-intensive industry is not disproportionately high in Australia.

There are two critical points in relation to the composition of total emissions in Australia:

- the share of CO_2 in total emissions is relatively low in Australia while our share of methane emissions is high. This is due to the relative importance of the livestock industry;

- the contribution of fuel combustion to total CO_2 emissions is relatively low in Australia by comparison with the other countries. This is due to the high level of CO_2 emissions arising from continued land clearing.

These results suggest two broad implications for policy measures to reduce greenhouse gas emissions. The first is that a greater emphasis should be placed on non-energy emissions. An end to land clearing and changes to livestock farming methods could have a large impact on emissions over time. However, ending land

clearing will have a slow cumulative impact on emissions as CO_2 is generally released from cleared land over several years. The importance of land use policies could be substantially enhanced by faster establishment of forest plantations.

The second broad policy implication relates to the impact of emissions reduction measures on Australian industry. The results indicate that Australia is not disproportionately dependent on fuel-intensive industries overall. While Australia has a relatively large non-ferrous metals sector, other OECD countries have large chemicals sectors.

Appendix 1

Data on Total Emissions for Selected OECD Countries 1990

Appendix 2

Method of Decomposing Changes in CO2 Emissions

For each year we have the equation

$$CO2 = \frac{CO2}{FOSS} \cdot \frac{FOSS}{TPES} \cdot \frac{TPES}{TFC} \cdot \frac{TFC}{GDP} \cdot \frac{GDP}{POP} \cdot POP$$

For ease of exposition we will write the equation for year 1 as

$C_1 = j_1.k_1.l_1.m_1.n_1.P_1$

and for year 2

$C_2 = j_2.k_2.l_2.m_2.n_2.P_2$

If we take logs of these then subtract year 1 from year 2 we obtain

$\ln C_2 - \ln C_1 = (\ln j_2 - \ln j_1) + (\ln k_2 - \ln k_1) + (\ln l_2 - \ln l_1) + (\ln m_2 - \ln m_1) + (\ln n_2 - \ln n_1) + (\ln P_2 - \ln P_1)$

This expression shows the percentage changes in each of the variables as required.

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Background Paper No. 1

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Clive Hamilton

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Australian Academy of Technological Sciences and Engineering

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