# The air and atmosphere

The atmosphere surrounding our planet is composed of a number of different gases, mostly nitrogen and oxygen, with traces of other gases, such as carbon dioxide, ozone, plus minute particles like dust. These gases each play a role in supporting life on earth, for example: oxygen is required to sustain living animals; a layer of ozone, some 15 to 30 kilometres above us in the stratosphere, shields us from harmful ultraviolet rays from the sun; and greenhouse gases, predominantly carbon dioxide, maintain the surface temperature of the earth at an average 15ºC. Some human activities change the nature of the atmosphere, impacting on air quality, the levels of UV radiation reaching the earth, and climate.

The commentary that follows comprises two subsections:

- Air quality: Air quality has direct impacts on human health and enjoyment of life, and is particularly an issue in urban areas. Ideally, a headline indicator would encapsulate all aspects of air quality, but pollution takes many forms and there is, as yet, no agreed way in which different pollutants could be combined into just one measure. The headline indicator considers urban air quality expressed as the concentration of fine particle pollutants in the atmosphere. Their distribution is monitored over time in all large cities and is a measure of the form of air pollution about which many health experts in Australia are most concerned. Other pollutants also have negative impacts. The highest one hour averages of sulfur dioxide in selected regional centres and the number of days when ozone concentrations exceeding guidelines in selected capital cities are also included as supplementary progress indicators. The commentary includes information about the impact of industrial activity and the growth in fossil-fuel dependent traffic on the air.

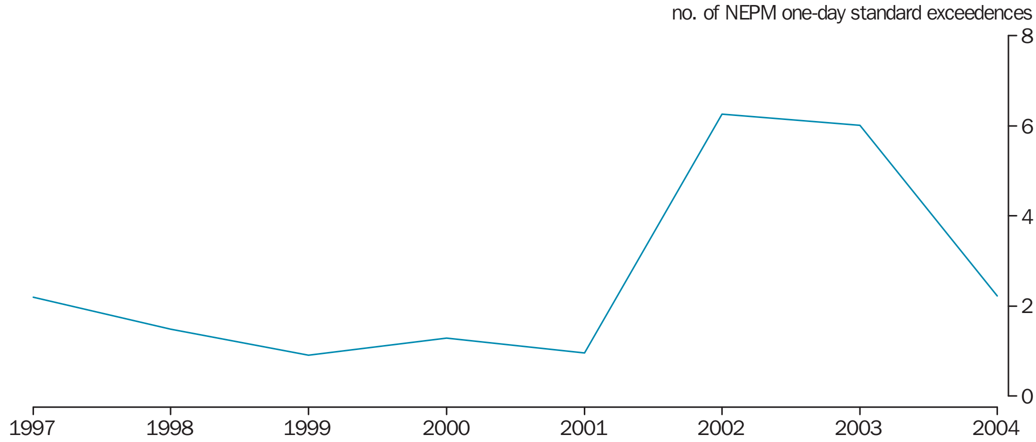
- Atmosphere: The atmosphere is an essential component of all ecological systems on Earth. Global warming and climate change are potential threats to biodiversity and to all ecosystems, economies and societies. Australia's net greenhouse gas emissions is the selected headline indicator. While Australian emissions are only a small contributor to the global emissions, our environment can be influenced by the actions of other countries, and we, in turn, can influence other countries' environments. The commentary also considers the important factors behind the growth in our emissions and considers these changes alongside the changes in per capita emissions and emissions per dollar of GDP. Renewable energy resources and the consumption of ozone depleting substances in Australia are also discussed.

The commentary and statistics that follow use a range of information from the Australian Bureau of Statistics and other sources. Three sources which we have used considerably are the National Environment Protection Council's ambient air quality measures, the National Pollutant Inventory database, and the National Greenhouse Gas Inventory (NGGI). The 2004 NGGI is scheduled for release in late May 2006. These are three of the most significant sources of detailed environmental data for Australia on air and atmosphere.

For this 2006 edition of MAP, the content of the Environment chapters was reviewed and some reorganisation of the chapters has occurred. Two key issues, the quality of our air and the Earth's atmosphere, were previously spread across two separate chapters (*The human environment* and *International environmental concerns*). These issues have now been brought together in this chapter on *The air and atmosphere,* along with their two headline indicators. The chapter on International Environmental concerns, which appeared in the 2004 edition of MAP, focussed exclusively on the issues of greenhouse gas emissions and climate change and has been completely subsumed into this new chapter. Some of the commentary in The Human environment, which did not relate to The Air and atmosphere, now appears in other areas of MAP 2006.

# The air and atmosphere: key points

**Urban air quality, days fine particle health standards were exceeded**




(a) Data are from representative sites in Sydney (Liverpool), Melbourne (Footscray), Brisbane (Rocklea), Perth (Duncraig) and Adelaide (Thebarton for 1997–2002 and Netley for 2003–2004), and have been combined in proportion to each city's population. (b) Number of days when the National Environment Protection Measures (NEPM) average daily PM10 standard is exceeded.

*Source: State environmental protection agencies, 2006*

Fine particle health standards were exceeded in the selected urban areas on average between one and two days each year between 1997 and 2004.

## The relationship of air quality to progress

Australians consistently rank air pollution as a major environmental concern. The state of our air is an important factor in the quality of life in Australian cities, where the main source of pollution is from motor vehicles (in regional centres industry and woodheaters have the largest impact). Poor air quality has a range of negative impacts: it can cause health problems, damage infrastructure, reduce crop yields and harm flora and fauna.

## About the headline indicator and its limitations: Urban air quality

Ideally, a headline indicator would encapsulate all aspects of air quality, but pollution takes many forms and there is, as yet, no agreed way in which different pollutants could be combined into just one measure. Fine particles and ozone are the air pollutants of concern in Australia, having peak concentrations at or above national air quality standards and showing no consistent downward trend in some major cities. For this reason, the headline indicator considers urban air quality based on the concentration of fine particles in the atmosphere.

Most pollutants are more common in urban and industrial areas than in rural Australia, and so the graph summarises data from Sydney, Melbourne, Adelaide, Perth and Brisbane. Meteorological conditions, for example still air, can slow down the removal of pollutants and increase the impacts of this pollution. In some regions of Australia, particularly during the cooler months, woodsmoke from woodheaters results in elevated particle levels. Further, high concentrations of fine particles from irregular events, such as forest fires, can obscure the longer trend in levels produced by regular sources, like car emissions.

## Air quality: Other indicators

Number of days when ozone concentrations exceed guidelines, selected capital cities; Highest one hour averages of $SO_2$, selected regional centres.

## Some differences within Australia

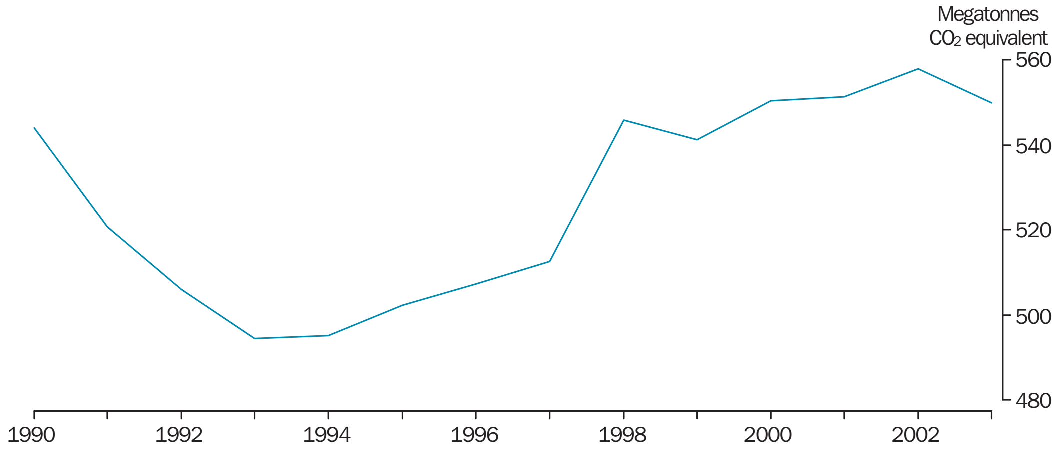
Different parts of the country experience different types and levels of air pollution, but air quality outside the major cities seems generally good, and levels of pollutants are generally well below actual or proposed standards.

## Links to other dimensions

See also the commentaries *Health, National income, The natural landscape,* and *Oceans and estuaries*.

# The air and atmosphere: key points

**Australia's net greenhouse gas emissions(a)**




(a) Kyoto-based estimates, expressed in millions of tonnes (megatonnes) of carbon dioxide equivalent.

*Source: Australian Greenhouse Office, National Greenhouse Gas Inventory 2003. The 2004 NGGI is scheduled for release in late May 2006.*

Under the Kyoto accounting provisions relating to Australia's internationally agreed target, Australia's net greenhouse gas emissions in 2003 totalled 550.0 Mt of carbon dioxide equivalent. Total net emissions were 1.1% (5.9Mt) higher in 2003 than in 1990.

### The relationship of the atmosphere to progress

Some of the things humans do change the nature of the atmosphere – impacting on air quality, the levels of UV radiation reaching the earth and the climate that all plants and animals depend on. Unlike air quality issues, which are generally localised, ozone depletion and climate change are global problems that the whole world contributes to, and feels the effect of.

The effects of global warming are very difficult to predict. Global warming could – if certain scenarios of the Intergovernmental Panel on Climate Change prove correct – have profound consequences for our economy and society (increasingly frequent and severe floods and rising sea levels, for instance, have the potential to cause damage and have significant consequences for low lying islands and coastal settlements). Australia's biodiversity and freshwater ecosystems might also be affected by climate change.

### About the headline indicator and its limitations: net Greenhouse gas emissions

The headline indicator assesses Australia's total net greenhouse gas emissions. Net emissions are estimated using information about total emissions, less any credits from forest sinks (the credits are estimates of how much carbon dioxide has been absorbed by new and expanding forests established in Australia since 1990).

### Atmosphere: Other indicators

$CO_2$-e emissions, total, per capita and per $GDP; Australia's greenhouse gas emissions for selected sectors, Carbon dioxide measurements, and Consumption of ozone depleting substances.

### Some differences within Australia

Climate change may have different impacts on different parts of Australia, but the regional impact of climate change is very difficult to predict.

### Links to other dimensions

See also the commentaries *National income, The natural landscape,* and *Productivity*.

# The air and atmosphere – Air quality

## Progress and the headline indicator

Poor air quality has a range of negative impacts: it can cause health problems, damage infrastructure, reduce crop yields and harm flora and fauna. Air pollution occurs both naturally and as a result of human activities. On occasion, natural events such as dust storms and bushfires can cause severe air pollution. Health effects from elevated levels of air pollution may be acute, when caused by short-term peaks, or chronic, from prolonged exposure to lower levels. A 2001 report estimated fine particle pollution had been linked to the deaths of up to 2,400 people a year in Australia, with an associated health cost of $17.2b.[1]

Australians consistently rank air pollution as a major environmental concern.[2] Ideally, a headline indicator would encapsulate all aspects of air quality. Pollution takes many forms and there is, as yet, no agreed way in which different pollutants could be combined into just one measure. Fine particles and ozone are the air pollutants of most concern in Australia, having peak concentrations at or above national air quality standards and showing no consistent downward trend in some major cities.[3] The headline indicator considers the concentration of fine particles in the atmosphere (see box), a measure of the form of air pollution about which many health experts in Australia are most concerned.[4]

The common air pollutants are found at higher levels in urban and industrial areas than in rural Australia. As there is little long-term information about air quality over much of Australia, the headline indicator graph summarises data from continuous air monitoring stations in Sydney, Melbourne, Adelaide, Perth and Brisbane.[5] It is important to note that daily changes in air quality depend on ambient conditions, like wind direction and the monitoring station's proximity to pollution sources. Further, high concentrations of fine particles from irregular events, such as forest fires, can obscure the longer trend in levels produced by regular sources, like car emissions.

Overall, air quality in Australia is relatively good and has generally improved during the 1990s. Fine particle health standards were exceeded in the selected urban areas on average between one and two days each year between 1997 and 2001. There was a rise in 2002 and 2003, mainly due to severe forest fires and dust storms around the Sydney and Melbourne areas which caused the National Environment Protection Measure (NEPM) goal to be exceed on 13 days in Sydney in 2002 and 10 days in Melbourne in 2003. The goal was also exceeded on seven days in Brisbane in 2002. Sydney and Brisbane recorded one and two day's exceedences, respectively, in 2004.

The station in Melbourne recorded air quality exceeding guidelines on ten days in 2003 and three days in 2004, but on only two days or fewer per year between 1999 and 2002.

### Fine particles

Fine particles in the atmosphere come from a wide variety of sources, including soil (dust), vegetation (pollens and fungi), sea salt, fossil fuel combustion, biomass burning (including bushfires) and industry. Particles suspended in air have the ability to penetrate the lower airways of the lung if smaller than 10 micrometres in diameter (referred to as PM10).

Increasing evidence suggests the acute health effects may, in fact, be the result of exposure to very fine particles, such as those smaller than 2.5 micrometres in diameter (referred to as PM2.5).[6] It is these finer particles that are the main cause of urban haze, which typically appears white. Most of these particles are generated by people, rather than occurring naturally. The human health effects are many and depend on the size and chemical composition of the particles. Particles can aggravate existing respiratory and cardiovascular disease and asthma, can affect eyesight and cause allergies.

Some plants and animals are particularly sensitive to fine particle pollution. Lichens for example are often among the first life forms to be affected, while particles can cover the leaves of larger plants and damage their ability to photosynthesise.

Air quality in Brisbane exceeded guidelines on seven days in 2002, and on no or only one day in other years between 1997 and 2001. The Perth station recorded four days exceedences in 1997, but no more than a single day's exceedence in each year between 1998 and 2003. The station in Adelaide recorded air quality guidelines were exceeded on two days in both 1997 and 1998, and five days in 1999 and 2004, and six days in 2003. Between 2000 and 2002, the levels of fine particles in the air met the NEPM standard every day.

## Some differences within Australia

Different parts of the country experience different types and levels of air pollution, but air quality outside the major cities is generally good, and levels of pollutants are generally well below actual or proposed standards.[7] Fine particles (particularly wind blown dust) are often the principal air pollution problem in most of our regional centres.[7] In some places like Armidale, Canberra and Launceston, high particle levels are more likely to occur during winter and autumn when people are using open fires and wood heaters for heating.[1] Some areas, far from major sources of pollution, can suffer from the long range transport of pollutants.

In the past year breaches of air quality have occurred in the latter part of the year due to drought conditions, and atmospheric and weather conditions.[8] Dust storms can also occur when there is a rapid change of wind speed and direction. Bushfires and controlled burn-offs also pollute.[7]

### Other air pollutants

The headline indicator for air quality focuses on one form of air pollution: fine particles. Other substances released into the air can be harmful to both people and the environment. Some substances pollute directly and are known as primary pollutants. The most widespread of these apart from fine particles are carbon monoxide, volatile organic compounds, hydrocarbons, oxides of nitrogen, sulfur dioxide and lead. Some pollutants can interact in the presence of sunlight to form secondary pollutants, called 'smog'.

There has been less and less lead in Australia's air since the introduction of unleaded petrol in 1986 and the phase out of leaded petrol which was completed by January 2002. Lead levels in major cities and towns are now very low, in some instances less than 10% of the level specified in the national air quality standard. Lead remains a problem where smelters are located close to urban areas and the national standard is exceeded on occasions in these locations.[9]

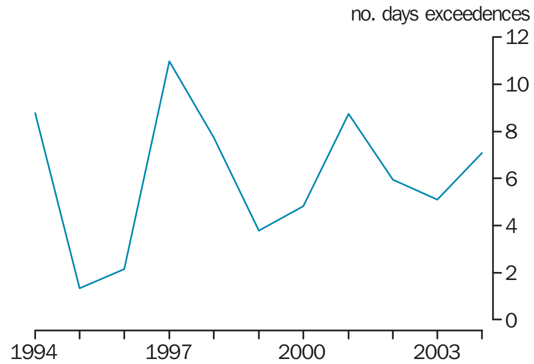
In most Australian towns and cities, the levels of carbon monoxide in air are below levels that are hazardous for human health. Only larger cities, like some of our capital cities, have the potential to have harmful levels of carbon monoxide.[10] Similarly the levels of nitrogen dioxide reached in most Australian towns and cities are thought to be acceptable for humans. However, in some of Australia's larger cities, it is possible that the concentration of nitrogen dioxide sometimes increases for a short time to levels that have an adverse health effect on people who are most at risk.[11] The incidence of photochemical smog has remained more or less stable and is discussed below.[7]

## Ozone and photochemical smog

Ozone ($O_3$) is formed when oxides of nitrogen react with sunlight in the atmosphere. It is a natural part of the upper levels of the atmosphere or 'stratosphere' where it absorbs harmful ultraviolet radiation, preventing it from reaching the earth. Near the ground, ozone is a secondary pollutant, often formed by the reactions of primary pollutants, such as oxides of nitrogen and volatile organic compounds in the presence of sunlight. These primary pollutants arise mainly from motor vehicle emissions, stationary combustion sources and industrial and domestic use of solvents and coatings. Ozone is strongly oxidising and can irritate the eyes and the respiratory tract and it also damages plants. Ozone is one of the irritant pollutants in photochemical smog and is often used as a measure of it. As sunlight is an important factor in the formation of ozone (and hence smog), smog is more likely on sunny days in cities.

Ozone has been monitored in most cities since the late 1970s. Peak ozone levels have declined significantly over that period although in recent years the trends are not as apparent. There is significant year-to-year variability in peak ozone levels due to weather variability. Exceedance of the current ozone standards are occasionally observed in most major Australian cities, with more frequent exceedances observed in Sydney.[12] Sydney often records more than five exceedance days per year; partly due to the topography of the Sydney Basin.

**Number of days when ozone concentrations exceed NEPM standard(a) in selected capital cities(b)**




(a) Ozone concentrations 4 hour average. Exceedance of 0.08ppm allowed on one day a year — the NEPM standard to be achieved by 2008. (b) Data are for Sydney, Melbourne, Brisbane, and Perth and have been weighted together in proportion to these cities' populations.

*Source: State enviromental protection authorities, 2006.*

## Sulfur dioxide emissions

Sulfur dioxide ($SO_2$) is a colourless, irritating and reactive gas with a strong odour. In Australia emissions of sulfur dioxide come primarily from industrial operations that burn fuels such as coal, oil, petroleum and gas and from wood pulping and paper manufacturing. It is also emitted by vehicles. It irritates the eyes, nose and throat, and people with impaired lungs or hearts and asthmatics are particularly at risk of exacerbating existing health problems.[13]

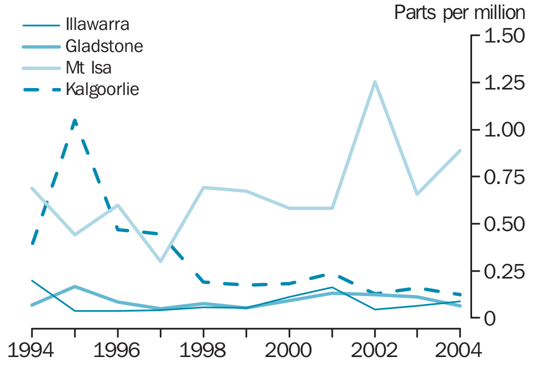
Ambient sulfur dioxide concentrations are generally low.[14] Sulfur dioxide levels vary between regions due to varied geographical distribution of major sources and different topographical and meteorological conditions. Sulfur dioxide levels in Australian cities are low compared to the USA and Europe because of the limited number of major sulfur dioxide emitting industries and low sulfur fuels.[14]

Sulfur dioxide pollution has been an issue in some mining areas, but is improving. Due to improvements in mineral extraction and processing activities at Kalgoorlie in Western Australia, sulfur dioxide levels have been reduced dramatically over the last 12 years. In New South Wales the copper smelting operations at Port Kembla which resulted in significant emissions, have recently ceased and sulfur dioxide levels are expected to reduce.[14] In recent years, one hour sulfur dioxide levels have been below NEPM standard levels at Gladstone, the Lower Hunter and La Trobe Valley (power generation areas using coal).[7]

## Factors influencing change

Air pollution is a problem in every major city of the world, although the degree of the problem varies. Air has always contained natural substances like sea-salt or gases from decaying plants and animals, but industrial activity and the growth in fossil-fuel

## Highest one-hour averages of $SO_2$ in selected regional areas(a)




(a) The National Environmental Protection Measure standard for $SO_2$ concentrattions is 0.2 parts per million.
*Source: State enviromental protection authorities, 2006.*

dependent traffic have released millions more tonnes of pollutants into the air (for example, over a million tonnes of PM10 emissions in 2002–03).[15] Most of these emissions (20%) are from the use of fossil fuels.

Motor vehicles are Australia's single largest source of air pollution.[7] For example, in Melbourne in 2004, their emissions contributed 83% of the carbon monoxide (which can affect memory and vision, cause heart disease and harm unborn children), 41% of hydrocarbons and 63% of nitrogen oxide levels (which contribute to photochemical smog formation) and were a major contributor to many volatile organic compounds (which contribute to smog).[17] Cars and trucks generate fine particles directly through burning fossil fuels, especially diesel. Diesel generates far more fine particles than petrol per litre, and generates more of the finest particles (smaller than 2.5 micrometres) which have serious health implications for humans.[18] Vehicles also generate fine particles when tyres lose rubber, while tyre and air turbulence wear away road surfaces.

To combat pollution from traffic in our cities government policy has aimed to cut emissions from motor vehicles through the Fuel Quality Standards Act 2000, paving the way for improved engine technology and tighter emission controls. Cleaner fuel for cleaner engines is expected to help cut pollutants associated with respiratory and cardiovascular diseases by up to 76% in metropolitan areas by 2015.[19]

Technology and strategies designed to control air pollution appear to have countered the rises which could have been expected given the increases in pollution sources.[2] Despite industrial activity and the numbers of cars growing during the 1990s, measured air quality has not deteriorated significantly. So far the improvement in air quality is mainly due to the phasing in of cleaner motor vehicles, controls on industrial emissions and the increasing adoption of cleaner processes and technology by industry, and the banning of backyard incineration in many regions. Projections prepared for the National Road Transport Commission suggest that by 2015, despite significant growth in numbers of diesel vehicles (light commercial vehicles in particular), fine particle emissions from all diesel vehicles will fall in the major cities to about 70% or less of their 1996 levels.[20] The main reason for the predicted fall is that older vehicles will be replaced by newer, less polluting vehicles. Cars and trucks are becoming cleaner in other ways too. For example, the switch to unleaded petrol and the use of catalytic converters has led to significant reductions in lead pollution in some areas (lead concentration at Mascot, inner Sydney, fell by some 60% between 1993 and 1996).[21] A greater use of renewable power sources to generate electricity could also reduce some forms of air pollution.

## Links to other dimensions of progress

Air quality is linked to human health. While the full effects of pollutants like fine particles are still poorly understood, Australian studies are consistent with those overseas which show that days of high pollution levels have increased mortality rates, hospital admissions and emergency room visits for respiratory and cardiovascular disease.[2]

Polluted air can harm biodiversity: smog and acid rain can affect many plants and animals.[22]

Air quality is linked to the generation of income. Economic activity, especially among the more energy-intensive industries, creates pollution. But in turn, air pollution has financial impacts, such as the cost of cleaning buildings, while acidic gases in the atmosphere can corrode iron and steel. Agriculture can also be affected: polluted air can harm crops and livestock. Land clearance and degradation contribute to air pollution: fine particles are created when vegetation is burnt, and when eroded soil is blown into the air.

See also the commentaries *National income*, *Transport*, *Health* and *The natural landscape*.

## Endnotes

1 Department of Environment and Heritage, *State of the Environment 2001, Fact Sheet: Air Quality* <http://www.deh.gov.au/soe/2001/fact-sheets/air.html>, last viewed 23 March 2006.

2 Australian Bureau of Statistics 2001, *Australia's Environment: Issue and Trends*, cat. no. 4613.0, ABS, Canberra.

3 Department of the Environment and Heritage, *Air Quality in Australia* <http:www.deh.gov.au/atmosphere/airquality/pollutants.html> last viewed 23 March 2006.

4 Experts, such as those who wrote Urban Air Pollution in Australia (at 18 below) generally mention both smog and fine particles as the two forms of air pollution with the most serious impacts on health. But the State of the Environment Report in 2001 noted that some studies from other countries have indicated that more deaths are attributable to the concentration of particulate matter of diameter below 2.5 micrometres (PM2.5) than to the concentration of PM10. However, particles with sizes between 2.5 and

10 micrometres may be more important in relation to asthma and respiratory illnesses.

5 The PM10 data from each state environmental protection agency was obtained using the Tapered Element Oscillation Microbalance (TEOM) method, which continuously monitors PM10 levels in the air averaged over a 24 hour period. 1997 was the first year all of the five EPAs used this method.

6 Department of Environment and Heritage, *Health Impacts of Ultrafine Particles — Desktop Literature Review and Analysis, September 2004,* <http://www.deh.gov.au/atmosphere/airquality/publications/health-impacts/summary.html> last viewed 23 March 2006.

7 State of the Environment Advisory Council (SEC) 2002, *Australia - State of the Environment Report 2001,SEC*, CSIRO Publishing, Melbourne.

8 Environment Protection Authority Victoria, *Effect of the drought on air quality in Victoria,* EPA Victoria <http://www.epa.vic.gov.au/Air/drought.asp> last viewed 23 March 2006.

9 Department of the Environment and Heritage - *Air Quality Fact Sheet - Lead* <http://www.deh.gov.au/atmosphere/airquality/publications/leadfs.html> last viewed 23 March 2006.

10 Department of the Environment and Heritage - *Air Quality Fact Sheet - Carbon Monoxide (CO)* <http://www.deh.gov.au/atmosphere/airquality/publications/carbonmonoxide.html> last viewed 23 March 2006.

11 Department of the Environment and Heritage — *Air Quality Fact Sheet - Nitrogen Dioxide (NO2)* <http://www.deh.gov.au/atmosphere/airquality/publications/nitrogendioxide.html> last viewed 23 March 2006.

12 National Environment Protection Council, 2005. *Preliminary Work on Ozone for the review of the Ambient Air Quality NEPM* - Issues Paper.

13 Department of Environment and Heritage, *National Pollutant Inventory: Sulfur* Dioxide<http://www.npi.gov.au/database/substance-info/profiles/77.html> last viewed 23 March 2006.

14 National Environment Protection Council, 2004. *Review of the practicability of a 10 minute sulfur dioxide standard* - Issues Paper.

15 The National Pollutant Inventory (NPI) was set up in 1996 to quantify, for the first time, the amount of pollution released into the environment at a national level. The NPI's database provides a comprehensive record of pollutants entering the air, land and water. Its first reporting period was 1998–99, and so it is still too early to consider national trends in air pollution, although this should be possible in a few years. Department of Environment and Heritage, Environment Australia 2002, National Pollutant Inventory: Particulate Matter 10.0 Summary - All Sources <http://www.npi.gov.au> last viewed 23 March 2006.

16 $CO_2$ equivalent emissions. Different greenhouse gases have different effects and remain in the atmosphere for different periods of time. A tonne of methane, for example, contributes as much to global warming as 21 tonnes of carbon dioxide ($CO_2$). To assess the impact of the different gases together, emissions of each gas are converted to a common $CO_2$ equivalent ($CO_2$-e) scale and added. For example, a tonne of methane and a tonne of $CO_2$ would equate to 22 tonnes of greenhouse gases $CO_2$-e.

17 Environment Protection Authority Victoria, *Motor Vehicle Emissions* <http://www.epa.vic.gov.au/Air/Issues/aq9122.asp> last viewed 23 March 2006.

18 Australian Academy of Technological Sciences and Engineering (AATSE) 1997, *Urban Air Pollution in Australia*, AATSE, Melbourne.

19 Department of Environment and Heritage - *National Pollutant Inventory - Helping Cut Emissions* Media release 30 January 2004 <http://www.deh.gov.au/minister/env/2004/mr30jan04.html> last viewed 23 March 2006.

20 Cox, J. 2001, *Diesel Fleet Characteristics: Emissions Projections Update*, National Environment Protection Council, Adelaide.

21 Cohen, D. 1996, '*Have fine particle lead concentrations fallen in Sydney during the last 4 years?*', in (ed.) Smith, A. Proceedings of the 13th International Clean Air and Environment Conference, Clean Air Society of Australia and New Zealand, pp. 238–243.

22 Commonwealth Scientific and Industrial Research Organisation (CSIRO) 2000, *Urban and regional Air Pollution: Information sheet,* <http:www.csiro.au/index.asp?type=faq&id=AirPollutionUrbanAndRegional&stylesheet=aboutCSIROInformationSheet> last viewed 8 March 2002.

# The air and atmosphere – Atmosphere

## Progress and the headline indicator

Greenhouse gases are a natural part of the atmosphere. They trap the sun's warmth, and maintain the Earth's surface temperature at the levels able to support life. However human actions – particularly burning fossil fuels (coal, oil and natural gas) and land clearing – are increasing the concentrations of these gases that trap more heat and change the climate. This is known as the greenhouse effect.[1]

Global warming is widely perceived as one of the most significant international environmental concerns. Australia's contribution to these international concerns is an important aspect of progress. Australia's greenhouse gas emissions are the focus of the headline indicator. This commentary also looks at Australia's ozone depleting emissions.

According to meteorological records, the global average surface temperature has increased. Global temperatures in 1998, 2002 and 2003 show these were the three warmest years since 1861 – when reliable direct weather recording began.[2] Global-average surface temperature has increased over the past 100 years by about 0.6°C.[2] In Australia annual mean temperatures have increased, although this has not been uniform.[3]

The effects of global warming are very difficult to predict. Australia will be hotter and drier in coming decades according to CSIRO's climate change estimates.[4] In its Third Assessment Report released in 2001, the international body, the Intergovernmental Panel on Climate Change (IPCC), presented a range of scenarios that provide projections of future climate change, some of which suggest significant global warming. The construction of IPCC scenarios is ongoing, and some have expressed concerns about their economic and statistical underpinning.[5]

The headline indicator presents Australia's total net greenhouse gas emissions. The indicator is based on estimated total emissions from human sources including fossil fuel burning and land clearing, less credits from carbon sinks (such as forests). These credits are estimates of how much carbon dioxide has been consumed by plantations established in Australia since 1990.[6] It is particularly difficult to measure and estimate the exchanges between the biosphere and the atmosphere accurately, such as emissions from land clearing and credits from reforestation.[6] Recent research findings about the methane emmissions of plants may impact on these measures.[7]

Estimates of Australia's emissions vary according to the accounting conventions used. Unless otherwise indicated, the emission estimates produced using the Kyoto accounting rules are used here. These estimates are higher than those calculated for the United Nations Framework Convention on Climate Change (UNFCCC), although changes over time are broadly similar (the main difference relates to the treatment of forest sinks).[6]

For 2003, Australia's net greenhouse emissions were estimated to be 550.0Mt carbon dioxide-equivalent ($CO_2$-e).[6] According to UNFCCC data for 2003 emissions, Australia accounts for 3.9% of total industrialised countries emissions.[8] The net amount emitted in Australia in 2003 was a 1.4% decrease on net emissions in 2002, largely reflecting decreases in emissions from Land use, land use change and forestry, and from Waste. Australia's net emissions in 2003 were 1.1% above 1990 levels. Emissions rose gradually over the period, with the sharpest rise between 1997 and 1998 when emissions from land use change rose rather than fell as they had done during most of the decade.[6]

Carbon dioxide is the major greenhouse gas in Australia's 2003 inventory with a share of 74% (404.6Mt) of the total $CO_2$-e emissions, followed by methane which comprises 20% (108.5Mt $CO_2$-e). The remaining gases make up 7% (37.0Mt $CO_2$-e ) of Australia's greenhouse gas emissions.[6]

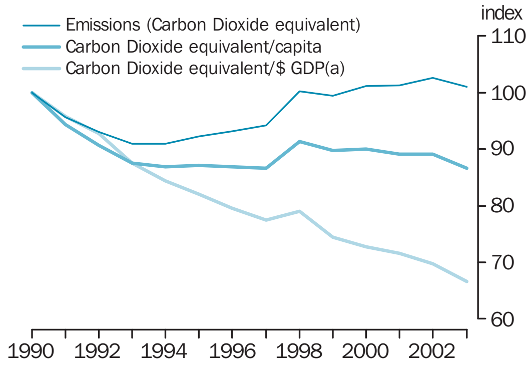
In order to compare countries of different population size, one can consider per capita emissions of greenhouse gases. According to UNFCCC estimates Australia has the highest net greenhouse gas emissions per capita in 2003 of all OECD countries. At 27.5 tonnes of $CO_2$-e per person, emissions by Australians are 32% higher than the USA and more than double the average for most OECD countries. In Australia, per capita emissions declined by almost 10% between 1990 and 2003.[8] This decline is accounted for by a large reduction in emissions from land-clearing. The fall in emissions from land clearing has masked the increase in emissions from other sources, especially energy.[9]

Australia's large per capita emissions in part reflect our heavy use of coal in electricity generation: according to OECD estimates for 2003, about 57% of Australia's carbon dioxide emissions arose in the production of public electricity and heat, a higher proportion than any other OECD country, with the exception of Poland (57%). Some 38% of the OECD's entire $CO_2$ emissions were generated for this purpose.[10] Unlike most OECD member countries, Australia does not use nuclear power to generate electricity. As well, the impact of international trade patterns result in Australia producing many goods with high associated emission levels, which are destined for export and consumption in other countries.

## Some differences in Australia

As the effects of global warming are very difficult to predict at a broad level it is even harder to predict the impacts for regions, although some attempts have been made. Over most of the continent, annual average temperatures are predicted to be 0.4°C to 2°C greater in 2030 compared to 1990. Temperatures are predicted to further increase, but the warming won't be the same everywhere. It is expected that there will be less warming in some

## $CO_2$-e emissions, net, per capita and per $ GDP




(a) GDP is a chain volume measure. In accordance with Kyoto Protocol Base year = 1990.

*Source: Australian Greenhouse Office (2005), National Greenhouse Gas Inventory - Analysis of Recent Trends and Greenhouse Indicators 1990–2003, Australian Greenhouse Office, Canberra.*

Australia's relatively high rates of population and economic growth are important factors behind the growth in our emissions, and it is interesting to consider the changes in overall net emissions alongside the changes in per capita emissions and emissions per dollar of GDP. Emissions of greenhouse gases per capita decreased by 13% between 1990 and 2003, and emissions per $ of GDP fell by 33%. The reduction in land use, land use change, and forestry emissions accounted for about 72% of the decline in emissions per dollar of GDP. As well there were structural changes in the economy, with stronger growth in the services sector than in the manufacturing sector. There has also been an improvement in the efficiency of energy use.[6]

coastal areas and Tasmania, and slightly more warming in the north-west.[11]

Although there has not been much change in the overall level of rainfall the patterns have changed. South-western Australia has experienced decreases in rainfall, as has parts of south-eastern Australia and Queensland. Wetter conditions have occurred in northern Australia in summer and inland Australia in autumn.

## Factors influencing change

The size of the economy, its structure and the energy intensity of industries are important determinants of greenhouse gas emissions. And it is informative to consider changes in the contribution of different sectors over time.

The rise in emissions over the period 1990 to 2003 has primarily been driven by a larger rise (31%) in emissions from the energy-sector. This rise has been partially offset by a significant decline (76.6Mt) in net emissions attributable to land use and land use change (this in turn comes from a reduction in emissions from land clearing).

In 2003, the energy sector (mainly power stations and transport) accounted for 68% (374.3Mt) of net emissions. Energy sector emissions were 1% (4.2Mt) higher than in 2002, and 31% (88.2Mt) higher than in 1990.[6] ABS figures from the mid-1990s show that more than half of this sector's greenhouse gases were emitted as a consequence of the production and/or consumption of goods and services used by households (particularly domestic electricity and motor vehicle fuel), and about a quarter of emissions were generated in the production of goods and services for export.[12]

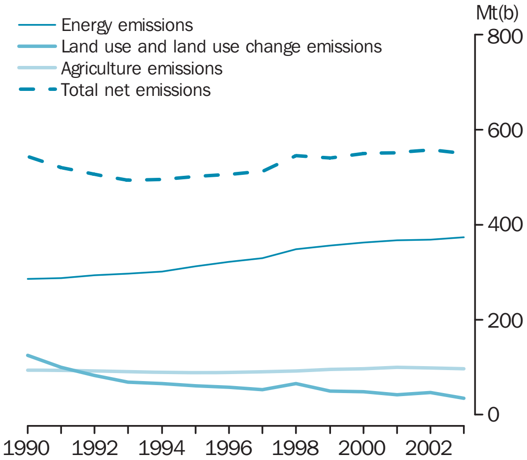
Agriculture was the second largest emitter of greenhouse gases, and accounted for 97.3Mt $CO_2$-e emissions or 18% of total net emissions in 2003. The agriculture sector is the major source of both methane and nitrous oxide — accounting for 68% and 77% respectively of the net national emissions for these two gases. Land use and land use change activities emitted about 49.6Mt $CO_2$-e, which represents a decline of 76.6Mt since 1990, and forest sinks consumed about 15Mt $CO_2$ during 2003. (Strictly speaking however, the credits from plantations established in Australia since 1990, are not officially accounted for until 2008–2012).[6]

Other things being equal, economic growth arising from industries that are emissions-intensive (such as iron, steel and aluminum smelting) will increase greenhouse gas output more than growth in sectors such as service industries which are less energy, and emissions, intensive.

The price of energy also has an influence in managing demand. Electricity prices fell in Australia during recent years, while the relatively low cost of vehicle fuel here helps to explain why our cars are larger, less fuel efficient and driven more than in many other countries.[13]

Reducing greenhouse gas emissions has become the subject of major international negotiations. In 1992, Australia ratified the UNFCCC, which sought to stabilise greenhouse gas concentrations in the atmosphere. The convention was updated by the Kyoto Protocol of 1997, which Australia signed but has not yet ratified. Under the protocol, developed countries are committed to reducing their greenhouse gas emissions by at least 5% below

## Australia's greenhouse gas emissions(a) for selected sectors




(a) Kyoto-based estimates. (b) Million tonnes (megatonnes) of carbon dioxide ($CO_2$) equivalent.[14]

*Source: Australian Greenhouse Office.*

## International comparison – Net greenhouse gas emissions

An OECD indicator comparable to the MAP headline indicator for atmosphere: net greenhouse gas emissions is available from United Nations Framework Convention on Climate Change (UNFCCC) reporting. However, the accounting provisions of the UNFCCC are broader in scope than those of the Kyoto Protocol, which is the basis on which net greenhouse gas emissions are reported in Australia's National Greenhouse Gas Inventory. This variation in accounting provisions is the reason for any differences in the data presented for Australia's net greenhouse gas emissions in this international comparison, compared with the headline indicator graph and commentary.

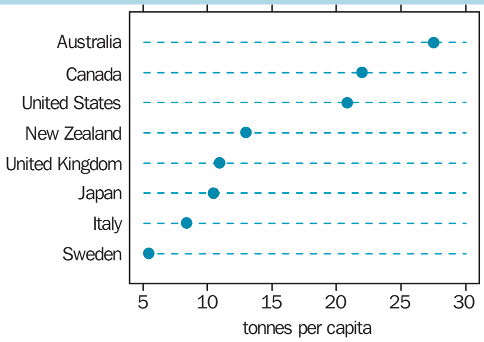
Increased greenhouse gas emissions from industrialisation and the potential for climate change are an environmental issue of international concern. The level of greenhouse gas emissions are indicative of the relative contribution of different countries to the global level of emissions. The change in greenhouse gas emissions per capita over time provide an indication of the response of different countries to the issues of reducing greenhouse gas emissions and climate change.

Two indicators are presented here – net greenhouse gas emissions per capita – 2003, and the change in net greenhouse gas emissions between 1990 and 2003 (based on the aggregate level of emissions). Net greenhouse gas emissions is the sum of the six greenhouse gases of the Kyoto Protocol expressed in $CO_2$ equivalents. The data include $CO_2$ emissions and $CO_2$ removals attributable to land use, land use change, and forestry.

In 2003, Australia had the highest per capita level of net greenhouse gas emissions of OECD countries (27.5 tonnes). Sweden had the lowest per capita level of emissions (5.5 tonnes).

Around one third of OECD countries experienced a decline in net greenhouse gas emissions during the period 1990–2003. The largest declines occurred in Poland (40% between 1988–2002) and the Slovak Republic (33%). Among OECD countries that experienced an increase in net greenhouse gas emissions during the period 1990–2003, the largest increase occurred in Canada (58%). Net greenhouse gas emissions increased by 5% in Australia during this time.

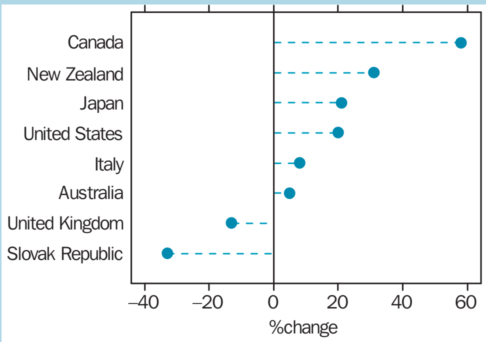
### Net greenhouse gas emission per capita(a) – 2003




(a)Includes emissions/removals from land use, land-use change and forestry.

*Source: Per capita greenhouse gas emissions levels calculated from UNFCCC, National greenhouse gas inventory data for the period 1990-2003 and status of reporting, 2005,[8] using population estimates from National Accounts of OECD countries, Volume 1, 2006.*

### Change in net greenhouse gas emissions(a) 1990 – 2003




(a) Includes emissions/removals from land use, land-use change and forestry.

*Source: UNFCCC, National greenhouse gas inventory data for the period 1990–2003 and status of reporting, 2005.[8]*

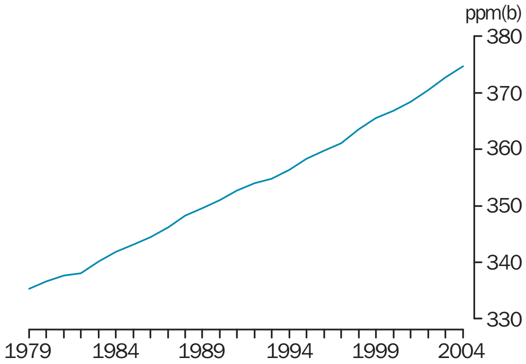
1990 levels by the first Kyoto commitment period (2008–12). However, at Kyoto, Australia negotiated an 8% increase in emissions.

## Ozone depleting emissions

Ozone near the Earth's surface can be a harmful pollutant, but in the upper atmosphere (the stratosphere) it absorbs most of the harmful ultraviolet (UV-B) radiation in the sun's rays. When excessive UV radiation reaches the Earth's surface it can cause health problems to people and other organisms, including damage to the eyes, skin and immune system. It can also affect crop yields and marine plankton (which might have flow-on effects to many marine ecosystems). Radiation can degrade plastics, wood, paper, cotton and wool.

Certain substances trigger the destruction of ozone. Human activity has been responsible for

### Carbon dioxide concentrations(a)

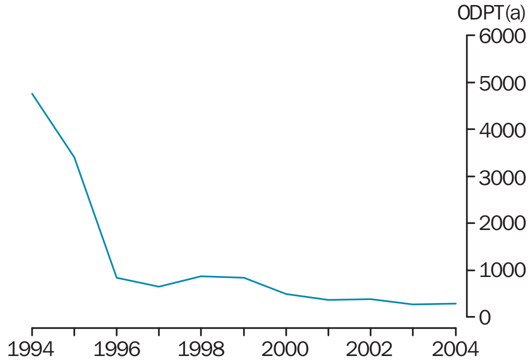



(a) Annual averages recorded at Cape Grim Baseline Air Pollution Station, Tasmania. (b) Parts per million.

*Source: CSIRO, 2005.*

Increasing greenhouse emissions are reflected in findings from atmospheric weather stations, such as the data from Cape Grim in Tasmania. The concentration of atmospheric $CO_2$ has increased steadily since 1979.

## Consumption of ozone depleting substances in Australia




a) Ozone depleting potential tonnes are an aggregated scale of measurement which allows the addition of quantities of different gases and weights them according to the amount of ozone each could potentially deplete.

*Source: The Department of Environment and Heritage.*

increasing the concentrations of these substances in the upper atmosphere: the main ozone depleting emissions are chlorofluorocarbons (CFCs) used in refrigeration, and halons and methyl bromide, used in many industries. As a result of these emissions, between 2% and 4% of ozone over Australia has been lost each decade since the 1950s, and we are now exposed to greater levels of UV radiation than in the past.[15]

Global consumption of these substances is now limited by the Montreal Protocol on Substances that Deplete the Ozone Layer to which Australia is a signatory. Concentrations peaked in the mid-1990s and are now declining. But the substances already in the atmosphere continue to destroy ozone, and because of these time lags, the depletion of ozone over Australia and Antarctica may not yet have peaked, although ozone levels may not decline much further.[15] The largest losses of ozone have been observed over Antarctica (more than 60% of natural levels).[15] These losses have led to the so-called Antarctic ozone 'hole', an area of the stratosphere within which ozone concentrations are well below the levels as at the beginning of the 20th century.

## Health effects linked to ultraviolet exposure

Australia has high levels of UV radiation and the highest per capita incidence of melanoma in the world, 46 per 100,000 persons in 2001, an increase of 60% since 1990.[22] Since 1980, UV exposure in tropical regions of Australia has increased by 20% as a result of simultaneous depletion of ozone and decreases in cloud cover. At mid-latitudes, no significant net increases per year were found because of increasing levels of cloud cover but clear day levels of UV radiation rose. The increase in the incidence of melanoma is mainly thought to stem from people spending more time outdoors but the increase in UV radiation will also affect skin cancer rates. And exposure is directly linked to cataracts. Awareness campaigns have been put in place encouraging people to adopt protective measures.[23]

## Renewable energy resources

Most of the energy produced in Australia depends on the burning of fossil fuels, a significant source of greenhouse gases and air pollution. Increasing the energy generated from renewable resources is one way of decreasing or slowing the expansion of  emissions. The Australian Government has set a mandatory renewable energy target of 9,500 gigawatt hours of renewable electricty by 2010.[16]

Data from the International Energy Agency show that the proportion of Australia's overall energy consumption that came from renewable resources was 8% in 2003, up from 6% in 1994. Although Australia's renewable energy consumption grew by one-quarter over the period, total energy consumption grew by one-third.[17]

Green power is the generic name given to electricity generated from clean, renewable energy sources that is available for use by consumers. Green power sources can include solar (photovoltaic and thermal), wind power, new hydro on existing dams, biomass, wave energy and landfill gas. In September 2005, around 180,000 (or 2% of) households and 6,500 commercial users belonged to a green power scheme.[18]

Some forms of renewable energy come with problems of their own. For instance, large hydro-electric schemes have had detrimental effects on river flows and have flooded river valleys, displacing people and animals and destroying flora. Some people find wind turbines aesthetically unpleasant.

Ozone depletion is not an irreversible problem and it appears that the achievements of the Montreal Protocol will result in the eventual recovery of the ozone layer. It is expected that the first signs of ozone recovery will be noticed in ten to fifteen years. Total recovery may occur as early as 2050, but could be delayed as long as 2100.[15]

Estimates of Australia's total consumption of ozone depleting substances, weighted according to the ozone depleting potential of each, are presented in the graph above. Consumption in 1994 was over 4,700 ozone depleting potential tonnes (ODPTs: an aggregated scale of measurement which allows one to add together quantities of different gases and weights them according to the amount of ozone each could potentially deplete). In 2004, it had fallen, in response to international restrictions, to 282 ODPTs, composed mostly of methyl bromide and hydrochlorofluorocarbons (HCFCs).

Australia stopped production of CFCs during the 1990s, and we are ahead of the Montreal Protocol's schedule in reducing our use of HCFCs, which are the minor ozone depleting substances used as interim replacements for CFCs.

## Links to other dimensions of progress

Climate change has been identified as one of the numerous pressures on the world's wildlife. It has led to some 25% of the world's mammals and 12% of birds being at significant risk of extinction.[19]

A major study of the likely impact of climate change on plants and animals concluded that minimal climate-warming scenarios for 2050 could lead to extinction of approximately 18% of species.

Mid-range and maximum warming could lead to extinction of 24% and 35% of species, respectively, by 2050.[19]

Australian research has found that the bioclimates of some species of plants and vertebrates will disappear with a warming of just 0.5°C–1.0°C.[19] The endangered Mountain Pygmy Possum could lose its entire alpine habitat with such a rise in mean annual temperature.[20] It also appears that many corals in the Great Barrier Reef are living close to their survival limits in terms of sea temperature.[21]

Greenhouse gas emissions and climate change are more than an environmental concern. While Australia's biodiversity and freshwater ecosystems might be affected by climate change, global warming could – if certain scenarios of the International Panel on Climate Change prove correct – have profound consequences for our economy and society (increasingly frequent and severe floods and rising sea levels, for instance, have the potential to cause significant damage). Emissions are linked to economic activity, through the burning of fossil fuels, certain industrial processes, agriculture and forestry. However, the development and adoption of new low-emissions technology, such as wind power, might play an important role in reducing emissions in the future.

See also the commentaries *National income,* and *Transport*.

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