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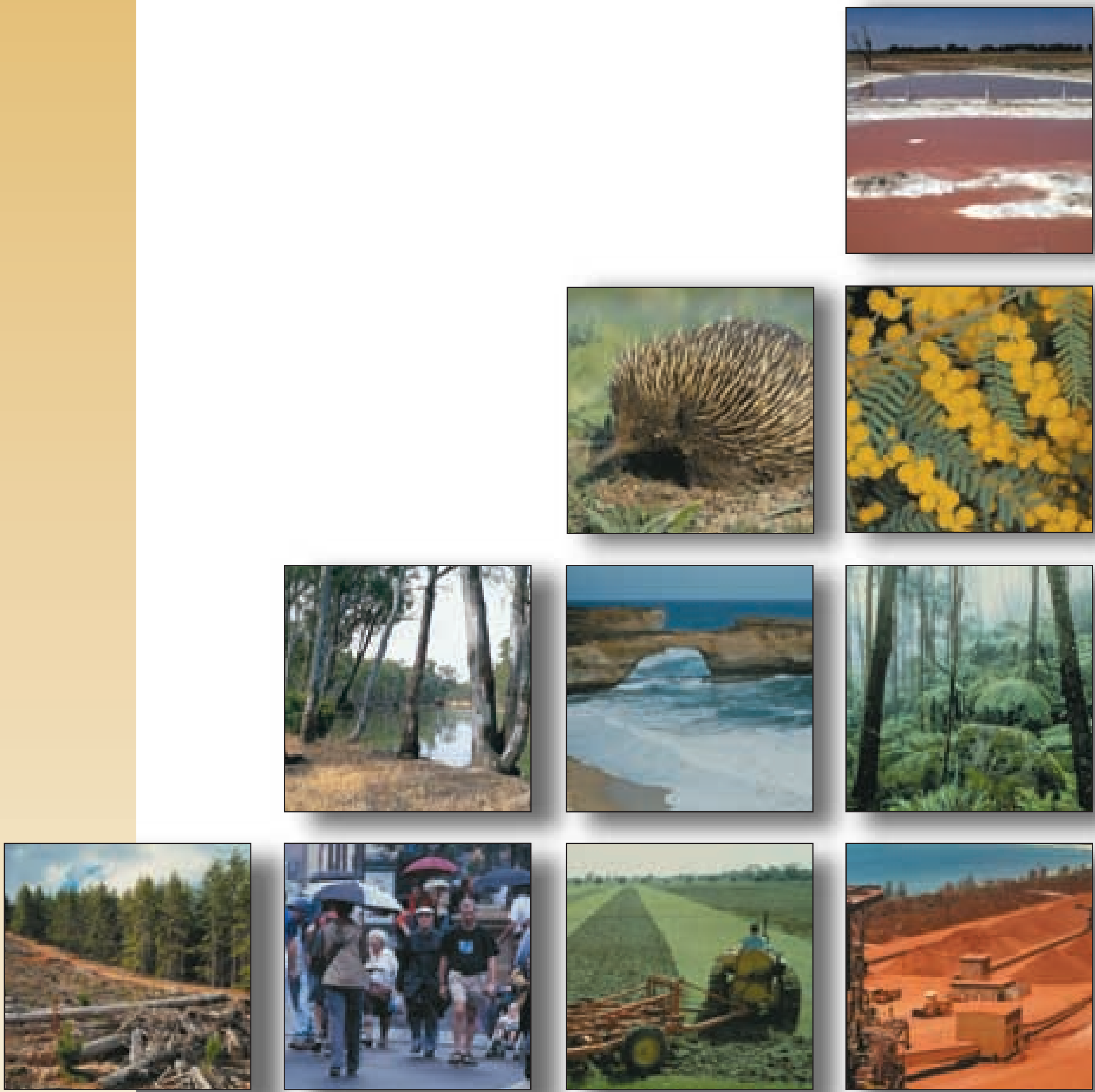
Australia's Environment Issues and Trends

2003



Australia's Environment: Issues and Trends

2003

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Australian Statistician

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- *Acacia cardiophylla*
- Murray at Gunbower Creek
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- Scarifying paddock
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PREFACE

Australia's Environment: Issues and Trends 2003 is the sixth general publication about Australia's environment produced by the Australian Bureau of Statistics (ABS). Its intended role is as a source of statistical information about major aspects of, and trends in, Australia's environment, which can address flexibly the changing needs and interests of statistical users in this field. In particular, the publication provides data relevant to the emerging discipline of sustainable development.

The 2003 edition looks in particular at the economic and other values that can be placed on Australia's environment and natural resources. Chapter 1 explores how economic, social and environmental changes and conditions can be measured. It also shows how the System of National Accounts has been used to measure natural resources. Subsequent chapters deal with the economic aspects and environmental impacts of the agriculture, forestry and mining industries, the industries that rely most heavily on direct inputs from the environment. The final chapter addresses waste and waste management in Australia. The publication does not aim to present data on all environmental issues and other topics will be covered in future editions.

The ABS welcomes feedback on this publication and suggested topics for future issues of this publication. Comments can be made to Director, Environment and Energy Section, Australian Bureau of Statistics, Locked Bag 10, Belconnen ACT 2616.

Dennis Trewin
Australian Statistician

CHAPTER 1 MEASURING ENVIRONMENTAL VALUES, CHANGES AND CONDITIONS

INTRODUCTION

'Measuring' the environment, and the changes to it, is a complex task. Measurement is needed, however, to determine whether the quality and quantity of Australia's natural resources and environmental assets are improving or declining, and whether actions undertaken to safeguard the environment are working effectively. A key part of the challenge is to define and determine exactly what features and values of the environment are of interest and how these might be integrated into our decision-making processes.

A key tension for decision-makers is to balance the economic value of a potentially resource-degrading activity against any other values that the resource might have. This chapter looks at a number of the ways in which Australia's natural resources and environmental assets are being measured or valued — in both monetary and non-financial terms.

The chapter provides a guide to the relevant issues and an introduction to work being undertaken both within Australia and overseas. Included are discussions of the main measurement framework (the System of National Accounts (SNA) covering gross domestic product (GDP), and the national balance sheet) and its extension into natural resource accounting, a range of environmental indicators, and techniques to measure the use of natural resources.

MEASUREMENT FRAMEWORKS

For many years, growth in GDP and GDP per capita have been used as benchmarks in the determination of changes in the standards of living and wellbeing of individuals and countries.

However, it has long been recognised that change in GDP is deficient as a measure of change in economic wellbeing, due in part to the particular decisions that have been taken to define its scope. For example, GDP does not indicate how equally income is shared between different groups in the population; its measurement excludes the production of services produced and consumed within the household, and it does not account directly for changes in unemployment rates, all of which can be seen as important determinants of economic welfare.

Despite caveats on the definition of GDP as a measure of economic welfare, in the absence of other accepted approaches to welfare measurement, GDP is still used in that context. Increasingly, however, the deficiencies of GDP as a measure of economic welfare are being recognised and alternative measures are being developed.

MEASUREMENT FRAMEWORKS *continued*

At the same time, it is also being recognised that the measurement of welfare must encompass more than just economic concerns. This broadening of the measurement agenda has moved in concert with the increasing focus in public and corporate policy on sustainable development, that is, the need for economic, social and environmental aspects of policy to be considered concurrently rather than individually.

This section begins by looking at the economic statistics frameworks used in Australia and overseas, and how they are being extended to cover environmental issues.

SNA and SEEA

The statistical framework for economic statistics is well developed, and this framework is used to derive national production (as summarised by GDP) and economic wealth (as summarised in the National Balance Sheet). The international standard is *System of National Accounts 1993* (SNA93) (Commission of the European Communities et al. 1993).

The statistical links between the economy and the environment are being increasingly well defined. The international standard (currently in final draft stage) is *System of Integrated Economic and Environmental Accounting 2002* (SEEA) (United Nations Statistical Commission 2002). SEEA describes techniques for:

- accounting for the stocks and flows of natural resources
- accounting for other environment-related transactions (such as expenditures related to protecting the environment and managing natural resources)
- analysing the components of eco-efficiency improvements.

Issues to do with depletion of non-renewable resources, loss of biodiversity, improvements in resource efficiency, degradation of the physical environment and the linkages between economic growth and environmental impacts can be looked at using SEEA. Since it uses the same framework as economic statistics, it is also possible to assess environmental impacts directly alongside certain economic and social benefits. The Appendix discusses in depth the extension of the Australian national accounting framework to account for the environment at an economy-wide level. Individual resource accounts, which are presented elsewhere in this publication, provide supply and use information by industry.

Techniques for valuing environmental goods and services that are not part of the market economy

SEEA describes techniques for valuing environmental goods and services that are not part of the market economy. Neither GDP nor the National Balance Sheet seek to measure environmental goods and services which are not transacted. Nor do statistical agencies normally adjust the national accounts data to include those measures. The core SNA by and large deals with the market economy, and where possible it uses market values (or valuations which seek to approximate market values).

Techniques for valuing environmental goods and services that are not part of the market economy *continued*

Many environmental values are not part of the market economy, but much work has gone into developing methods which can translate environmental values into monetary terms. By doing this, trade-offs between environmental and economic objectives are presented in a common currency (dollars).

An alternative view is that social and environmental values may be devalued by measuring them in monetary terms (Hamilton & Deniss 2000). It is also difficult for an economic value to be attached if we do not know the extent and properties of the aspect of the environment we are attempting to value. Hence the development of economic valuation needs to proceed hand-in-hand with physical measurements of the environment, and the debate concerning the best way to integrate this information is ongoing.

Dollar values are determined for environmental assets using three broad types of technique:

- market-based
- use of surrogate markets
- simulated market approaches.

These are summarised in table 1.1. In general, values that can be observed or calculated from market transactions are considered more reliable than other techniques. Some of these market-based techniques are presented later.

Surrogate and simulated market approaches are harder to determine. For example, the use of contingent valuation (a simulated market approach) to assess environmental damage arising from mining at Coronation Hill (near Kakadu National Park) was heavily criticised, and many policy advisers in Australia remain skeptical about its use in decision-making (Bennett et al. 1997). Detailed descriptions and reviews of these methods are beyond the scope of this chapter, but several references are available (e.g. Winpenny 1991; Lothian 1999). In addition, the New South Wales Environment Protection Agency has on its web site (<http://www.epa.nsw.gov.au>) a database 'Envalue' which lists Australian and international studies that value the environment.

1.1 TECHNIQUES FOR ESTIMATING ENVIRONMENTAL VALUES IN MONETARY TERMS

Technique	*Description*	*Examples*
Market based		
Market value	The dollar value of traded goods, applied to total stocks whether traded or not	Land, timber and minerals in Australian National Accounts
Preventative expenditure	The money spent preventing or mitigating environmental harm	Environmental Protection Expenditures publication
Replacement cost	The money required to replace an environmental good or restore environmental integrity to an area	Mine rehabilitation, construction of an artificial wetland to replace a natural system that has been destroyed
Change in productivity	The dollar value of 'lost' production resulting from environmental change	Reduced agricultural yields caused by salinity or erosion
Change in income	Earnings foregone and costs of illness due to changes in the environment	Impacts of air pollution
Relocation cost	The dollar cost to maintain an activity or output moved for environmental reasons	Relocation of a recreational facility
Opportunity cost	Dollar value of alternative uses of the environment	The income derived from developing a national park into a tourist facility
Surrogate market approaches		
Hedonic pricing (property value technique)	The dollar value environmental factors contribute to property values	The difference between equivalent properties, one located in a highly polluted area, another in an area with little pollution
Travel cost	A dollar value estimated from the time and money people have spent travelling to and camping at a natural area or site	Includes fuel costs, wear and tear on vehicle, public transport costs, park entrance and camping fees, income foregone visiting the site and time spent at the site
Wage differential	Differences in wages assumed to be due to the environmental qualities of a region (i.e. higher wages paid in polluted, noisy areas)	Air pollution, workplace safety
Proxy good	The dollar value of a good with a market price, being substituted for an environmental good that provides for a similar or related experience or use	The cost of a swimming pool being assigned to a water hole commonly used for swimming
Simulated market approaches		
Contingent valuation	Survey techniques asking people to select a dollar value relative to their willingness to keep an environmental good or prevent environmental harm	Costs selected for reducing pollution or to conserve a natural area
Trade-off	Two alternatives are defined in terms of outcomes, one of which is monetary (i.e. a cost benefit scenario is described) and people are asked to choose which outcome they prefer	Analysing costs and benefits of allowing or banning commercial fishing
Contingent ranking and rating	People are asked to rank or rate alternatives and environmental values are imputed	Pollution and choosing priorities for protection

Source: Lothian 1999.

Accounting for environmental protection expenditure

Environmental protection expenditure (EPE) delineates, within the system of national accounts, the relevant transactions which have actually taken place to protect the environment. Since we, as a nation, choose to incur those expenditures, they represent the minimum value the society places on the environment.

Environmental protection activities are defined as those where the primary purpose is the protection of the environment, that is, the prevention, avoidance or remediation of the negative effects on the environment caused by economic activities.

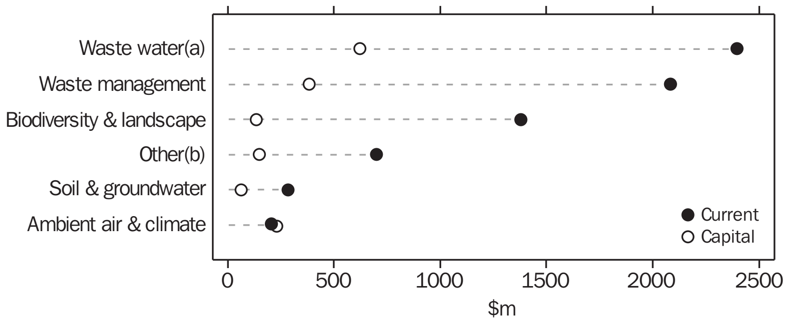
Accounting for environmental protection expenditure *continued*

Accounts of EPE can be used to analyse the effects of economic policy measures on environmental activities. They can also be used more simply to derive indicators to highlight change in key areas such as resources spent on pollution prevention and abatement, and associated savings, the contribution that the environment protection industry makes to economic growth, the shift to clean technologies etc.

EPE for Australia have been compiled across a range of sectors from 1990–91 to 1996–97 inclusive. The coverage of EPE has increased over time, as collection methodologies have evolved. For 1996–97, comprehensive environmental protection transactions were compiled across all sectors and industries (general government; households; and the agriculture, manufacturing, mining, utilities and services industries), with information collected for waste management; waste water management and water protection; ambient air and climate protection; protection of biodiversity and landscape; protection of soil and groundwater; and other environmental protection activities. Total expenditure for environment protection was estimated at $8.6b for 1996–97, representing approximately 1.6% of GDP (ABS 1999).

The majority of national expenditure to protect the environment was on waste water management and water protection ($3.0b) and waste management activities ($2.5b). Together these represented 63% of EPE (graph 1.2). Expenditure to protect biodiversity and landscape contributed a further 18% to total expenditure ($1.5b), with protection of ambient air and climate, and of soil and groundwater, representing only about 6% and 4% respectively. Chapters 2 to 5 explore environmental protection expenditure in more detail.

1.2 ENVIRONMENTAL PROTECTION EXPENDITURE, By domain — 1996–97



(a) Includes protection of water.
(b) Includes noise and vibration abatement, research and development.
Source: Environment Protection Expenditure Australia 1995–96 and 1996–97 (cat. no. 4603.0).

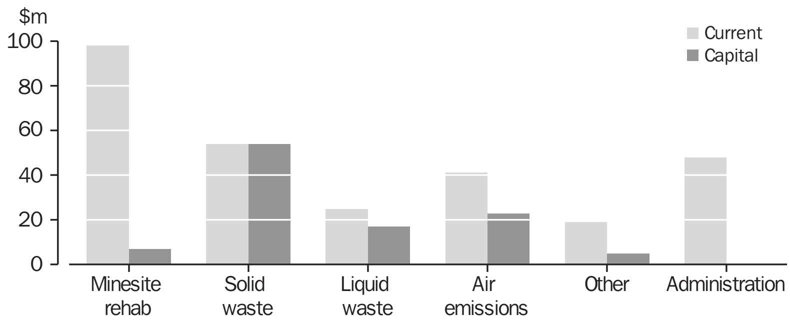
The 2001–02 Environment Management Survey identified environmental protection expenditure in the mining and manufacturing industries for the 2000–01 financial year (ABS 2002a).

Accounting for environmental protection expenditure *continued*

In the mining industry, approximately 65% of businesses undertook current environment protection expenditure. These businesses spent $284m on payments to government, payments to private organisations and other expenses in 2000–01. Current expenditure on environment management was less than 1% of total current expenses for this industry. Minesite rehabilitation accounted for $98m and solid waste management accounted for $54m (graph 1.3). Metal ore mining (ANZSIC 13) was the subdivision with the highest expenditure ($154m). Western Australia was the state with the highest expenditure ($105m).

Total capital environment protection expenditure for the mining industry was $107m, or 2% of total capital expenditure in the mining industry. Approximately 28% of mining businesses accounted for this amount. Solid waste management had the highest expenditure ($54m). Metal ore mining industry (ANZSIC 13) was the subdivision with the highest expenditure ($71m). Western Australia was the state with the highest expenditure ($61m).

1.3 ENVIRONMENTAL PROTECTION EXPENDITURE FOR THE MINING INDUSTRY, By domain — 2000–01

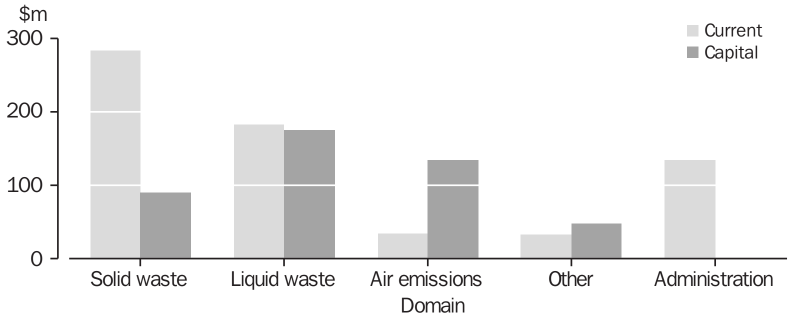


Source: Environment Protection, Mining and Manufacturing Industries, Australia, 2000–2001 (cat. no. 4603.0).

Total current environment protection expenditure in the manufacturing industry was $668m in 2000–01, less than 0.5% of total current expenditure. 70% of businesses undertook such expenditure in that year (graph 1.4). Food, beverages and tobacco manufacturing (ANZSIC 21) was the subdivision with the highest expenditure ($164m). New South Wales was the state with the highest expenditure ($212m). Total current environment protection expenditure on waste management was over $500m.

Capital environment protection expenditure accounted for nearly $438m, or 4% of total capital expenditure for the manufacturing industry. More than 17% of businesses in the manufacturing industry undertook capital environment protection expenditure in 2000–01. Liquid waste management accounted for $176m. Metal product manufacturing (ANZSIC 27) was the subdivision with the highest expenditure ($128m). New South Wales was the state with the highest expenditure ($138m).

1.4 ENVIRONMENTAL PROTECTION EXPENDITURE FOR THE MANUFACTURING INDUSTRY, By domain — 2000–01



Source: Environment Protection, Mining and Manufacturing Industries, Australia, 2000–2001 (cat. no. 4603.0).

Treatment of non-monetary values

Many environmental values are not usually described in monetary terms. The main ones are broadly described in table 1.5.

1.5 NON-MONETARY VALUES OF THE ENVIRONMENT

Value	*Example or description*
Source of natural resources	Timber, fish, land and water
Ecosystem services	Maintenance of water quality
Existence	Sense of wellbeing derived from knowing a natural place exists
Bequest	Sense of satisfaction derived from protecting a natural place for the enjoyment of future generations
Scientific	Teaching or research site
Aesthetic	Places valued by the community for scenic qualities
Cultural and social	Recreational activities (camping, bushwalking, recreational fishing)
Spiritual	Indigenous view of ‘country’ and sacred places

Source: Lothian 1999.

In some cases it is difficult to decide the most appropriate category for a value. For example, ecosystem services, such as maintenance of water quality, are important for agricultural production and human health. Both aspects rely on maintenance of water quality, and can be given an economic value. Water is also vital for the survival of all species; however, while a direct economic value can be calculated for some species which are used for food or clothing (kangaroos, crocodiles, possums, etc.), much of the value of species is non-economic. That is, animal and plant species have existence, bequest, aesthetic, cultural and spiritual values, and species are dependent for their survival on ecosystem services to maintain water quality. Therefore ecosystem services have both economic and non-economic values.

The multiple values of ecosystem services highlight the complex nature of the environment and the diverse range of views and interpretations about how environmental values are defined, categorised and measured.

THE ROLE OF ENVIRONMENTAL INDICATORS

Indicators are measures which quantify, simplify and communicate complex phenomena into a more readily used and understood form (Oakley 1997). The use of indicators is one way in which information on social, environmental and economic change can be presented and assessed together, relative to the principles and goals of environmental policy. In Australia, sets of indicators are the basis for State of the Environment Reporting. They also featured in the Australian Bureau of Statistics publication *Measuring Australia's Progress* (cat. no. 1370.0), first released in 2002. Environment Australia and other Commonwealth agencies have developed and published a core set of headline sustainability indicators aimed at assessing Australia's progress in relation to Ecologically Sustainable Development.

International indicator projects include the Organisation of Economic Co-operation and Development's environmental compendia, the Montreal Process for Forests, World Resources Institute compendiums, the Worldwatch Institute's State of the World Report, World Bank environmental indicators, and the United Nations (UN) World Commission for Sustainable Development. The progress of the UN's environment program and human development program are also routinely informed by indicator-based reporting. Readers interested in seeing the range and scope of international, national, regional, and local sustainability indicator projects are referred to the *Compendium of Sustainable Development Indicator Initiatives* at <http://iisd1.iisd.ca/measure/compinfo.htm>.

Implied in the selection and use of sustainability indicators is the idea that the information they convey is important to society, and that ignoring negative trends conveyed by an indicator is likely to result in adverse social, economic or environmental outcomes. Given the potential importance of this role, the quality of sustainability indicators is integral to sound decision-making.

Qualities of good indicators, including sustainability indicators, are that they:

- reflect a valued element of the environment, the economy or society
- are useful on a range of spatial scales
- are based on credible methods
- are cost effective
- are robust to change
- are readily interpreted
- are relevant to policy and management needs
- are monitored regularly (ANZECC 1999).

The remainder of this section outlines some examples of indicators which include social, economic and environmental dimensions.

Indicators used in *Measuring Australia's Progress*

The ABS publication *Measuring Australia's Progress* (cat. no. 1370.0) contains the following 'headline dimensions' and associated headline indicators (table 1.6).

1.6 MEASURING AUSTRALIA'S PROGRESS, HEADLINE DIMENSIONS AND INDICATORS

Headline dimension	*Headline indicator*
Health	Life expectancy at birth
Education and training	People aged 25–64 years with a vocational or higher education qualification
Work	Unemployment rate
Biodiversity	Number of extinct, endangered and vulnerable birds and mammals
Land clearance	Annual area of land cleared
Land degradation	Assets at risk in areas affected by salinity or in areas with a high potential to develop salinity
Inland waters	Proportion of water management areas where use exceeds 70% of sustainable yield
Air quality	Days in which health standards for fine particle concentrations are exceeded in selected capital cities
Greenhouse gases	Net greenhouse gas emissions
National wealth	Real national net worth per capita
National income	Real net national disposable income per capita
Economic disadvantage and inequality	Real equivalised average weekly disposable income of households in the second and third deciles of the income distribution
Housing	No headline indicator
Crime	Unlawful entry with intent and assault (victimisation rates)
Social attachment	No headline indicator

Source: Measuring Australia's Progress, 2002 (cat. no. 1370.0).

Headline sustainability indicators for Australia

Tables 1.7 to 1.10 present the core sustainability indicators developed by Environment Australia and other Commonwealth agencies to address the policy goals outlined in the National Strategy for Ecologically Sustainable Development. Readers interested in seeing how these indicators have been used to assess Australia's progress toward sustainable living are referred to *Headline Sustainability Indicators — National Report* (EA 2001).

The National Strategy for Ecologically Sustainable Development commits all Australian governments to the following three core objectives:

- to enhance individual and community wellbeing and welfare by following a path of economic development that safeguards the welfare of future generations
- to provide for equity within and between generations
- to protect biological diversity and maintain essential ecological processes and life-support systems.

For each of these objectives, a set of 'values' has been identified, each value representing one key aspect of the objective. Collective desirable trends against all of the values identified against an objective would be generally indicative that the objective is being achieved.

1.7 ENHANCING INDIVIDUAL AND COMMUNITY WELLBEING AND WELFARE

Value	Indicator	Units	Data	Year	Desired trend	Actual trend over last decade (if known)
1. Living standards and economic wellbeing	1. Gross National Income (GNI) per capita (GNI = GDP less net income paid overseas)	$	31 847	1999–2000	Up	Up
	2. Gross per capita disposable income	$	31 851	June 2000	Up	Up
2. Education and skills	3. Percentage of people aged 25–64 who have attained upper secondary and/or attained post secondary qualifications including vocational training	%	64.3	2000	Up	Up
3. Healthy living	4. Disability adjusted years life expectancy (DALE)	no.	71.16	1996	Up	na
4. Air quality	5. Number of occasions where concentrations of pollutants exceeded NEPM standards for ambient air quality in major urban areas	no.	98	1999–2000	Down	na
	6. Total SOx, NOx and particulate emissions	bill kg	3.6	1999–2000	Down	na

Source: Environment Australia 2001, 'Headline Sustainability Indicators — National Report'.

1.8 ECONOMIC DEVELOPMENT SAFEGUARDING WELFARE OF FUTURE GENERATIONS

Value	Indicator	Units	Data	Year	Desired trend	Actual trend over last decade (if known)
5. Economic capacity	7. Multifactor productivity (Gross product per combined unit of labour and capital)	%	1.1	1999–2000	Up	Up
6. Industry performance	8. Real GDP per capita	$	32 636	1999–2000	Up	Up
7. Economic security	9. (i) National net worth	$b	2 431.4	2000	Up	Up
	(ii) National net worth per capita	$	127 666	2000	Up	Up
8. Management of water	10. (i) Surface water units within 70% of sustainable yield	%	74	2000	Up	na
	(ii) Groundwater management units within 70% of sustainable yield	%	60	2000	Up	na
9. Management of forests	11. Total area of all forest types	mill ha	157	1998	Up	na
10. Management of fish	12. Percentage of major Commonwealth harvested wild fish species classified as fully or under fished	%	37	1999	Up	na
11. Management of energy	13. (i) Renewable energy use as a proportion of total	%	5.8	1998–99	Up	Down
	(ii) Total renewable and non-renewable energy use	PJ	4 858	1998–99	—	na
12. Management of agriculture	14. Net value of rural land (Interim indicator — Agreed indicator: 'net value of agricultural land use' not yet available)	$b	111.7	2000	Up	Up

Source: Environment Australia 2001, 'Headline Sustainability Indicators — National Report'.

1.9 PROVIDING FOR EQUITY WITHIN AND BETWEEN GENERATIONS

Value	Indicator	Units	Data	Year	Desired trend	Actual trend over last decade (if known)
13. Economic and gender equity	15. Adult female full-time (OT) average weekly earnings as a proportion of adult male full-time (OT) average weekly earnings	%	84.85	2001	Up	Unchanged
14. Economic and educational equity	16. Percentage difference in the Year 12 completion rate between bottom and top socioeconomic decile	%	16	1999	Down	Down
15. Economic and health equity	17. (i) Percentage difference in burden of life years lost due to disability between bottom and top socioeconomic quintile	%	41–45	1996	Down	na
	(ii) Percentage difference in burden of life years lost due to mortality between bottom and top socioeconomic quintile	%	26–41	1996	Down	na
16. Locational equity	18. Percentage difference in the Year 12 completion rate between urban and remote locations	%	12	1996	Down	Down

Source: Environment Australia 2001, 'Headline Sustainability Indicators — National Report'.

1.10 PROTECTING BIOLOGICAL DIVERSITY AND MAINTAINING ESSENTIAL ECOLOGICAL PROCESSES AND LIFE SUPPORT

Value	*Indicator*	*Units*	*Data*	*Year*	*Desired trend*	*Actual trend over last decade (if known)*
17. Biodiversity and ecological integrity	19. Extent and condition of native vegetation, freshwater habitats, coastal habitats, estuarine habitats and marine habitats including extent to which represented in reserves and non-reserve systems Actual indicators used:					
	(i) Proportion of (354) biogeographical sub-regions with greater than 30% of original vegetative cover	%	84	2000	Up	na
	(ii) Proportion of (354) biogeographical sub-regions with greater than 10% of the sub-region's area in protected areas	%	26	2000	Up	na
	20. Number of extinct, endangered and vulnerable species and ecological communities Actual indicators used:					
	(i) Number of extinct, endangered and vulnerable species	no.	1 560	2000	Down	Up
	(ii) Number of endangered ecological communities	no.	23	2000	Down	na
18. Climate change	21. Total net greenhouse gas emissions	Mt	458.2	1999	Down	Up
19. Coastal and marine health	22. Estuarine condition index — proportion of estuaries in near pristine or slightly modified condition	%	72	2001	Up	na
20. Freshwater health	23. Proportion of assessed sites which are with high in-stream biodiversity, based on macro-invertebrate community structure (Interim indicator — Agreed indicator: 'river condition index' not yet available)	%	60	2001	Up	na
21. Land health	24. Catchment Condition Index — proportion of assessed catchments that are in moderate or good condition	%	83	2001	Up	na

Source: Environment Australia 2001, 'Headline Sustainability Indicators — National Report.'

Single number summary indicators

In the same way that GDP is a single measure of production, many people have desired single measures of sustainable development and welfare which combine economic, social and environmental factors, and some measures have been developed. These single indicators require the aggregation of a variety of economic, social and environmental variables in the same way that GDP requires the aggregation of specific economic variables.

Some aggregate indicators combine information on a broad range of variables, which are either aggregated in monetary terms or weighted together to form a composite index. These indicators include:

- Genuine Progress Indicators (GPI) and Indicators of Sustainable Economic Welfare originally developed by Nordhaus and Tobin in the early 1970s (see the Australia Institute's web site <http://www.gpionline.net> which gives a GPI for Australia). The next section briefly discusses the GPI and its relationship to GDP
- the Index of Economic Wellbeing developed by Osberg and Sharpe (see Osberg & Sharpe 2000)
- the Genuine Savings measure developed by Pearce and Atkinson. This extends the traditional economic statistics boundaries to allow for environmental factors and human capital (see <http://www.worldbank.org>)

Single number summary indicators *continued*

- the 'wealth accounting' focus developed by the World Bank. This looks specifically at the composition of and changes in countries' wealth as the determinant of sustainability (see World Bank 2001).

Although single number summary indicators provide a simplicity of message, there remain too many concerns over their conceptual and statistical validity for them to be actively measured officially. Concerns relate to the lack of widely accepted frameworks, the difficulties in valuing environmental and social factors meaningfully and hence allowing aggregation, and the subjectivity of selecting and weighting variables to include in composite indices. Measuring dimensions of the environment and effectively integrating this information into economic and social decision-making is complex, and very much a work in progress.

Gross domestic product (GDP) and genuine progress indicators (GPIs)

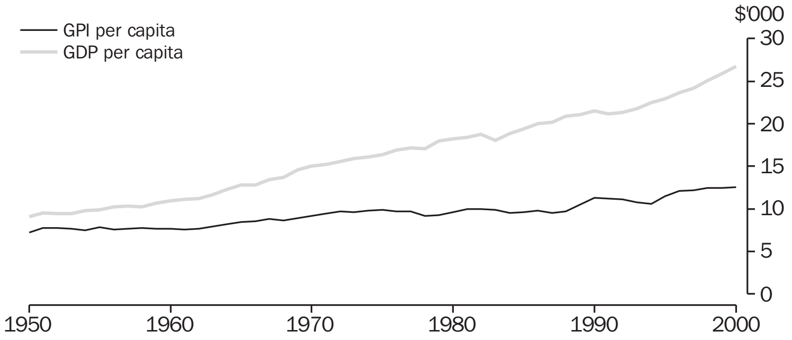
Changes in GDP broadly measure the extent to which an economy has grown or contracted over time. Hamilton and Deniss (2000) have argued that GDP is a misleading indicator of national welfare, because it does not account for the distribution of economic output within the community, the contribution of unpaid work such as housework, and changes in the value of natural capital (this includes environmental assets, such as healthy ecosystems).

They also note that defensive or negative expenditures, such as money spent to mitigate an environmental disaster or to protect against the socioeconomic effects of a crime wave, make a positive contribution to GDP.

Other commentators, however, point to correlations between rising GDP in nations and rising levels of wellbeing as measured by other indicators, with much of this evidence coming from international comparisons of both rich and poor nations (Castles 1997), and more broadly, that the system of national accounts provides a useful initial indicator of welfare (Mamalakis 1996).

An experimental composite indicator which seeks to directly address the perceived shortcomings of GDP as a broad national measure of welfare is the genuine progress indicator (GPI), sometimes termed an Index of Sustainable Economic Welfare. GPIs include and exclude dollar values for components making up GDP, in an attempt to derive a 'better' summary measure of national welfare by factoring in, among other things, environmental and social costs. Graph 1.11 compares GPI to GDP between 1950 and 2000, while graph 1.12 shows how the environmental components of the GPI influence the trend over the same period.

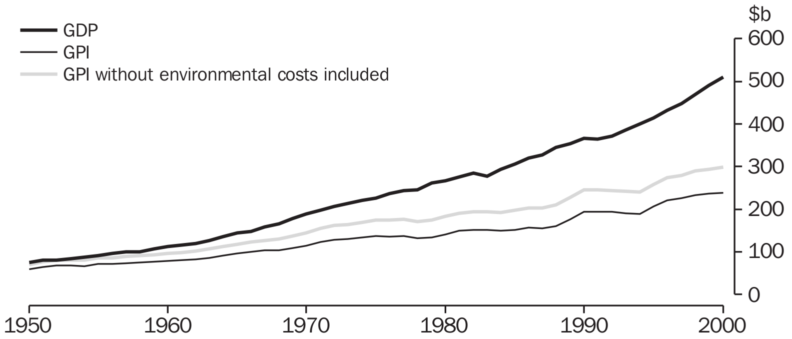
1.11 GPI AND GDP(a), PER CAPITA



(a) Adjusted for inflation. Reference year is 1989–90.

Source: Hamilton & Deniss 2000.

1.12 GPI AND GDP(a)



(a) Adjusted for inflation. Reference year is 1989–90.

Source: Hamilton & Deniss 2000.

GPIs have been strongly criticised on technical and conceptual grounds by some commentators (e.g. see Castles 1997). Some of the major difficulties are associated with what elements to include in the indicators and what relative weights to give to those elements.

Composite or highly aggregated environmental indicators

A related approach to summary indicators focuses specifically on measuring change in Australian environmental outcomes. Composite environmental indicators can be used to measure environmental change, an advantage being the simplicity of understanding and interpreting trends presented for a single number. However, because they are less transparent than more 'raw' forms of data, they can also be very misleading, and in the process of simplification, may lead to oversimplification of complex issues. Moreover, decision-makers looking to respond to a situation or issue are likely to need disaggregated data when looking to influence outcomes. Some examples of composite environmental indicators are outlined below.

Total material requirements

An aggregate measure of environmental pressure in Australia is the 'total material requirements' of the economy. In brief, total material requirements is an aggregate of the weight of materials that an economy uses or disturbs, and can be expressed in tonnes per person (Yencken & Wilkinson 2000). Total material requirements comprise the weight of the materials that enter the economy as commodities with a market value (e.g. tonnes of black coal and mineral ores, termed direct materials), and also the weight of materials disturbed or moved to produce these materials, and which do not have a market value (e.g. overburden from mining, or eroded soil from agriculture, termed hidden flows).

An important limitation of material requirements as an indicator of environmental pressure is that only the volume of materials used and/or disturbed is accounted for, while many important environmental effects are related to the nature of materials (such as their toxicity and behaviour in the biosphere). Information on trends in the total material requirements of the Australian economy is presented in Chapter 5, Waste and waste management in Australia.

Ecological footprints

International comparisons of ecological footprints were presented and discussed in the 2001 edition of *Australia's Environment: Issues and Trends*. In summary, an ecological footprint is a composite indicator, developed to show the land area a population uses to produce the natural resources it consumes and to assimilate the waste it generates. The larger the ecological footprint the more demanding that population is per person on natural resources and on the capacity of the environment to cope with waste products.

Criticism of ecological footprints arises from the way the model is constructed and the data that are included in the calculation: the size of the footprint is largely based on converting fossil fuel consumption into an estimate of the land area required to assimilate carbon dioxide emissions (Simpson et al. 2000). This approach conceals a great deal of the complexity involved when considering the effects of economic activity on the environment.

MEASURING NATURAL RESOURCES

The economy cannot function without drawing in natural resources from the environment and using the environmental media to absorb the unwanted by-products, or externalities, of economic production. Measuring the stocks of particular resources and their flows into the economy, and emissions from it, can provide information to help answer the following sorts of questions: Is there, or will there be in future, a scarcity of natural resources? How damaging are the effects of the outputs from the economy to the environmental media? Which sectors of the economy are having the greatest impact? Does this pose a threat to sustainability in the future?

MEASURING NATURAL RESOURCES *continued*

Issues of interest in the use of environmental resources include:

- the potential scarcity and increased use of natural resources (including minerals, fish and forests)
- the level of emissions into the environment (gases; liquids discharged directly or indirectly into rivers, estuaries, etc.; and solid waste going to treatment plants or landfill)
- environmental degradation, including land degradation and loss of biodiversity.

Many of these issues are addressed in this publication.

This section outlines the main approaches to measuring, in physical and monetary terms, the natural resources existing in and used by the economy. The ABS has compiled physical environmental accounts for a number of natural resources including fish, minerals, water, energy, and greenhouse gas emissions. The section begins by outlining a number of these accounts.

Energy account

Physical supply and use tables for energy products are useful for the analysis of energy savings and efficiency, as well as for the construction of supply tables for energy-related residuals, such as the greenhouse gases carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4).

Table 1.13 is an energy use table. It shows that the Australian economy is highly dependent on fossil fuels, with the electricity supply, manufacturing and transport industries having the highest use of energy products. A total of 4,866 petajoules (PJ) of primary energy was used domestically in 1997–98, with the manufacturing and electricity sectors accounting for more than 85%, as these sectors are responsible for transforming primary energy products into secondary energy products. The majority of fuels for primary energy production are exported (8,667 PJ).

1.13 PRIMARY ENERGY USE(a), BY INDUSTRY(b) — 1997–98

	Energy used									
	Firewood	*Black coal*	*Brown coal*	*Crude oil*	*Natural gas*	*LPG*	*Uranium*	*Bagasse*	*Solar*	*Total*
Industry	*PJ*	*PJ*	*PJ*	*PJ*	*PJ*	*PJ*	*PJ*	*PJ*	*PJ*	*PJ*
Agriculture	—	—	—	—	—	7	—	—	—	7
Mining	—	7	11	—	146	—	—	—	—	164
Manufacturing	27	271	8	1 672	359	39	—	113	—	2 489
Electricity	—	1 061	627	—	167	—	—	—	—	1 855
Construction	—	—	—	—	2	2	—	—	—	4
Transport	—	4	—	—	11	21	—	—	—	36
Other services	1	1	1	—	61	26	—	—	—	90
Total intermediate use	*28*	*1 344*	*647*	*1 672*	*746*	*95*	—	—	—	*4 645*
Household consumption	82	—	—	—	117	19	—	—	4	222
Total domestic use	*109*	*1 344*	*647*	*1 672*	*863*	*114*	—	*113*	*4*	*4 866*
Exports	—	4 613	—	547	416	76	3 015	—	—	8 667
Total use	**109**	**5 980**	**648**	**2 225**	**1 276**	**170**	**2 725**	**113**	**4**	**13 250**

(a) A distinction is made between primary and secondary energy sources (the production of which is a result of a conversion of primary energy types). There is potential for double counting because both primary energy (e.g. coal) and the converted energy (e.g. electricity produced by coal) are included. Hence, these amounts are not totalled in the use tables.

(b) Energy use is broken down into intermediate consumption by industries, private household consumption, and exports.

Source: Energy and Greenhouse Gas Emissions Accounts, Australia, 1992–93 to 1997–98 (cat. no. 4604.0).

1.14 SECONDARY ENERGY USE(a), BY INDUSTRY(b) — 1997–98

	Energy used								
	Automotive petrol	*Kerosene*	*Gas/fuel oil*	*Refinery products*	*Coal by-products*	*Coke*	*Electricity (Hydro)*	*Electricity (remainder)*	*Total*
Industry	*PJ*	*PJ*	*PJ*	*PJ*	*PJ*	*PJ*	*PJ*	*PJ*	*PJ*
Agriculture	9	—	89	—	—	—	1	9	108
Mining	1	—	98	1	2	—	4	44	150
Manufacturing	9	—	53	83	34	102	20	220	521
Electricity	—	—	26	1	—	—	8	83	118
Construction	7	—	62	—	—	—	—	—	69
Transport	70	180	164	—	—	—	1	8	423
Other services	37	—	41	—	—	—	11	129	218
Total intermediate use	*133*	*180*	*533*	*84*	*36*	*102*	*45*	*493*	*1 606*
Household consumption	492	1	32	—	—	—	13	153	691
Total domestic use	*626*	*181*	*565*	*84*	*36*	*102*	*58*	*646*	*2 295*
Exports	54	27	92	9	—	5	—	—	186
Total use	**674**	**204**	**650**	**97**	**36**	**124**	**58**	**646**	**2 489**

(a) A distinction is made between primary and secondary energy sources (the production of which is a result of a conversion of primary energy types). There is potential for double counting because both primary energy (e.g. coal) and the converted energy (e.g. electricity produced by coal) are included. Hence, these amounts are not totalled in the use tables.

(b) Energy use is broken down into intermediate consumption by industries, private household consumption, and exports.

Source: Energy and Greenhouse Gas Emissions Accounts, Australia, 1992–93 to 1997–98 (cat. no. 4604.0).

Greenhouse gas accounts

Greenhouse gas emissions are a major residual resulting from the use of these energy products. In Greenhouse gas accounts, emissions are attributed to the economic activity directly responsible for their generation. Thus emissions generated from electricity production are attributed to electricity suppliers and not to electricity consumers. The attribution of pollution (or resource use) to final users should be considered as an extension to the physical accounts that are discussed below in 'Integrating physical and monetary accounts'.

Emissions of CO_2, CH_4 and N_2O (the major greenhouse gases) are presented in carbon dioxide equivalents in table 1.15. The electricity supply industry accounted for nearly half of total energy-related emissions, followed by the manufacturing industry (17%) and households, which contributed around 13% (mostly motor vehicle use). Detailed information can be found in *Energy and Greenhouse Gas Emissions Accounts, Australia, 1992–93 to 1997–98* (cat. no. 4604.0).

1.15 ENERGY-RELATED GREENHOUSE GAS EMISSIONS, SUMMARY — 1997–98

	Carbon dioxide (CO_2)	*Methane (CH_4)*	*Nitrous oxide (N_2O)*	*Total*
Emitter	*Gg CO_2-e*	*Gg CO_2-e*	*Gg CO_2-e*	*Gg CO_2-e*
Agriculture	7 081	23	84	7 188
Mining	15 059	33	44	15 136
Manufacturing	56 748	60	358	57 166
Electricity	168 197	79	569	168 845
Construction	4 885	13	60	4 958
Transport	30 272	126	540	30 939
Other services	9 497	35	247	9 780
Households	40 671	2 021	2 896	45 587
Total	**332 410**	**2 390**	**4 797**	**339 597**

Source: Energy and Greenhouse Gas Emissions Accounts, Australia, 1992–93 to 1997–98 (cat. no. 4604.0).

Water account

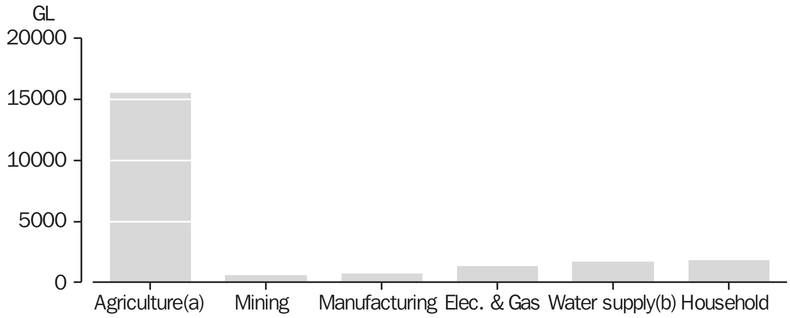
The nature of Australia's climate, combined with a limited supply of water resources in major agricultural and urban areas, means that ineffective and inappropriate use of water can result in serious environmental problems.

Water Account for Australia, 1993–94 to 1996–97 (cat. no. 4610.0) provided the first national overview of water use in Australia since 1985 (AWRC 1987a & b). The water account describes the physical flow of the water resource from the environment through various economic sectors. The data are presented in the form of water supply and water use tables for each state and territory, and Australia as a whole. The publication also contains information on regulated discharge and effluent reuse. The framework used to collect and present the data facilitates the integration of physical and monetary data (see Chapter 2, Agriculture and the Environment for more information on integrated environmental and economic indicators for water).

Water account *continued*

In 1996–97 an estimated 68,703 GL of surface water and groundwater were extracted from the environment for various uses. Most of this amount was in-stream use (46,517 GL, primarily for hydro-electric power generation) and discharged directly back to surface waters, resulting in net water consumption totalling 22,186 GL. The agricultural sector is by far the largest net consumer of water in Australia (15,502 GL in 1996–97) (graph 1.16). Water use in the agricultural sector and its impacts are further explored in Chapter 2.

1.16 NET WATER CONSUMPTION, By sector — 1996–97



(a) Includes services to agriculture; hunting and trapping.
(b) Includes sewerage and drainage services.

Source: Water Account for Australia, 1993–94 to 1996–97 (cat. no. 4610.0).

Integrating physical and monetary accounts

The physical flow information described in the previous section can also be integrated with monetary data in the national accounts. Integrated economic and environmental accounting systematically records physical flows in connection with economic transactions as presented in the national accounts. The analytical power of physical flow data and matching indicators is greatly increased when they are linked to the economic accounts structure and related economic statistics.

By manipulating Input-Output matrixes, integrated economic and environmental accounting can also be used to allocate to final products the resources used or the emissions generated by production processes. The physical accounts described in the previous section show the direct amount of resource use or pollution generated by various production and consumption activities. Each production or consumption process aims eventually to satisfy human consumption needs — either locally or for an overseas market. Using integrated economic and environmental modelling, the energy and pollution requirements of the final products can be analysed. These energy or emissions requirements can then be allocated to the final users.

Table 1.17 shows that household consumption accounted for about 56% of Australia's energy-related greenhouse gas emissions. The production of goods and services for export contributed a further 23% to total (energy) emissions, with the bulk of the remainder attributed to gross capital formation and government final consumption.

Integrating physical and monetary accounts *continued*

The production of electricity for household consumption was the single largest contributor to (energy-related) greenhouse gas emissions (over 50,000 Gg CO_2-e). Direct emissions from households (mainly motor vehicle use) were the next largest contributor (44,000 Gg CO_2-e). Together these accounted for almost one-third of Australia's energy-related greenhouse gases.

Other significant contributions include emissions induced by demand for: construction (the products of which have a high embodied energy content); basic non-ferrous metals and metal products, almost wholly for export; and products of wholesale, retail and repairs, the bulk of which is consumed by households. Each of these contributed about 7% towards total greenhouse gas emissions.

1.17 PRODUCTION OF ENERGY-RELATED GREENHOUSE GASES BY FINAL USE, TOP TEN USERS — 1994–95

	Production of energy-related greenhouse gases for				
	Household final consumption	*Exports*	*Gross fixed capital formation*	*Government final consumption*	*Total(a)*
Final user	*Gg CO_2-e*	*Gg CO_2-e*	*Gg CO_2-e*	*Gg CO_2-e*	*Gg CO_2-e*
Electricity	51 036	305	2 006	1 806	55 153
Direct consumption by households(b)	44 051	—	—	—	44 051
Construction	—	48	20 464	885	21 397
Basic non-ferrous metal and products	550	19 058	36	—	19 752
Wholesale, retail, repairs	14 866	1 928	2 851	4	19 730
Mining	224	13 568	1 067	70	14 161
Accomm., cafes, restaurants; cultural & recreational; personal & other services	10 638	886	87	2 444	14 057
Finance & insurance; ownership of dwellings; property & business services	10 581	544	1 382	285	12 791
Education, health & community services	3 824	371	28	7 852	12 075
Transport equip.; other machinery	2 608	3 051	5 810	—	11 788
Total(c)	**170 514**	**69 317**	**36 553**	**25 638**	**302 958**

(a) Includes change in inventories.

(b) Refers to the direct production of emissions by households, mainly through motor vehicle fuels. Other less significant contributors include use of gas and firewood.

(c) Total greenhouse gas emissions. Will not equal total of top ten products with highest emission requirements.

Source: Energy and Greenhouse Gas Emissions Accounts, Australia, 1992–93 to 1997–98 (cat. no. 4604.0).

By directly linking economic and environmental information it is possible to see what economic and social benefits are derived from use of the environment, and which uses provide the greatest benefits. In this context use of the environment refers to both the consumption of natural resources (e.g. timber, coal, water) and the production of pollution, where the environment is used as a sink (e.g. greenhouse gases).

Eco-efficiency — combining environmental, social and economic indicators

A concept related to Ecologically Sustainable Development is eco-efficiency. It may be defined as 'the efficiency with which ecological resources are used to meet human needs', and is sometimes described as doing more with less. Eco-efficiency can be thought of as a ratio of outputs to inputs, assessed relative to social, economic and environmental goals. The ratio, in this context, is an output divided by an input. The output is the positive value to society of products and services produced by a firm, sector, or the economy as a whole, and the input is the sum of environmental pressures generated by the firm, sector or economy. This foundation to eco-efficiency is very broad and can be controversial, as assessment of 'value' may include the influence of a product or service on human welfare in terms other than monetary, such as its influence on social, political, economic and environmental goals.

At a more practical level, the concept of eco-efficiency is used to set specific, measurable goals for industries and industrial processes which are aimed at improving environmental performance, for example, inputs (such as units of energy or water used) per unit of production. Measuring environmental inputs and performance per unit of production is typically aimed at: reducing the material and energy intensity of goods and services; minimising toxic waste and pollution; enhancing the capacity of materials to be recycled; maximising the use of renewable resources; and extending the durability of products.

Collecting data on inputs and outputs is a basic requirement for measuring eco-efficiency. The data collected also need to be relevant to identified environmental and socioeconomic goals. Examples of national input and output indicators of eco-efficiency are shown for Australia in table 1.18.

1.18 EXAMPLES OF INPUT AND OUTPUT INDICATORS, NATIONAL LEVEL

Indicator	*Units*	*1989–90*	*1998–99*	*Percentage change*
Environmental indicators (input)				
Consumption of coal	kt	95 287	127 924	34.3
Consumption petroleum products	ML	41 678	48 974	17.5
Consumption wood	kt	6 215	6 887	10.8
Greenhouse gas emissions (CO_2-e)	Mt	390.3	458.2	17.4
Estimated land cleared	ha/year	475 000	425 000	–10.5
Energy consumption	PJ	3 946	4 858	23.1
Social and economic indicators (output)				
GDP(a)	$m	440 584	591 546	34.3
Household disposable income per capita(b)	$	17 495	20 523	17.3
Education (bachelor degree or higher)	%	8.9	15.4	73.0

(a) Chain volume measures, 1997–98 reference year.

(b) Real prices, 1997–98 reference year.

Source: Australian National Accounts: National Income, Expenditure and Product, June 2002 (cat. no. 5206.0); Energy and Greenhouse Gas Emissions Accounts, Australia, 1992–93 to 1997–98 (cat. no. 4604.0); ABARE 2001; NGGI 2002.

Eco-efficiency — combining environmental, social and economic indicators *continued*

Table 1.18 lists examples of national indicators of input and output which could be used to broadly assess eco-efficiency. Socioeconomic outputs listed include: gross domestic product, changes in which indicate the overall growth or contraction of the national economy; average household income per capita, which provides an insight into the material quality of life through the capacity of people to consume goods and services; and the proportion of the population with a degree, which is arguably indicative of the number of people satisfying a higher human need through educational attainment and its intrinsic (as well as material) rewards.

Of the input indicators, consumption of oil and coal is a pressure on the environment because they are non-renewable (see Glossary) and have polluting effects on the biosphere from use and production; consumption of wood (a renewable energy source) is a pressure because of wood smoke and adverse effects on biodiversity when wood is harvested from native ecosystems; greenhouse gas emissions contribute to the threat of accelerated global warming; and land clearing has adverse effects on ecosystems.

The data in table 1.18 can be used to show how the relationship between outputs and inputs may be used to make judgements about eco-efficiency. For example, in 1989–90 for every $1,128m of GDP there was 1 Mt of greenhouse gases produced ($440,584m/390.3 Mt CO_2-e = $1,128m/Mt CO_2-e). In 1998–99 the equivalent figure was $1,291m/Mt CO_2-e an increase of $163m/Mt CO_2-e, and as such eco-efficiency, as measured by GDP to CO_2-e, increased between 1989–90 and 1998–99. Another example is average household income per capita for every PJ of energy consumed. In 1989–90 the figure was 4.43 ($ per household/PJ in 1997–98 prices) but in 1998–99 this had fallen to 4.42, representing a slight decrease in eco-efficiency. More examples are provided in the next section.

An important point in relation to the indicators presented in table 1.18 is that they have little meaning relative to eco-efficiency unless they are assessed against explicit quantitative targets, with a measurable end point (i.e. a target date). These targets can be set in a broader policy context, and provide the basis from which national governments could interpret changes in any indicators used. For example, in 1988 Environment Ministers from the OECD agreed ‘to promote innovative approaches, such as eco-efficiency, aiming to achieve substantial improvements in resource productivity, for example by a factor of 4 and eventually 10’ (OECD 1999, in Yencken & Wilkinson 2000). Meeting factor 10 productivity targets as described by the OECD requires industrialised nations to set and implement eco-efficiency measures which reduce the use of key resources (e.g. fossil fuels) by as much as 90% within 30 to 50 years (Yencken & Wilkinson 2000).

Eco-efficiency — combining environmental, social and economic indicators *continued*

The data presented in table 1.18 focus on two points in time and the magnitude of change between them. The concept of eco-efficiency can also be used to compare industry sectors, or be narrowed further to examine component parts of an individual business. Table 1.19 compares three industry sectors, using energy consumed during production in Australia (consumption excludes energy exported as energy products), expressed per person employed. In this case, energy consumed during production is the input, and people directly employed is the positive benefit or output derived by society. Table 1.19 shows that in 1998–99, agriculture consumed less energy per person directly employed than either manufacturing or mining.

1.19 COMPARISON OF THREE INDUSTRY SECTORS, ENERGY CONSUMED BY PRODUCTION PER PERSON EMPLOYED — 1998–99

Industry sector	*TJ consumed*	*Employment*	*TJ consumed per job*
Agriculture	70 100	421 800	0.17
Mining	264 500	79 600	3.32
Manufacturing	1 177 000	1 082 500	1.09

Source: Labour Force Survey, data available on request; ABARE electronic datasets.

Total fuel and energy used in Australia is a different concept to domestic energy consumption in that the energy embodied in exported energy products, like uranium, is included as a use in national accounting terminology. Table 1.20 shows that although the Australian economy has grown considerably since 1977–78, the nation consumed and exported (in total) more energy per $100m of GDP in 1997–98 than was the case twenty years earlier. This is the consequence of the fact that total energy use has increased at a faster rate than GDP over this period.

1.20 RATIO OF ENERGY USED(a) TO GDP(b)

	GDP	*Energy used*	*Energy used/GDP*
	$m	*PJ*	*PJ/$100m*
1977–78	291 211	4 838.8	1.66
1982–83	327 778	7 006.9	2.14
1987–88	408 191	9 103.2	2.23
1992–93	457 735	9 665.3	2.11
1997–98	565 881	13 666.7	2.42

(a) Total energy used is an aggregate of energy consumption, conversion losses and energy exported as energy products (e.g. uranium).

(b) Chain volume measures, reference year 1997–98.

Source: Australian National Accounts: National Income, Expenditure and Product, June 2002 (cat. no. 5206.0); Australian System of National Accounts (cat. no. 5204.0); ABARE, unpublished data.

Natural resources and the National Balance Sheet

The ABS produces annual estimates in real terms of some of Australia's natural resources, namely land, minerals and native timber. At 30 June 2001 the values were estimated at $908b, $143b and $2b respectively. The environmental assets on the National Balance Sheet are presented in table 1.21.

Natural resources and the National Balance Sheet *continued*

Land is different to other natural assets as it cannot be created or destroyed in large amounts. It can, however, be degraded through depletion of soil nutrients, salinity, etc. This issue is discussed more fully in Chapter 2, Agriculture and the environment.

The National Balance Sheet is prepared using the methods described in the publication *Australian National Accounts: Concepts, Sources and Methods* (cat. no. 5216.0). The methods accord with the latest international standard for national accounts statistics, SNA93. This framework recognises the need to better integrate economic and environmental accounting, to be able to account for some of the impacts of human activity on the environment. The appendix outlines the work being undertaken to take account of environmental assets in the Australian System of National Accounts.

1.21 AUSTRALIA'S ENVIRONMENTAL ASSETS, CHAIN VOLUME MEASURES(a) — AS AT 30 JUNE

	1993	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*
	$b	*$b*	*$b*	*$b*	*$b*	*$b*	*$b*	*$b*	*$b*
Land	781	805	824	805	824	839	860	886	908
Subsoil assets	110	108	129	124	135	139	136	137	143
Native standing timber	3	3	3	3	3	3	2	2	2
Plantation standing timber	6	7	7	7	7	8	8	8	8
Total environmental assets	900	922	963	939	969	988	1 006	1 034	1 061

(a) Reference year for chain volume measures is 1999–2000.

Source: Australian National Accounts: National Income, Expenditure and Product, June 2002 (cat. no. 5206.0).

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CHAPTER 2 AGRICULTURE AND THE ENVIRONMENT

INTRODUCTION

Agriculture is an important part of the Australian economy. In 1999–2000 the gross value of agricultural production was over $30b, and the sector provided jobs for around 319,000 people on some 146,000 farms, while rural exports (including meat, cereals and their preparations and wool) made up $23.6b worth of exported goods. Furthers details of agricultural production and the contribution of this industry to the economy can be found in *Agriculture, Australia* (cat. no. 7113.0).

As for other industry activities, agricultural activity has a range of environmental consequences. The impacts of the agriculture sector can be seen particularly through its use of land and water. Agriculture is the largest user of land and water in Australia. Around 456 million hectares (ha), some 60% of the Australian landmass, were used for agriculture in 1999–2000; in 1996–97, the latest year for which data are available, agriculture used some 15,500 gigalitres (GL) of water, or 70% of total water used.

This chapter examines aspects of Australian agriculture and its environmental impacts. It focuses on the period 1990 to 2000, which saw substantial changes in the agricultural sector. Agricultural practices changed in response to market forces, increased awareness of land degradation and a recognition of the need to reduce the impact of agriculture on the environment. A significant change has been a substantial growth in the amount of land devoted to crops; this has led to increases in the use of energy, water, fertilisers and other farm chemicals. The environmental implications of these changes are important. For example, increases in the use of fertiliser can sometimes contribute to water pollution and the incidence of algal blooms, and some farm chemicals are linked to human health risks. The chapter also addresses land degradation.

AGRICULTURE BETWEEN 1990 AND 2000

The ways in which land and water are used play a large part in determining the profitability and environmental sustainability of agricultural systems. Farmers largely decide how land and water are used on their holdings. Rainfall and the natural soil conditions play an important part in determining which agricultural activities can be undertaken at particular places and times, while the prices paid for different agricultural commodities also strongly influence farmers' decisions. These factors are constantly changing, resulting in changing land use patterns. Changes to land use are often difficult to assess in the short term, but over longer periods trends can be seen. This section examines changes to agriculture between 1990 and 2000.

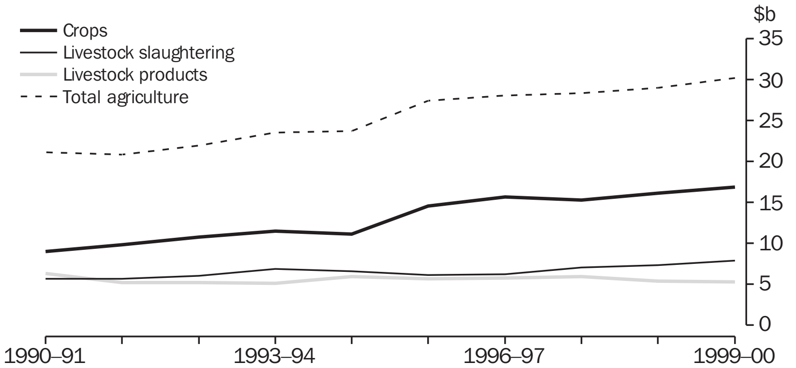
The volume and value of agricultural production increased over the decade 1990 to 2000 (graphs 2.1 and 2.2). Between 1990–91 and 1999–2000 the value of agricultural production increased from just over $20b to $30b, largely due to the greater volume of crops produced. The growth in volume was achieved through increases in the area planted to crops (discussed later) and increased yields (tonnes/ha) for many crops.

2.1 VOLUME OF AUSTRALIAN FARM PRODUCTION

(a) Reference year: 1997–98 = 100.0.

Source: ABARE 2001.

2.2 GROSS VALUE OF AGRICULTURAL PRODUCTION, Current prices



Source: Agriculture, Australia, 1999–2000 (cat. no. 7113.0).

Prices received for commodities declined slightly between 1989–90 and 1999–2000 (graph 2.3). There was, however, a long-term decline (over several decades) in the prices received for commodities (NLWRA 2002). The response of many farmers was to increase the area planted with crops, in order to maintain or increase incomes (Muaradian & Martinez-Alier 2001). Producing more commodities to compensate for lower unit prices has been described as an environmental 'race to the bottom', implying that this approach carries with it unacceptable environmental costs (Daly 1993).

2.3 INDEX OF PRICES RECEIVED BY FARMERS

(a) Reference year: 1997–98 = 100.0.

Source: ABARE 2001.

AGRICULTURE BETWEEN 1990 AND 2000 *continued*

The growth in the value of Australian crop production has been matched by growth in the area planted with crops. In 1990 just under 17 million ha were used to grow crops, but by 2000 this had risen to nearly 24 million ha, a 40% increase (table 2.4).

2.4 LAND(a) USED FOR AGRICULTURAL PRODUCTION

	1990	*2000*	*Change*
	'000 ha	*'000 ha*	*%*
Crops(b)	16 953	23 769	40.2
Sown pastures and grasses	30 861	23 814	–22.8
Agricultural land(c)	466 561	455 516	–2.4
Non-agricultural land(d)	301 723	313 687	4.0
Total land(e)	**768 284**	**769 203**	**—**

(a) Agricultural land is generally divided into cropped land, sown land to pastures and grasses, and a broad balance comprising grazing land, land lying idle or under fallow, etc.

(b) Excludes crops harvested for hay and seed.

(c) Total area of establishments with Estimated Value of Agricultural Operations (EVAO) of $5,000 or more.

(d) Comprises conserved land forestry, urban and unused land such as vacant Crown land, commercially unused land on Aboriginal and other Crown reserves, and waste land, ephemeral lakes, mangrove swamps, etc., as well as establishments not included in the scope of the Agricultural Commodity Survey.

(e) Total area for Australia includes Jervis Bay Territory.

Source: Agriculture, Australia, 1999–2000 (cat. no. 7113.0); Summary of Crops, Australia, 1990–91 (cat. no. 7330.0).

The area under crops also changed in its composition (table 2.5). For example, the area of canola increased from 50,000 ha in 1990 to almost 2 million ha in 2000. In the same period the areas of cotton, lupins and grain sorghum each increased by more than 60%, but the area of oats fell by 46%.

2.5 AREA OF SELECTED CROPS

	Units	*Cotton*	*Canola*	*Wheat*	*Barley*	*Hay*	*Lupin*	*Oats*	*Rice*	*Grain sorghum*
1989–90	'000 ha	240	50	9 004	2 310	1 319	801	1 089	105	380
1990–91	'000 ha	279	73	9 218	2 556	1 031	793	1 044	89	378
1991–92	'000 ha	312	151	7 183	2 744	1 163	939	1 160	114	569
1992–93	'000 ha	287	107	8 275	2 947	1 087	1 032	1 149	106	427
1993–94	'000 ha	293	177	8 383	3 424	1 251	1 150	947	125	499
1994–95	'000 ha	245	356	7 891	2 470	na	1 407	897	119	687
1995–96	'000 ha	315	377	9 221	3 111	1 685	1 323	1 136	137	770
1996–97	'000 ha	378	407	10 936	3 366	1 284	1 259	1 052	152	544
1997–98	'000 ha	381	698	10 441	3 521	1 427	1 425	937	147	507
1998–99	'000 ha	446	1 247	11 543	3 167	1 568	1 406	909	148	587
1999–2000	'000 ha	435	1 911	12 168	2 596	1 373	1 347	584	131	622
Change 1989–90 to 1999–2000	'000 ha	195	1 861	3 164	286	54	546	–505	26	242
Change 1989–90 to 1999–2000	%	81	3 722	35	12	4	68	–46	25	64

Source: ABS data available on request, Agricultural Commodity Survey.

AGRICULTURE BETWEEN 1990 AND 2000 *continued*

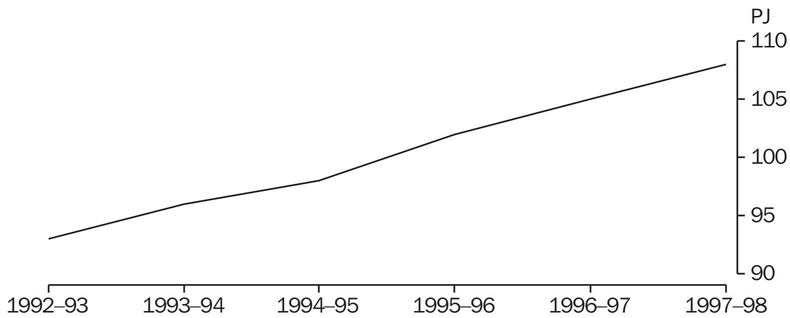
Most forms of cropping require larger inputs than grazing, in terms of the use of water, energy, farm chemicals and fertilisers. Therefore, increases in the area used for cropping are associated with an increased use of other agricultural inputs (graphs 2.6–2.9). Consumption of water fluctuated during the 1990s, but overall there was an increase between 1993–94 and 1996–97 (graph 2.6). The use of water by agriculture, and the impacts of water use, are discussed in more detail later in the chapter. Energy consumption by agriculture steadily increased over the period 1992–93 to 1997–98 (graph 2.7). The main direct environmental impact of energy consumption is the generation of greenhouse gases produced by burning fossil fuels. Greenhouse gases are also produced by livestock (methane), from soils used for agriculture (nitrous oxide) and from burning. In 1999 agriculture, excluding the gases produced from energy use in the sector, produced 94 Mt CO_2-e and accounted for just under 21% of Australia's greenhouse gas emissions (AGO 2001). Machinery can compact the soil, which can significantly reduce agricultural production of affected soils (Gretton & Selma 1996).

2.6 NET WATER CONSUMPTION IN AGRICULTURE(a)

(a) Excludes services to agriculture; hunting and trapping.

Source: Water Account for Australia, 1993–94 to 1996–97 (cat. no. 4610.0).

2.7 ENERGY CONSUMPTION IN AGRICULTURE, FORESTRY AND FISHING(a)



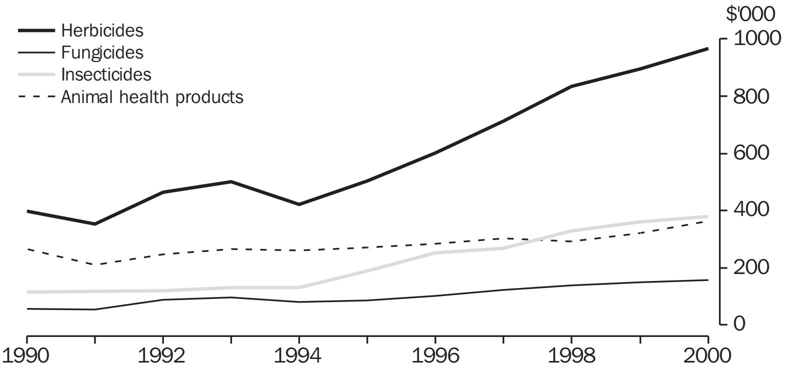
(a) Includes use of primary and secondary energy products.

Source: Energy and Greenhouse Gas Emissions Accounts, Australia, 1992–93 to 1997–98 (cat. no. 4604.0).

AGRICULTURE BETWEEN 1990 AND 2000 *continued*

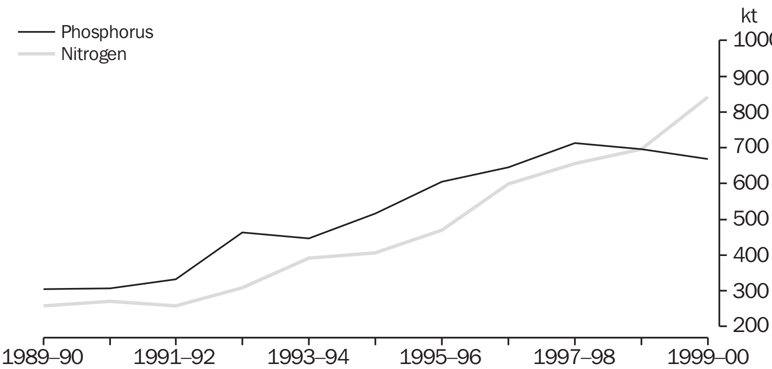
The use of farm chemicals and fertilisers increased between 1990 and 2000. Sales of farm chemicals such as herbicides and insecticides more than doubled (graph 2.8). The price index for farm chemicals rose from 93.2 in 1989 to 101.6 in 2000, an 11% increase, suggesting that the increase in value of sales was due mainly to use of a greater volume of chemicals. For example, the amount of phosphorus use more than doubled, while nitrogen use more than tripled (graph 2.9).

2.8 SALES OF FARM CHEMICALS, By type of chemical



Source: ABARE 2001.

2.9 FERTILISER CONSUMPTION (PHOSPHORUS AND NITROGEN)



Source: ABARE 2001.

Each commodity requires its own suite of inputs, which means that the production of each commodity has different impacts on the environment. For example, rice requires large volumes of water to grow, so an increase in production can be expected to lead to an increase in water consumption, although this may not always be the case as water use efficiency can also increase. There has been a massive increase in canola production during the decade to 1999–2000 (3,700%). There is also commercial interest in the development and use of genetically modified (GM) canola, which poses a new set of environmental concerns (see the section Genetically Modified Organisms).

AGRICULTURE BETWEEN 1990 AND 2000 *continued*

Grazing occurs over large parts of Australia. In addition to the agricultural land surveyed by the Australian Bureau of Statistics (ABS), some privately owned forests and publicly owned multiple use forests are also grazed. ABS data for 1990–2000 indicate that the area devoted to grazing, pastures and grasses, and other agricultural land decreased (see table 2.4). However, because of changes to the ABS definitions of pastures and grasses and in the sampling strategy used in ABS agricultural surveys, the results should be interpreted cautiously. ABS data on livestock show increased numbers of beef and dairy cattle, but a reduced number of sheep (table 2.10). The steady decline in sheep numbers was largely the result of continuing low wool prices (Hamblin 2000).

2.10 LIVESTOCK NUMBERS

	Units	*Sheep*	*Dairy cattle*	*Beef cattle*
1989–90	millions	173.38	2.59	22.28
1999–2000	millions	118.55	3.14	24.45
Change	millions	–54.83	0.55	2.17
Change	%	–31.6	21.2	9.7

Source: Agriculture, Australia, 1999–2000 (cat. no. 7113.0).

Most grazing occurs in rangelands — areas of native grasslands, shrublands and woodlands that cover a large proportion of the arid and semi-arid regions of Australia. Although stocking rates are low, grazing in these regions is considered partly responsible for the extinction of many plant species and continues to threaten around one-quarter of the plant species listed as endangered (SoE 2002).

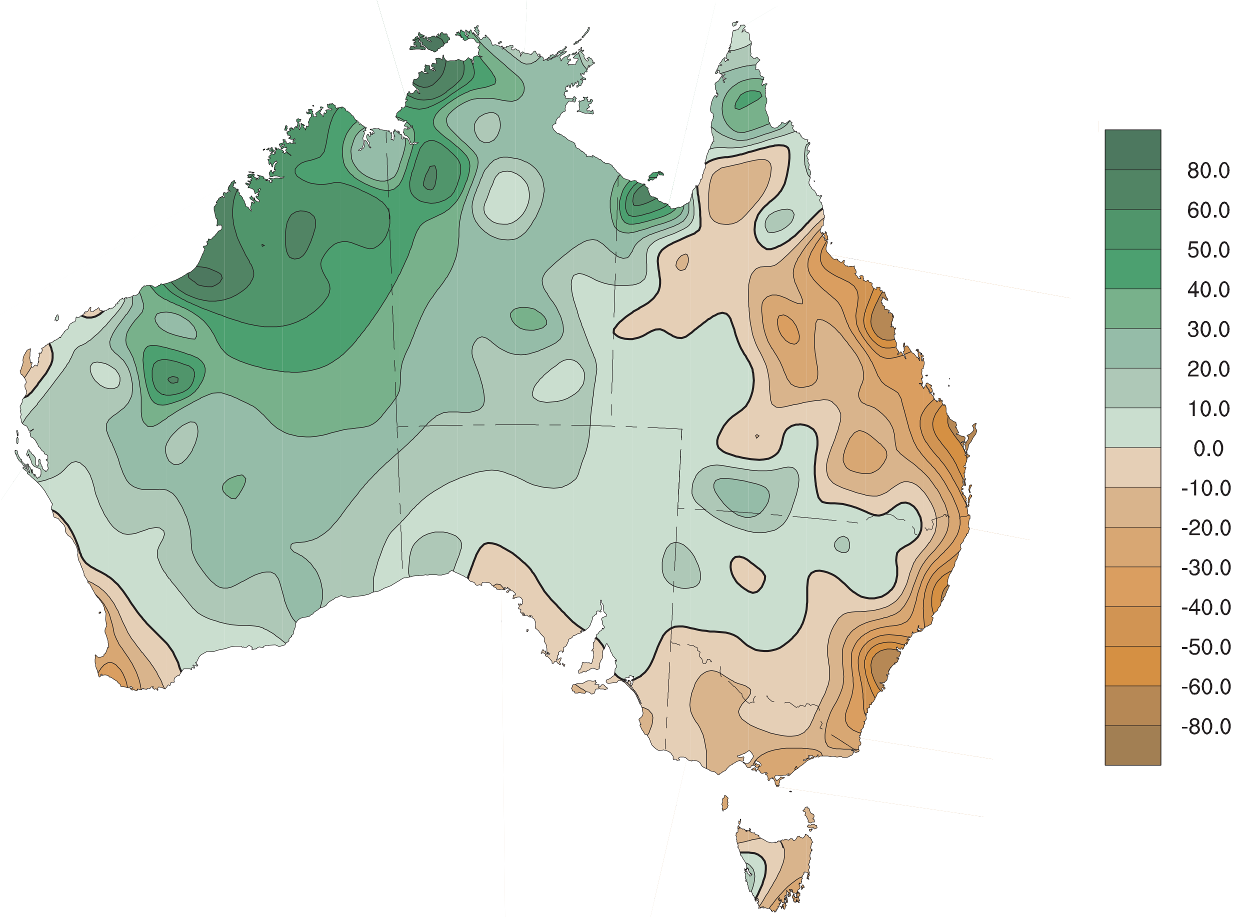
The amount of grazing pressure that can be sustained without causing an increase in bare soil, and hence the potential for erosion, varies greatly with the type of pasture, animal species and production needs, and the season. Good grazing management requires careful attention to pasture and animal condition. The ability of rangelands to recover from overgrazing depends on the removal of the pressures that caused the degradation and the time to the next sustained wet phase — often more than two or three decades.

WATER

Rainfall, run-off and groundwater

The amount of water available for agriculture (and all other users of water) is determined by rainfall, run-off and the amount of groundwater. Run-off is the amount of rainfall that reaches streams, or storages such as dams. Australia is a relatively dry continent; some 80% of it is arid or semi-arid. Annual rainfall is unevenly distributed, both geographically and seasonally. The vast majority of annual rainfall occurs along the coastal and surrounding regions, particularly in the north and east of the continent. The pattern of rainfall in Australia has changed between 1950 and 2001 (map 2.11). One of the most important changes is that prime agricultural regions in eastern and western Australia, and particularly those adjacent to the coast, are receiving less rain than they did 50 years ago.

2.11 AVERAGE ANNUAL RAINFALL (mm/10 YEARS) — 1950 TO 2001



Note: The average trend (mm/decade) in annual total rainfall over Australia over the past half century, showing the strong trend towards wetter conditions over north-west Australia and a drying trend over much of eastern Australia and the southwest corner.

Source: Bureau of Meteorology.

Australia has 246 river basins which drain into 12 major drainage divisions. Some details of these are presented in table 2.12. The drainage divisions vary enormously in size; the smallest is Tasmania (68,000 km^2) and the largest the Western Plateau (2,450,000 km^2). The area of each drainage division does not reflect the relative mean annual run-off. For example, despite its great size the Western Plateau has one of the lowest levels of run-off (1,486 GL). All 12 drainage divisions support agriculture, but they each have different run-off patterns. Three drainage divisions account for over 65% of the total run-off, while the six with the least amount of run-off account for slightly less than 6% of the total.

Approximately 68% of the Australian landmass has access to groundwater, either through bores or natural springs. It has been estimated that 25,780 GL of groundwater suitable for drinking or use in agriculture can be extracted each year in a sustainable manner (NLWRA 2000). Currently about 10% (2,489 GL) is actually used in this way. Groundwater cannot be used for all types of agriculture. Approximately 70% of the total groundwater is of suitable quality for irrigating crops (i.e. with less than 1,500 milligrams of salt per litre) and approximately 20% can be used for livestock (with 1,500–5,000 mg/l of salt) (AWRC 1987).

2.12 AUSTRALIA'S MAJOR DRAINAGE DIVISIONS

Drainage division	Division area '000 km^2	Mean annual run-off GL	Annual available groundwater GL
North-east coast	451	73 411	2 875
South-east coast	274	42 390	3 350
Tasmania	68	45 582	553
Murray-Darling	1 060	23 850	3 680
South Australian Gulf	82	952	406
South-west coast	315	6 785	3 010
Indian Ocean	519	4 609	1 668
Timor Sea	547	83 320	6 230
Gulf of Carpentaria	641	95 615	3 210
Lake Eyre	1 170	8 638	2 209
Bulloo-Bancannia	101	546	167
Western plateau	2 450	1 486	2 774
Total	**7 679**	**387 184**	**30 132**

Source: AWRC 1987; NLWRA 2000.

Water quality

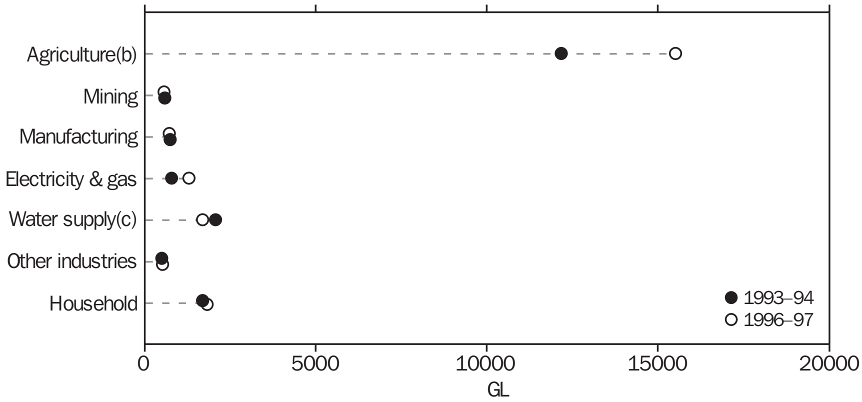
Water quality can be affected by agriculture. When water flows across or through farmland it can pick up nutrients and other particles that can reduce water quality. Nutrients come from several sources: fertilisers containing nitrogen and phosphorus; chemicals, such as pesticides and herbicides; and animal and plant wastes. As discussed earlier, use of fertiliser and farm chemicals increased significantly during the 1990s (see graphs 2.8 and 2.9). This increases the chance of unused nutrients and farm chemicals building up in the environment, which may increase the risk of toxic effects on streams and lakes. Algal blooms are one example of the effects of high levels of nutrients in water.

The National Land and Water Resources Audit (NLWRA) assessed water quality in around 70 river basins, for nutrient levels, turbidity and salinity (NLWRA 2001). These assessments found that 61% of basins had nutrient levels in excess of water quality guidelines. Turbidity, which is a measure of the soil content of water, was an issue in 61% of basins. Turbidity increases with soil erosion, but some of the turbidity is a result of natural conditions — for example in areas with highly erodable soils and heavy rainfall. Salinity in water was an issue in 32% of the river basins surveyed, and is discussed later in the chapter.

Water use by agriculture between 1990 and 2000

During 1996–97, the agriculture sector was the largest user of water in Australia, extracting 15,500 GL, which accounted for 70% of total water use (graph 2.13). Total water consumption in Australia increased from 18,600 GL in 1993–94 to 22,200 GL in 1996–97, an increase of 19%. Over the same period agricultural water use increased by 3,400 GL, representing nearly 95% of the total increase in water use.

2.13 WATER CONSUMPTION, By sector(a)



(a) Excludes in-stream water use.
(b) Agriculture includes services to agriculture, hunting and trapping; and forestry and fishing. Forestry and fishing account for less than 0.2% of total agricultural water use.
(c) Includes sewerage and drainage services.

Source: Water Account for Australia, 1993–94 to 1996–97 (cat. no. 4610.0).

While overall water use has increased over time, there are differences in water use between the crops grown and across the states and territories (table 2.14). The cotton and rice industries are the main users of water. They account for nearly a quarter of the total water used by agriculture nationally and nearly half of the total water used by agriculture in New South Wales. Both of these industries had significant increases in water consumption between 1993–94 and 1996–97, accompanied by increases in production.

2.14 NET WATER CONSUMPTION(a) — 1996–97

Industry	*NSW & ACT* '000 ML	*Vic.* '000 ML	*Qld* '000 ML	*SA* '000 ML	*WA* '000 ML	*Tas.* '000 ML	*NT* '000 ML	*Aust.* '000 ML	*Change 1993–94 to 1996–97* %
Livestock, grains and other agriculture	3 405	3 549	726	640	402	70	4	8 795	34.8
Cotton	1 417	—	423	—	—	—	—	1 840	35.8
Rice	1 643	—	—	—	—	—	—	1 643	21.8
Grapevines	242	218	4	172	11	—	1	649	45.4
Fruit and vegetables	473	280	213	180	146	43	4	1 339	21.0
Sugar	—	—	1 176	—	60	—	—	1 236	–10.2
Total agriculture	*7 181*	*4 047*	*2 542*	*992*	*619*	*113*	*9*	*15 503*	*27.5*
Non-agricultural industries(b)	1 535	2 639	1 138	269	806	201	97	6 683	4.1
Total(c)	**8 716**	**6 687**	**3 680**	**1 261**	**1 424**	**314**	**103**	**22 186**	**19.4**

(a) Net water consumption = mains water use plus self-extracted water use less mains water supply. Excludes in-stream use.

(b) Includes manufacturing, construction and mining, forestry, households, etc.

(c) All values have been rounded; hence column totals may not tally exactly.

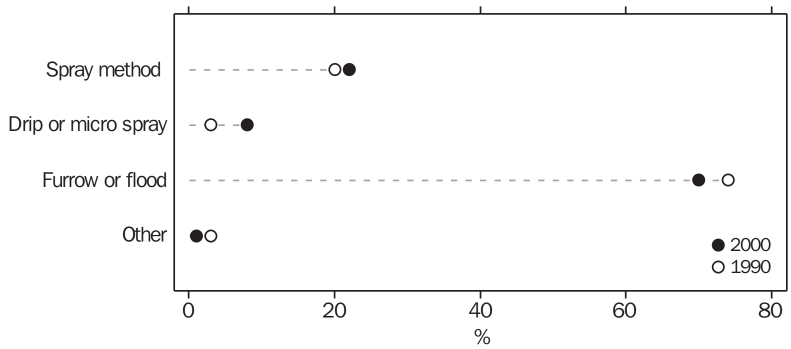
Source: Water Account for Australia, 1993–94 to 1996–97 (cat. no. 4610.0).

Water use by agriculture between 1990 and 2000 *continued*

The growth in water use has resulted from increases in the area of irrigated land. Between 1990 and 2000 the area under irrigation increased by more than half a million ha or 30%. The growth in irrigated area was greatest in Queensland, from 312,000 ha in 1990 to 548,000 ha in 2000. Environmental problems associated with irrigation practices include decline in soil structure in intensely irrigated areas, and in water quality as a result of the high levels of fertilisers used in conjunction with some irrigation methods. Irrigation is also a factor contributing to salinity (discussed later in the chapter). Reduced river flows, brought about by the construction of dams, weirs and water diversions, compound the problem as there is inadequate flow to dilute the saline groundwater inflows (ABS 1996).

While the area irrigated and volume of water used have increased, there has also been an increase in the use of irrigation methods that are more efficient in terms of water delivery. A number of factors affect the choice of irrigation method by farmers. These include cost of establishment and maintenance, available technology, soil type, type of crop, climate and topography (Smith 1998). Around 30% of irrigators reported using more efficient methods of irrigation (spray, microspray or drip irrigation) in 1999–2000 compared with 23% in 1990 (graph 2.15). In 1999–2000, the spray method was used on approximately 22% of irrigated land and the drip or micro irrigation method was used on a much smaller scale than other methods, accounting for approximately 8% of irrigated land. Drip or micro-irrigation is generally used on high value crops like grapes, citrus and tomatoes. There were also differences in the use of irrigation methods across the states and territories. For example, Tasmania had the highest propensity to use the more efficient irrigation methods (92%), and New South Wales the lowest (14%).

2.15 IRRIGATION METHODS



Source: Agriculture, Australia, 1999–2000 (cat. no. 7113.0); Summary of Crops, Australia, 1990–91 (cat. no. 7330.0).

LAND DEGRADATION

Many agricultural land and water management practices have led to degradation of the Australian land. Land degradation is a decline in the quality of land; it can result from a variety of human uses and take many forms. Degradation of agricultural land can reduce its productivity and cause a range of detrimental environmental impacts. For example, the clearing of native vegetation has led to a loss of some plant and animal species.

LAND DEGRADATION
continued

Significant clearing of native vegetation has occurred since European settlement, with around 38% of native forests cleared between 1788 and 1997 (NFI 1997). Between 1991 and 1999 over 3 million ha were cleared (table 2.16), the great majority for agricultural production. In 1999 and 2000 nearly 86% of all land cleared was used for pasture for grazing animals and 10% was used for cropping. The remaining 4% was used for a combination of activities which included forestry, mining, infrastructure and settlement (SoE 2002).

2.16 AVERAGE ANNUAL LAND CLEARING RATES

	1991 to 1995	*1996 to 1999*
State	*ha*	*ha*
New South Wales	19 120	30 000
Victoria	2 450	2 450
Queensland	289 000	382 500
South Australia	1 370	2 088
Western Australia	21 150	3 145
Tasmania	940	940
Northern Territory	3 320	3 320
Australian Capital Territory	—	—
Australia(a)	**337 350**	**424 444**

(a) All values have been rounded; hence column totals may not tally exactly.

Source: AGO 2000.

The main types of land degradation are listed and described in table 2.17. One of the most costly forms of degradation to Australian agriculture is soil acidification. While many of Australia's soils are naturally acidic, acidification can be caused or exacerbated by agricultural activity. This condition can be treated with lime and dolomite, and preliminary data show that in 2001 some 1.8 million tonnes of lime were applied to 1.2 million ha of land. Acidification can result from nitrogen fixation by legumes in pastures or crops and from the increased use of nitrogen fertilisers. The NLWRA estimates that 50 million and 23 million ha of Australia's agricultural zone are already experiencing impacts from soil acidity in surface and subsoil layers, respectively. While acidity has a big impact on agricultural production in terms of value, and sodicity has a large impact in terms of area affected, it is salinity that has generated the most concern in recent years (see MDBC 1999 and the National Action Plan for Salinity and Water Quality).

2.17 TYPES OF LAND DEGRADATION, BY PHYSICAL PROPERTY GROUP

Type of land degradation	*Description*
Chemical change in soil	
Dryland salinity	The build-up of salt in surface soil on non-irrigated areas usually as a result of rising water tables and subsequent groundwater seepage
Irrigation salinity	Salting associated with irrigated land. Soils become saline when soluble salts are concentrated in the surface horizon as a result of rising water tables
Induced soil acidity	A process or set of processes whereby the level of hydrogen ions or of certain toxic elements increases when compared to the pristine land condition. While many soils are naturally acidic, others may become acidic by the use of acidifying nitrogen fertilisers and legume dominated pastures which fix high levels of nitrogen, the removal of alkaline products and waste (e.g. manure) and increased soil organic matter
Heavy metal contamination	Contaminated soil associated with residues from livestock dips, and from some fertilisers
Soil structure and erosion	
Soil structure decline (including sodicity)	Soil structure is produced by the arrangement of soil particles and the air spaces between them. Soil structure decline refers to undesirable changes in this structure as a result of various land use practices
Surface scalding	Scalds are bare unproductive areas, varying in size from a few square metres to hundreds of hectares. They form when the surface soil is removed by wind and water erosion, exposing a more clayey subsoil which is relatively impermeable to water
Sheet and rill erosion hazard	Sheet erosion involves the removal of a fairly uniform layer of soil from the land surface by rain-drop splash and/or run-off. No perceptible channels are formed. Rill erosion is the removal of soil by run-off, with numerous small channels, generally up to 30 cm deep being formed
Gully erosion	A gully is an open incised erosion channel down which water flows during or immediately after rain. Gullies are generally deeper than 30 cm. Any erosion channel less than this depth is classified as rill as it can usually be removed by tillage. Areas of stream bank erosion are included in the assessment of gully erosion
Tunnel erosion	The transportation of sub-surface soil by water while the surface remains relatively intact. It relies on the seepage of water into dry soil, causing dispersion of soil particles into suspension. Dispersed soil is then removed by seepage until the seepage path gradually enlarges in to a tunnel
Mass movement of slopes	A process that involves the downward movement of soil and rock materials under the influence of gravity
Wind erosion hazard	The detachment and transportation of soil by wind
Biological condition	
Woody shrub infestation	Woody weeds are inedible native plants that are rapidly infesting large areas of semi-arid to arid regions. Exotic woody weeds also fit this description, especially in northern Australia
Decline of perennial bush	The death of edible perennial bush is a significant form of land degradation in the semi-arid and arid regions of New South Wales. Perennial bush cover provides protection of the soil surface
Tree decline	The sudden or gradual death of trees
Clearance of native vegetation	Replacement of the canopy with a herbaceous layer of crop or pasture plants
Feral animal and pest invasion	The rabbit, fox, cat and pig are the most significant in terms of biotic impoverishment on a continental scale. Populations of native animals may become invasive as habitat changes favour certain species
Weed invasion	Typically non-native plants which render land useless or partly so for agricultural purposes, due to mass infestation
Dispersed organic chemical residues and farm waste residues	Residues from farm chemicals such as pesticides and herbicides accumulate in the soil. In addition, farms carry organic matter such as animal wastes and nutrients such as phosphorus, and act as a store for these materials

Source: Gretton & Selma 1996.

There are two types of salinity: irrigation and dryland. The major cause of dryland salinity is the clearing of deep-rooted perennial woody vegetation and its replacement with shallow-rooted annual crops and pastures. The shallow roots of these plants do not use as much of the rainwater as the native vegetation that they replaced, and as a result more water enters the water table (groundwater) than previously. Consequently groundwater levels rise, and in so doing they dissolve the natural salt in the soils found over large areas of Australia. Halting or reversing rising groundwater requires farming systems with similar water use to those of natural vegetation that was originally present. It has taken 10 to 100 years for these changes to become evident, and similar times will be needed to reverse the rise in groundwater levels and improve the water balance (NLWRA 2001).

Irrigation-induced salinity is caused by increased 'leakage' of water from the surface into groundwaters due to over-irrigation or the irrigation of inappropriate soils. It has similar impacts to dryland salinity, but is easier to manage. Increased use of more efficient irrigation methods helps to ensure that over-watering does not occur, reducing the impacts of irrigation-induced salinity.

2.18 EXTENT AND COST(a) TO AGRICULTURE OF SALINITY, SODICITY AND ACIDITY — 2000

	NSW	*Vic.*	*Qld*	*SA*	*WA*	*Tas.*	*NT*	*ACT*	*Aust.*
EXTENT ('000 ha)									
Saline soils	89	287	62	472	2 169	26	—	—	3 206
Sodic soils	24 713	8 008	42 191	7 635	14 615	504	11 533	1	109 219
Acidic soils	4 095	2 754	6 192	20	4 602	677	2 973	4	21 317
COST ($m)									
Saline soils	6.3	18.5	10.2	39.1	111.0	1.9	—	—	187.0
Sodic soils	280.3	342.5	180.3	126.4	89.7	12.3	3.0	—	1 034.6
Acidic soils	378.7	471.1	232.5	2.9	226.1	214.8	58.2	0.2	1 584.5
Combined cost(b)	**624.1**	**757.4**	**392.9**	**162.0**	**341.6**	**220.3**	**61.1**	**0.2**	**2 559.5**

(a) Value of lost production. For a description of method used to derive see NLWRA 2002.

(b) Salinity, sodicity and acidity constraints often coincide, so the aggregate effect is less than sum of each constraint.

Source: NLWRA 2002.

GENETICALLY MODIFIED ORGANISMS (GMOs)

The development of GMOs is being driven by a pressure to produce higher yields of food per unit area of land, to satisfy the demands of a growing world population. While future GMOs may include diverse products such as fuels, plastics, detergents and pharmaceuticals, the raw materials for many of these will be grown by primary producers. GMOs are organisms (plant, animal, fungi, bacteria or viruses) that have been modified in such a manner that they cannot be derived through 'traditional' breeding methods. Activities of this nature are broadly termed gene technology. This technology has enormous potential worldwide for agriculture, forestry, mining, manufacturing and medicine. Examples of potential environmental benefits from GMOs include reduced use of agricultural chemicals, the ability to grow new crops in degraded land and new remediation technology (e.g. the use of genetically modified plants to decontaminate toxic areas). Gene technology creates the opportunity to selectively isolate the individual genes of a desired trait, not only in related species, but also in totally unrelated organisms, referred to as transgenic. For example, a fish gene for anti-freeze has been used in tomatoes so that they can be grown in cool climates.

While the potential benefits of GMOs have led to their adoption by some primary producers, some sectors believe they pose risks to the environment. Rapid growth of the GMO industry has placed demands on the capacity to measure and manage information, to reduce risk. The response to this challenge has been to develop complex legislation and policies to control the release of GMOs with the aim of minimising or avoiding adverse effects on people and the environment. To comprehend the diversity of GMOs, and the future of this industry, the types of GMOs being trialled have been classified into three broad categories based on their genetic modification (table 2.19).

History and global adoption rates of genetically modified crops

Gene technology is new. The first GMO was produced in 1971 in a laboratory, the first field trial occurred in 1986 and the first GMO was available to be purchased by farmers in 1992. The first genetically modified crops suitable for human consumption were grown commercially in 1994, and widespread plantings first occurred in 1996. The adoption rates for transgenic crops are the highest recorded for any new agricultural technology to date (James 1999). Worldwide, only four GM crops are grown commercially on a large scale (graph 2.20). In 2000, the four main genetically modified crops (soya beans, canola, corn and cotton) covered 44 million ha (16%) of the 271 million ha planted (conventional and GM) to these crops (James 2001).

2.19 CATEGORIES OF GENETICALLY MODIFIED ORGANISMS

Category 1 — Improved production traits(a)

- Resistance to insects, viruses, bacteria, fungi etc.
- Herbicide tolerance
- Seed or plant sterility
- Tolerance of environmental stress (e.g. frost, drought and soil salinity)
- Increased yield

Category 2 — Improved output traits

- Nutrient characteristics
- Increased micronutrients (e.g. vitamins)
- Altered product quality and flavour
- Processing characteristics
- Storage characteristics (e.g. resistance to browning in potatoes)

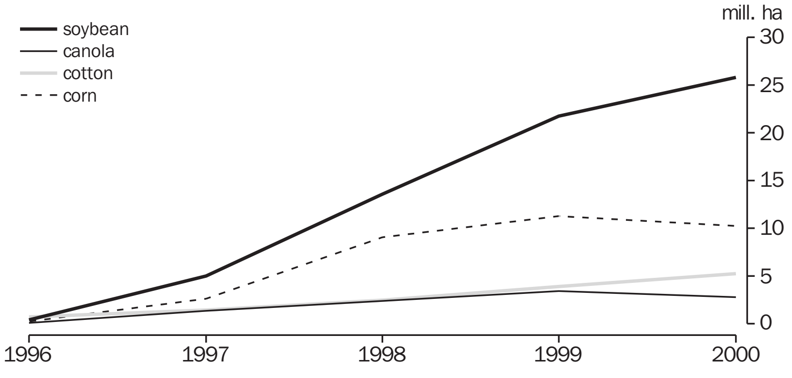
Category 3 — Replacement of other productions systems

- Biologically based polymers, lubricants etc. (replacing petrochemicals)
- Vaccines for diseases or disease-preventing micronutrients
- Pharmaceuticals and antibiotics
- Remediation (e.g. use of plants to clean up areas contaminated with toxic chemicals)

(a) by the end of 1998 approximately three-quarters of the field trials undertaken globally were classified under Category 1 (Foster et al. 1999).

Source: Brenner 1998; Foster et al. 1999.

2.20 AREA PLANTED WITH GENETICALLY MODIFIED CROPS, World-wide



Source: CEC 2000; James 2000.

History and global adoption rates of genetically modified crops *continued*

The rapid increase in the use of GMOs by primary producers is significant because it means that the systems being developed by governments to safeguard their use are under considerable pressure to keep up with the pace of the technology. Currently, genetically modified crops are grown commercially in 15 countries. The areas of these crops vary greatly, with the United States of America accounting for the majority of plantings and the most rapid increase — from 1.45 million ha in 1996 to 30.3 million ha in 2000 (table 2.21). The other countries trialling GMOs are listed in the table. The rates of adoption vary with recent plantings in some countries, including Australia, down from peak levels.

2.21 LAND SOWN WITH GENETICALLY MODIFIED CROPS

	1996	*1997*	*1998*	*1999*	*2000*
Country(a)	*mill. ha*	*mill. ha*	*mill. ha*	*mill. ha*	*mill. ha*
United States of America	1.45	7.16	20.83	28.64	30.30
Argentina	0.05	1.47	3.53	5.81	(b)10.00
Canada	0.11	1.68	2.75	4.01	3.00
China	1.00	1.00	1.10	1.30	0.50
Australia	—	**0.20**	**0.30**	**0.30**	**0.15**

(a) Other countries currently trialling GMOs include Belize, Bolivia, Costa Rica, Chile, Cuba, Columbia, Dominican Republic, Egypt, Guatemala, Indonesia, India, Kenya, Malaysia, Nigeria, Peru, Thailand, Uganda, Venezuela and Zimbabwe (see DaSilva 2001).

(b) Data from James 2000 and 2001 include data for Brazil with Argentina. This is because while Brazil has a ban on growing GM crops, it is estimated 10% of the soya bean grown in Brazil is from seed illegally imported from Argentina (see CEC 2000, p. 12).

Source: CEC 2000 (1996–1999 data); James 2000 & 2001 (2000 data).

Environmental risks

As GMOs are a relatively new technology, the risks of their use are not well understood. Concern about gene technology has focused on the potential human health effects of genetically modified foods. However, a number of scientists are also concerned about the potential risks to the environment. Examples of these concerns include the risk of 'escape' of GMOs to where they can become a problem (e.g. as weeds), the hybridisation of GMOs with related native species, and the transfer of the modified genes to other species. There is widespread concern that inserting foreign genes into a host genome may have unpredictable ecological consequences (Yencken & Wilkinson 2000).

Health risks

The health risks concern the contamination of the food supply and the flow-on effects of GMOs to humans. The European Union has enacted legislation for the labelling of genetically modified foods and the import of genetically modified products, after extensive public opposition to GMOs. Despite testing of GMOs prior to release, studies in the United States of America provide evidence that commercially grown genetically modified crops can have adverse effects (e.g. James 2001).

The risk management process

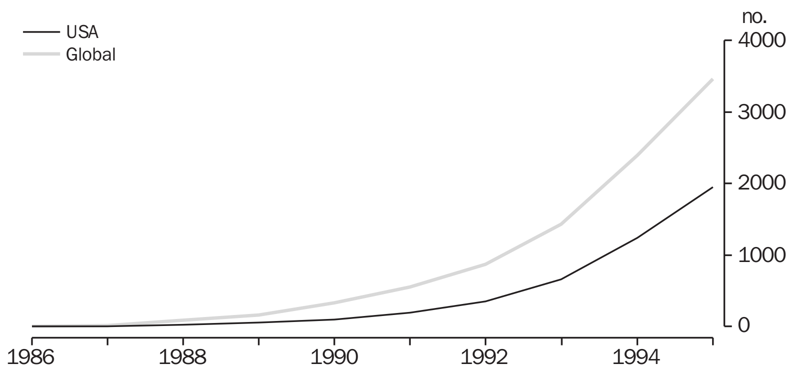
The process of developing and releasing a GMO for commercial use is long and complex. In most countries it begins with intensive development and testing in the laboratory. Approval is then sought from a regulating body for field testing. The GMO is tested in the field and approval is required again from the regulating body for commercial release. This process can take many years. However, regulations for GMOs and their commercial release differ greatly between countries. Many developing countries lack operational field testing regulations, and there is concern that GMOs will be tested in countries where regulations are lacking or less stringent (see UNEP 1993; cited in James & Krattiger 1996).

Risk management in the future

Field trials are designed to minimise the risk of something going wrong prior to the commercial release of a GMO, both in terms of its performance as a new agricultural product and its risk to the environment. Trials entail some risk to the environment, as it is possible for GMOs and/or the genes they contain to escape and become established in the biosphere.

In order to comprehend the future risks and the risk management needed, it is important to understand the future direction of the GMO industry. The future scale and speed of development of the GMO industry are indicated by the number of field trials being undertaken (graph 2.22). However, not all trials lead to commercial release.

2.22 GMO FIELD TRIALS



Source: James and Krattiger 1996.

Australian perspective

In Australia, the first field trial of a GMO occurred in 1991, and was of a virus resistant potato (James & Krattiger 1996). The number of field trials in Australia has increased with time, from 45 trials in 1995 to 112 in 1999 (Foster et al. 1999). Currently four genetically modified crops are commercially available in Australia:

- INGARD® insect resistant cotton
- Monsanto's Roundup-ready® herbicide resistant cotton
- a carnation with improved vase life
- a carnation with violet coloured flowers.

Australian perspective *continued*

INGARD® has been grown commercially in Australia since 1996. Large scale field trials for Monsanto's Roundup-ready® cotton commenced in 1999 and it was released in 2000. One carnation (with improved vase life) was grown commercially in 1994 and the other in 1996. Around 220,000 ha of GM crops are estimated to have been grown in Australia in 2001–02. The area of GM cotton is approximately 220,000 ha, of which INGARD® comprises 140,000 ha and Roundup-ready® comprises the remaining 80,000 ha. The area of Roundup-ready® has increased by 663% from 12,000 ha in 2000–01. (Source: Office of the Gene Technology Regulator).

In the last two years there have been two important developments in the GMO industry in Australia. The first was the passing of the *Gene Technology Act 2000*; the second was the labelling of genetically modified food products for human consumption, which came into force in late 2001. The objective of the Act is to protect the health and safety of people, and to protect the environment by identifying risks posed by gene technology, and manage those risks by regulating dealings with GMOs. The Gene Technology Regulator was set up to administer the Act.

THE DECADE OF LANDCARE PLAN

In 1989, the Commonwealth Government and the state and territory governments formally proclaimed the 1990s as the Decade of Landcare. This initiative was developed to combat land degradation throughout Australia and other issues impacting upon economic production, ecological processes and rural communities (Commonwealth of Australia 1997). The objective of the Decade of Landcare Plan was to:

> ...develop and implement resource management practices which enhance our soil, water and biological resources and sustain individual and community benefits now and in the future (Landcare 1997).

The plan acknowledged that this objective would require the participation of individual landholders, community based groups, local government, and the state and territory governments. The role of the Commonwealth Government was to provide national support (Commonwealth of Australia 1997).

The Landcare movement in rural and urban Australia was integral to achieving the goals of the Decade of Landcare Plan. Landcare was interpreted in a number of ways (Cary & Webb 2000), but generally referred to the activities of community Landcare groups established to deal with land degradation and work towards sustainable natural resource management. Members of these groups were generally volunteers from the local community, and typically comprised farmers and land managers acting with assistance from government agencies. The National Landcare Program was a Commonwealth and state/territory government initiative that supported the collective action of these community Landcare groups in partnership with the government and industry. The National Landcare Program was strengthened by the funding from the $1.5b Natural Heritage Trust Fund. Despite the conclusion of the Decade of Landcare in 1999, community Landcare groups and the National Landcare Program remain active, with over 4,000 groups throughout Australia.

THE DECADE OF LANDCARE PLAN *continued*

The Decade of Landcare Plan established a number of goals from which its performance could be assessed. Such evaluations are problematic because of the difficulty in relating the actions undertaken to the long-term nature of many natural resource problems (Commonwealth of Australia 1997). Four performance indicators were identified for monitoring the Decade of Landcare Plan:

- awareness
- skills/education
- participation rate
- implementation.

It is beyond the scope of this publication to present a comprehensive evaluation of the Decade of Landcare Plan, but this section presents some data relating to the four performance indicators, with a particular emphasis on land degradation and land management issues in agricultural systems.

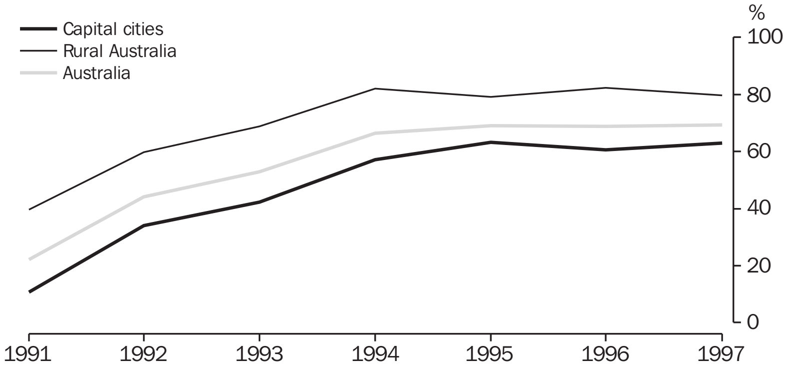
Awareness

The Decade of Landcare Plan endeavoured to raise awareness of natural resource management and land degradation issues among landholders and the general public. It was seen as particularly important that landholders recognise the significance of natural resource management matters, and that they be primarily responsible for managing the resources they control (Walker 2000). The Decade of Landcare Plan performance indicator for awareness refers to:

> ...a measure of the level of understanding of landcare, not just an awareness that it exists, as an indicator of behavioural change.

An evaluation of the National Landcare Plan found high levels of awareness of Landcare and its importance throughout the Australian community, especially in rural areas and among farmers (Walker 2000). Graph 2.23 shows an increasing awareness of Landcare in Australia between 1991 and 1997. The level of awareness was higher in rural areas than in capital cities throughout the decade. Television, newspapers, radio, and personal experience were the primary resources identified as having raised awareness.

2.23 PERCENTAGE OF POPULATION AWARE OF LANDCARE



Source: Walker 2000.

Awareness *continued*

An increased awareness of the Landcare movement was not translated into increased concern for land degradation and management issues. National levels of concern about land degradation in Australia fell over the course of the Decade of Landcare, with land degradation of concern to a higher proportion of non-metropolitan than metropolitan residents (table 2.24). This downturn in concern for land degradation has been part of a general decline in concern for environmental issues as a whole (ABS 1999).

2.24 PEOPLE CONCERNED ABOUT LAND DEGRADATION/SOIL EROSION AND SALINITY(a)

	1992	*1999*	*Change 1992–1999*
Location of respondents	*%*	*%*	*%*
Metropolitan	11.8	8.5	–3.3
Non-metropolitan	20.9	13.5	–7.4
Australia	15.3	10.2	–5.1

(a) Land degradation including soil erosion/salinity (the 1992 question referred to land degradation, not soil erosion and salinity as in 1999).

Source: Environmental Issues: People's Views and Practices 1993, 1999 (cat no. 4602.0).

While there have been declines nationally in the levels of environmental concern among Australians, the levels have remained constant or increased slightly among farmers.

Two surveys of members of farming organisations in 1991 and 2000 by Reeve (2001) found a slightly increased concern about the seriousness of land degradation. At a state level, falls in concern in Queensland, New South Wales and Tasmania were offset by increases in Victoria, South Australia and Western Australia, where salinity problems had received a lot of attention. Reeve also identified increased concern about the environmental and health effects of agricultural chemicals and chemical residues, and increased awareness that agricultural practices had impacts on the environment outside the farm boundary.

Skills and education

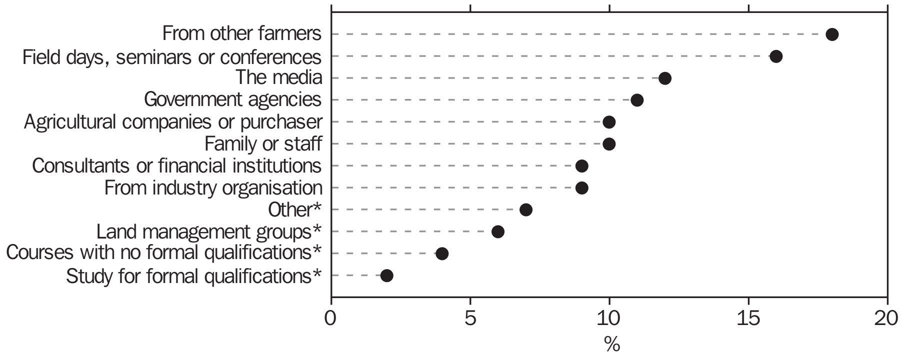
The Decade of Landcare Plan aimed to enhance the knowledge and skills of land managers in regard to natural resource management. This was to allow land managers to implement changes in their management practices. The skills and education performance indicator of the Decade of Landcare Plan referred to:

> ...an assessment of the managerial competencies of farmers, other land managers and community groups and the availability of competent advice.

Skills and education *continued*

Farmers who made changes to land management practices relied on a variety of information (graph 2.25). Other farmers and field days, seminars or conferences were identified as the main sources of information and advice. Alexander et al. (2000) found that workshops and field days organised by Landcare groups, industry or grower groups, along with other short training courses, were the most common forms of training undertaken among broadacre and dairy farmers. A lack of information was seldom reported (by less than 2% of farmers) as a factor hampering changes to farming practices, while lack of resources or the ensuing costs were identified as the major barriers to changes in land management among farmers (ABS, Agricultural Financial Survey).

2.25 SOURCE OF INFORMATION OR ADVICE PROMPTING CHANGES TO FARMING PRACTICES(a) — 1996–97



(a) Non-exclusive categories.

Note: * Data subject to sampling variability between 25% and 50%.

Source: ABS data available on request, Agricultural Financial Survey 1997.

Participation rates

The Participation Rate indicator as described under the Decade of Landcare Plan was:

> ...measuring community involvement in property management practices for agricultural production and conservation activities.

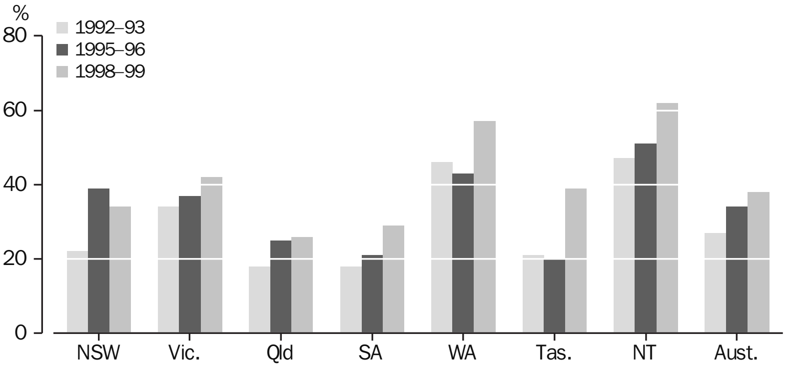
Participation in the National Landcare Program was voluntary, and groups generally formed as a result of shared concern for local natural resource management and land degradation problems (Mues et al. 1998). These groups frequently operated at catchment or subcatchment levels, and generally focused on privately owned or leased land managed by group members (Curtis & van Nouhuys 1999).

In the early 1990s there were approximately 200 community Landcare groups in Australia (Walker 2000), but in 1998 this had grown to over 4,000, involving an estimated 120,000 volunteers (Curtis & van Nouhuys 1999). This is over four times the number envisaged at the beginning of the Decade of Landcare. A survey of rural landowners by Reeve (2001) found substantial increases in landcare group membership during the Decade of Landcare, from 23% of respondents in 1991 to 43% in 2000.

Participation rates *continued*

Across the broadacre and dairy industries, the proportion of properties with a landcare member grew from 27% in 1992–93 to 34% in 1995–96, and was estimated at 38% in 1998–99 (graph 2.26). Different levels of participation have been found between regions and industries, with Landcare membership being highest in the wheat-sheep zone, the pastoral zones (Walker 2000), and in Western Australia and the Northern Territory.

2.26 LANDCARE MEMBERSHIP, All broadacre and dairy industries



Source: Alexander et al. 2000.

Groups established to address natural resource management issues extend beyond those involved in the National Landcare Program. A range of Integrated Catchment Management Groups have formed throughout Australia. Integrated catchment management is a coordinated approach to the management of land, water, vegetation and other natural resources in water catchments to balance resource use and conservation. The Landcare movement has given rise to several similar government initiatives such as Coastcare, Rivercare, Dunecare and Bushcare, each focusing on its own particular area of concern.

Across Australia, over 220,000 people were members of Catchment Management or Landcare groups in 2001. This was a 34% increase from 164,000 members recorded in 1998. In 2001, Victoria and New South Wales had the majority of members with 33% and 31% respectively (table 2.27). Members of Landcare or Catchment Management groups were more likely to live outside of capital cities in 2001. Around 28% of landcare members lived in capital cities. An additional 380,000 people were involved in other non-specified environmental groups. These groups may also undertake land management activities.

2.27 MEMBERSHIP OF ENVIRONMENT GROUPS — 2001(a)

	NSW	Vic.	Qld	SA	WA	Tas.	NT	ACT	Capital city(b)	Rest of state(b)	Aust.
	'000	'000	'000	'000	'000	'000	'000	'000	'000	'000	'000
Landcare or catchment management group	67.4	73.2	30.8	15.5	23.0	*6.0	*1.3	*3.0	99.2	121.1	220.3
Marine conservation group	*12.4	20.4	*19.2	*5.4	*7.6	*1.7	*0.5	*0.6	47.3	20.5	67.8
Any other environmental group	111.4	87.2	67.7	41.8	46.3	9.1	*3.6	12.6	237.0	142.6	379.6
Total members	**180.7**	**164.3**	**97.6**	**58.9**	**71.3**	**15.5**	***5.0**	**15.5**	**350.5**	**258.4**	**608.9**

(a) Totals do not equal the sum of items in each column because more than one group may be specified.

(b) ABS data available on request, ABS Monthly Population Survey, March 2001.

Source: Environmental Issues: People's Views and Practices, 2001 (cat. no. 4602.0).

Implementation

The final performance indicator for the Decade of Landcare was:

> ...the implementation of a set of best management practices for agricultural production and conservation activities.

On-ground work undertaken by land management groups included tree planting and seed collection, building salinity and erosion control structures, weed and pest control, and fencing creeks and other degraded areas (Curtis & Van Nouhuys 1999). In the late 1990s, the estimated number of trees and shrubs planted as seedlings increased from 31.7 million in 1996–97 to 50.8 million in 1998–99, but fell to 43.4 million in 1999–2000.

In 2000 an estimated 43.4 million trees and shrubs were planted as seedlings on 153,000 ha (table 2.28). Of these, one-third (or 15.0 million) of the seedlings planted were for timber and pulp production, but they accounted for only 10% (14,700 ha) of the total area planted. The remaining 28.3 million trees were planted for other purposes, which included protection of land and water (11.4 million trees on 47,400 ha), production of fodder and plant products (6.8 million trees on 8,500 ha) and enhanced production, through the provision of shade, windbreaks etc. (6.0 million trees on 42,200 ha).

2.28 TREES AND SHRUBS PLANTED AS SEEDLINGS(a)

	1999		2000	
	Number	Area	Number	Area
	'000	ha	'000	ha
Seedlings planted for				
Timber or pulp production	17 217	(b)	15 020	14 695
Other purposes				
Nature conservation	1 656	7 234	3 551	34 697
Enhanced production (e.g. shade, windbreaks, etc.)	5 928	23 526	5 967	42 219
Fodder and plant products (e.g. bush food, oils, etc.)	14 708	7 720	6 808	8 520
Protection of land and water	10 485	32 676	11 382	47 361
Other plantings	738	1 654	*632	1 353
Total other purposes	*33 515*	*72 809*	*28 341*	*138 150*
Total seedlings planted	**50 786**	**(b)**	**43 361**	**152 844**

(a) While this represents the best estimate from the data available, the result should be interpreted with caution owing to high variability in responses, which may be due to difficulties in attributing tree plantings to specific purposes.

(b) Data not collected.

Source: Agriculture, Australia, 1999–2000 (cat. no. 7113.0).

Implementation *continued*

In 1999–2000 the total length of new fencing constructed to protect areas from grazing was 48,900 km (table 2.29). This was a 41% increase on the previous year, but only fractionally up on the 1996–97 figure. Between 1996–97 and 1999–2000, the protection of planted trees and shrubs was the main reason reported for fence construction, with 32% of all new fencing constructed for this purpose in 1999–2000. The protection of creeks and rivers and the protection of remnant native vegetation were next, each representing 18% of total construction. Fencing of saline areas represented approximately 10% of total new fencing constructed in each of the survey years.

2.29 FENCING BUILT FOR PROTECTION FROM GRAZING — 2000

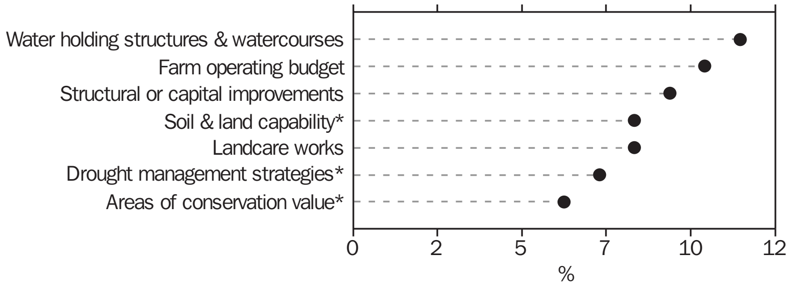
	NSW	*Vic.*	*Qld*	*SA*	*WA*	*Tas.*	*NT*	*ACT*	*Aust.*
	km	*km*	*km*	*km*	*km*	*km*	*km*	*km*	*km*
Remnant native vegetation	2 593	1 244	590	*1 496	2 098	564	1	6	8 592
Planted trees and shrubs	4 587	4 986	324	1 401	3 924	220	13	22	15 476
Creeks and rivers	1 978	2 547	*1 322	419	1 973	542	54	15	8 849
Saline areas	1 290	885	np	752	1 972	*44	—	—	5 499
Other degraded areas	*278	*537	np	*296	434	29	2	—	2 833
All other areas	1 296	2 629	*2 331	390	719	200	111	10	7 686
Total fencing length(a)	**12 020**	**12 827**	**6 381**	**4 753**	**11 120**	**1 598**	**181**	**53**	**48 933**

(a) All values are rounded; hence column totals may not tally exactly.

Source: Agriculture, Australia, 1999–2000 (cat. no. 7113.0).

The development and implementation of farm plans is one indication of the adoption of better land management practices. Farm plans may be ‘a map and/or some other form of documented record addressing the present farm situation and outlining strategies for future management and development decisions’ (Alexander et al. 2000). The ABS Agricultural Finance Survey in 1997 showed that around 13% of farmers had farm plans. These plans covered a wide variety of management issues (graph 2.30), ranging from economic development to natural resource management (i.e. water, soil and land management), and often included strategies for lessening land degradation (i.e. conservation and Landcare initiatives). Alexander et al. (2000) estimated that, in 1998–99, just over a quarter (27%) of broadacre and dairy farmers had some form of documented farm plan, of which 68% had information on soil or land capability and 65% had information on existing or proposed landcare works. Throughout the Decade of Landcare, estimates of the proportion of farmers with a documented farm plan increased from 25% in 1992–93 to 36% in 1995–96, but fell to 27% in 1998–99.

2.30 CONTENT OF FARM MANAGEMENT PLANS(a) — 1996–97



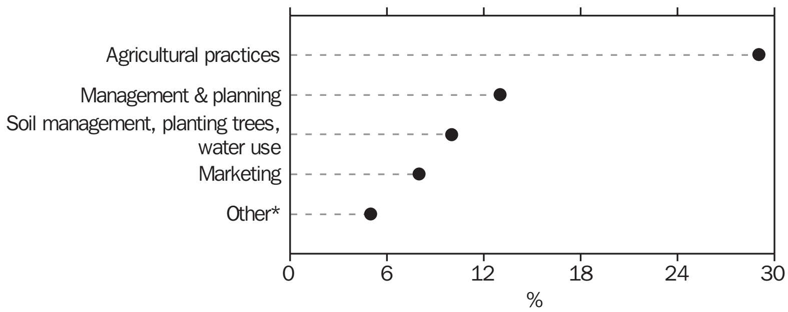
(a) Non-exclusive categories.

Note: * Data subject to sampling variability between 25% and 50%.

Source: Data available on request, ABS Agricultural Financial Survey 1997.

Farmers' decisions about how to use agricultural land are based on a wide range of environmental, economic and social factors. The ABS has collected data from farmers about changes to their farm management practices and the motivation for these changes. In regard to land degradation and natural resource management, around 29% of all farmers reported changing agricultural practices and about 10% reported making changes to soil management, planting trees or water use (graph 2.31). While the perceived benefits of changing farming practices are wide ranging, most farmers reported productivity and reduced costs as the key reasons for changed farming practices, while a smaller proportion of farmers reported potential environmental benefits, such as erosion control, water conservation, land regeneration and salinity reduction (graph 2.32).

2.31 CHANGES TO FARMING PRACTICES(a), For the three years to June 1997

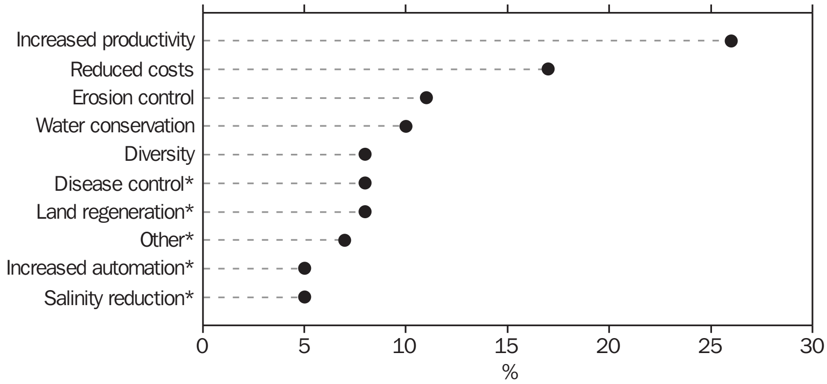


(a) Non-exclusive categories.

Note: * Data subject to sampling variability between 25% and 50%.

Source: Data available on request, Agricultural Financial Survey 1997.

2.32 EXPECTED BENEFITS OF CHANGES TO FARMING PRACTICES(a)



(a) Non-exclusive categories.

Note: * Data subject to sampling variability between 25% and 50%.

Source: Data available on request, Agricultural Financial Survey 1997.

ENVIRONMENT PROTECTION EXPENDITURE

The on-ground environment protection expenditure by the agricultural industry is presented in table 2.33 for 1999–2000. In 1996–97 total agricultural environment protection expenditure was $192m (ABS 1999). The 1999–2000 estimate represents a 15% increase from 1996–97 in actual dollar terms, although comparisons between years must be made with caution owing to the continuing evolution of the collection and presentation of data. The total expenditure of $221m in 1999–2000 represents about 1% of total turnover in the agriculture industry. Government subsidies to the industry provided an additional $27.1m for environmental protection. The largest expenditure by the industry was $49.5m (22%) on earthworks for sustainable land management, which included the construction of contour banks and alteration of slopes and creek banks to reduce erosion. Weed prevention and control (17%) and the construction and maintenance of fences (17%) were the next largest areas of environment protection expenditure.

2.33 ENVIRONMENT PROTECTION EXPENDITURE, AGRICULTURE — 1999–2000

Type of expenditure	*$m*
Environmental taxes, levies, fines and licences paid to government	1.8
Construction and maintenance of fences	37.2
Weed prevention and control	38.4
Control of non-native feral animals	12.0
Establishing and maintaining vegetation for land management	26.3
Earthworks for sustainable land management purposes	49.5
Disposal, treatment and transportation of liquid waste and wastewater	11.7
Converting from open to reticulated irrigation to manage salinity and/or to reduce evaporation	22.0
Handling, storage, transport or disposal of non-hazardous solid waste	5.6
Preventing accidental soil contamination by agricultural chemicals and other hazardous waste	2.4
Controlling unpleasant smells, smoke and other emissions	0.7
Measures to protect cultural heritage places	11.4
Self-education costs for environmental/sustainable management	2.2
Total expenditure by the agriculture industry	**221.3**
Government subsidies to agriculture industry for environmental protection/management	27.1

Source: Agriculture, Australia, 1999–2000 (cat. no. 7113.0).

AGRICULTURE IN THE FUTURE

The face of agriculture changed between 1990 and 2000. Much of this was driven by economic circumstances, but a substantial amount was due to increased concern for the environment by farmers, and was supported by associated government funding initiatives. The increased use of more efficient irrigation methods, planting of trees and fencing of native vegetation, and adoption of other improved land use practices, indicated that farmers were taking steps to lower the environmental impact of their activities.

As concerns about environmental impacts and sustainability continue, and as new technologies such as GMOs develop, agriculture will continue to change. While GMOs have emerged as a technology with the potential to revolutionise agriculture in Australia and around the world, they bring with them their own particular concerns and issues. However, agriculture will continue to be constrained by economic factors, the quality of soil and amount of water available. With land and water resources both under pressure, and showing signs of degradation, the challenges for the future will be first to halt and then reverse the adverse impacts resulting from past land and water management practices.

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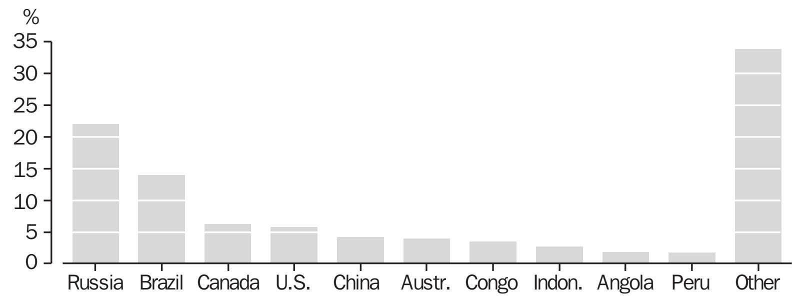
CHAPTER 3 FORESTS AND FORESTRY IN AUSTRALIA

This chapter examines forests and their use. It starts by looking at the global situation and then goes on to examine forests and forestry in Australia. It also looks at the extent and types of forests as well as how they are used and valued by the Australian community. Both native forests and plantations are covered in this chapter.

AUSTRALIA'S FORESTS IN A GLOBAL CONTEXT

According to the United Nations Food and Agriculture Organization (UNFAO) there are an estimated 3,870 million hectares (ha) of forest worldwide, of which almost 95% are natural forest and 5% are plantations (UNFAO 2001). Of the world's land area, about 30% is under forest. Two-thirds of the world's forests are located in only ten countries, Australia's forest area comprising the sixth largest share of the world's forests (graph 3.1). The world average of forest area per person is 0.6 ha (UNFAO 2001). Only 22 countries have more than three ha of forest per capita, Australia having a relatively high 8.3 ha of forest per person (UNFAO 2001).

3.1 COUNTRIES WITH LARGEST PERCENTAGE OF WORLD'S FORESTS(a)



(a) With the exception of Australia, the area of forest for each country was estimated using the UNFAO definition of forests (UNFAO 2001). Australia's forest area was derived using the 1992 National Forest Policy Statement definition of forests (see box 1).

Source: UNFAO 2001.

Australia is one of twelve countries considered 'mega-diverse', with ecosystems of exceptional variety and uniqueness. Australia's forests are particularly diverse in their type, species composition, structure and the fauna they support. Australia's forest ecosystems range from tropical rainforests to mulga scrub, but are generally dominated by Eucalypt species. There are over 1,200 vertebrate species and more than 13,600 higher plant species in forested areas of the continent (NFI 1998). The species-rich forested regions of Northern Queensland and the South-west of Western Australia (with over one-third of Australia's plant species, of which 70% are endemic) are internationally recognised as being major centres of biodiversity (SoE 1996).

AUSTRALIA'S FORESTS IN A GLOBAL CONTEXT *continued*

Land clearing remains the single most pervasive threat to terrestrial biodiversity, particularly for forest ecosystems (SoE 2001). Recent estimates of native vegetation clearing in Australia include 240,000 ha for 1998 (AGO 2001a) and 564,000 ha for 2000 (ACF 2001). These estimates differ widely for a number of reasons. The most obvious are that they refer to different years and used different methods to collect data. The ACF (2001) used a wide variety of administrative data to compile its estimate, while the AGO (2001a) estimate was based on the analysis of satellite images (AGO 2001b). In both estimates Queensland accounted for approximately 75% of Australia's native vegetation clearing. Aside from the loss and depletion of plant species, clearing of vegetation impacts on biodiversity through habitat loss and fragmentation. The *Environment Protection and Biodiversity Conservation Act 1999* specifically identifies the deliberate clearing of native vegetation and the passive loss of remnant vegetation through landscape deterioration as processes which threaten Australia's biodiversity (EA 1999).

DEFINING AND CLASSIFYING AUSTRALIA'S FORESTS

In order to gather useful information about forests, it is necessary to create consistent definitions and classifications (box 1). Forests are generally classified as either plantations or native based on their distinct ecosystem structure, species composition and management. Native forests refer to those forested lands occurring naturally in Australia, such as *Eucalyptus* and *Acacia* species. While in the past, woodland ecosystems were considered distinct from forest ecosystems, the current forest definition, described in box 1, encompasses woodlands. Plantation forests are generally intensively managed, consisting of either native or exotic species. A stocktake of Australia's native forests and plantations is provided by the National Forest Inventory and the National Plantation Inventory (see <http://www.affa.gov.au/nfi>) using the definitions outlined in box 1.

Box 1. What is a forest? Defining forests in Australia

When measuring environmental variables, it is important to develop clear definitions based on sound technical and scientific understanding. Adopting uniform definitions enables consistent reporting of environmental variables, such that measured data from different sources are comparable. Formulating appropriate definitions for forests has become particularly pertinent as our techniques for measuring forests improve.

The National Forest Inventory is a cooperative project between the Commonwealth Government and the state and territory governments which aims to provide a stocktake of Australia's forests by establishing national data on attributes such as forest type, ownership and protection status (Commonwealth of Australia 2001). In compiling the National Forest Inventory, Australia uses the definition of forest outlined by the 1992 National Forest Policy Statement:

> An area, incorporating all living and non-living components, that is dominated by trees having usually a single stem and a mature or potentially mature stand height exceeding two metres and with existing or potential crown cover of overstorey strata about equal to or greater than 20%. This definition includes Australia's diverse native forests and plantations, regardless of age. It is also sufficiently broad to encompass areas of trees that are sometimes described as woodlands.

This definition differs from previous widely used definitions by encompassing woodland and forest-forming mallees. Australia's forests may be further classified according to the density of their crowns and their height. Percentage crown cover may be used to distinguish between 'woodland', 'open forest' and 'closed forest', and potential mature stand height determines the distinction between 'low', 'medium' and 'tall' forest.

The National Forest Inventory definition of forest incorporates plantations, but they are usually reported separately for the purposes of measuring forest area. The 1992 National Forest Policy Statement definition of a timber plantation is:

> ...intensively managed stands of trees of either native or exotic species, created by the regular placement of seedlings or seeds.

Source: National Forest Policy Statement 1992.

Distribution of Australia's native forests

According to the 2001 National Forest Inventory, Australia has approximately 165 million ha of forested land, covering about 21% of Australia's total land area (table 3.2). The distribution of Australia's forests depends on a variety of environmental attributes including rainfall, temperature, soil fertility, frequency and intensity of bushfires and the effects of past management regimes. Australia's forests form a broad crescent around Australia (map 3.3). They are limited to areas of relatively high rainfall across the tropical north, around the eastern, south-eastern and south-western coasts of mainland Australia, and across Tasmania.

In general, the distribution of forest types reflects a decreasing rainfall gradient with increasing distance from the coast, where closed and open forests give way to eucalypt woodlands, which in turn give way to acacia shrubland. Queensland has the largest area of forest, followed by the Northern Territory and Western Australia (table 3.2). Despite having relatively small areas under forest, the Australian Capital Territory and Tasmania have the greatest proportion of their land areas under forest. Less than 15% of the land area of South Australia and Western Australia is covered by forest.

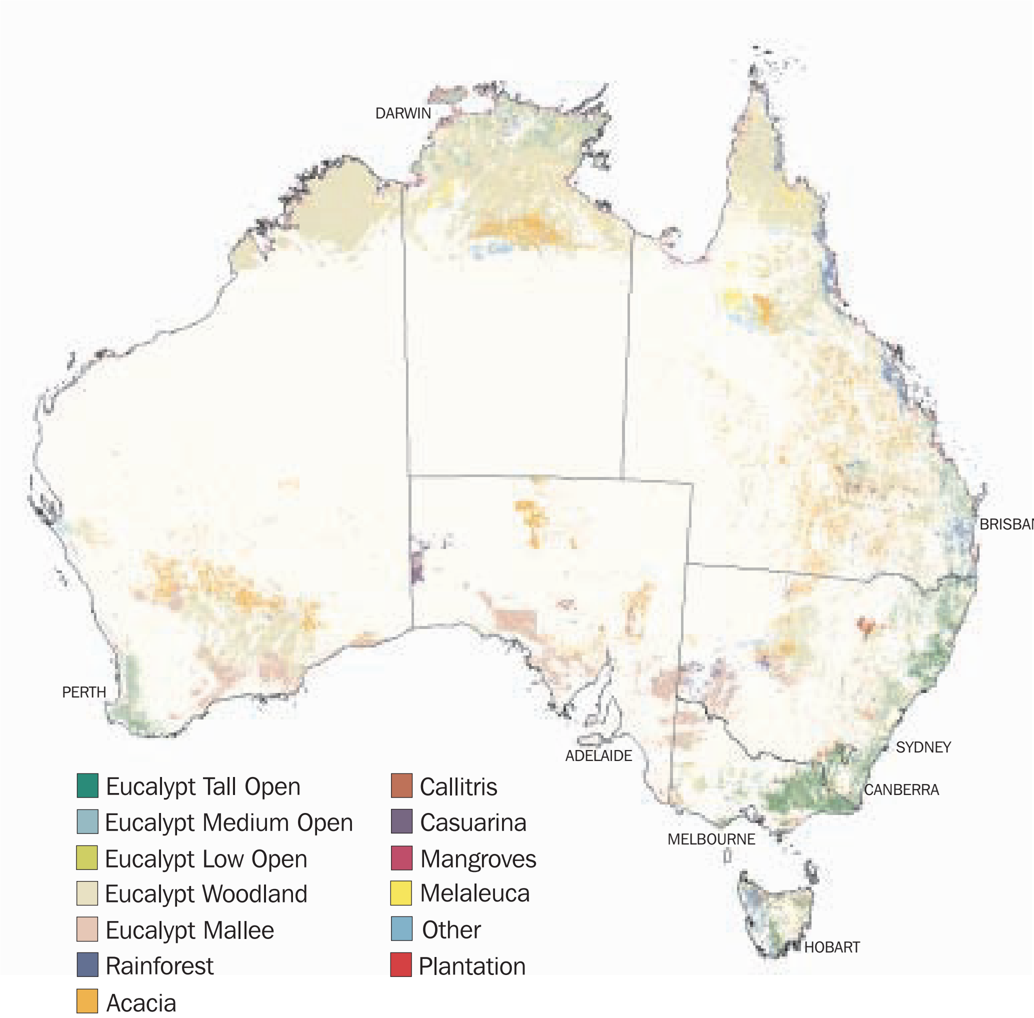
3.2 NATIVE FOREST(a) — 2001

	Units	*NSW*	*Vic.*	*Qld*	*SA*	*WA*	*Tas.*	*NT*	*ACT*	*Aust.*
Forested land	'000 ha	26 742	7 716	46 228	10 789	34 800	3 137	34 879	121	164 411
Proportion of Australia's total forest area	%	16.3	4.7	28.1	6.6	21.2	1.9	21.2	0.1	100.0
Proportion of state area	%	33.4	33.9	26.7	11.0	14.0	45.9	25.9	51.3	21.4

(a) All values have been rounded; hence column and row totals may not tally exactly.

Source: Australian National Accounts: National Balance Sheet, 1999–2000 (cat. no. 5241.0.40.001); NPI 2001.

3.3 DISTRIBUTION OF FOREST TYPES(a) IN AUSTRALIA — 2001



(a) Forest types are outlined in text.

Source: Commonwealth of Australia 2002b.

Native forest area by crown cover

Crown cover measures the area of ground covered by tree canopies. It provides a simple, broad index of how open or closed a wooded ecosystem is. The term 'woodland' is used generally to describe ecosystems that contain widely spaced trees with their crowns not touching (Yates & Hobbs 2000). By definition, woodlands have a 20–50% canopy cover (box 1). The other crown cover categories are 'open forest' (51–80% canopy cover), comprising mainly wet and dry sclerophyll forests, and 'closed forest' (81–100% canopy cover), consisting primarily of rainforest and mangroves. Closed forest ecosystems comprise only 3% of Australia's native forest area, with most existing in Queensland (table 3.4). Woodlands dominate Australia's native forest, making up about 71% of the forest area, with the majority occurring in Queensland and Western Australia.

3.4 AREA(a) OF NATIVE FOREST CROWN COVER — 2001

	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Aust.
	'000 ha	'000 ha	'000 ha	'000 ha	'000 ha	'000 ha	'000 ha	'000 ha	'000 ha
Woodland	22	10 514	26 613	35 797	8 256	1 650	2 257	31 617	116 725
Open	100	15 758	7 504	7 351	2 513	889	5 440	3 003	42 557
Closed	—	470	763	3 080	20	598	19	180	5 129
Total	**121**	**26 742**	**34 879**	**46 228**	**10 789**	**3 137**	**7 716**	**34 800**	**164 411**

(a) All values have been rounded; hence column and row totals may not tally exactly.

Source: NFI 2001.

Temperate eucalypt woodlands are among the most poorly conserved and threatened ecosystems in Australia, having been subjected to intensive agricultural development and land degradation for well over 150 years (Yates & Hobbs 2000). Changes in the area occupied by woodlands from before European settlement have been estimated by AUSLIG (1990) and are summarised in table 3.5. Regional estimates of woodland clearing range from 70% to almost complete elimination for particular woodland communities across Australia (Woodgate & Black 1988; Silvertsen 1994; Hobbs et al. 1993; Robinson & Traill 1996). The subsequent decline in relative abundance and status of numerous woodland-dependent species is of particular concern for the conservation of biodiversity. For example, comparative estimates of the population density of woodland birds indicate that between 1,000 and 2,000 birds permanently lose their habitat for every 100 ha of woodland cleared (Glanznig & Kennedy 2000). Temperate eucalypt woodlands contain one of the highest concentrations of extinct and threatened birds of any region or habitat in Australia (Robinson & Traill 1996).

3.5 WOODLANDS CLEARED AND REMAINING IN AUSTRALIA(a) — 1990

	Area remaining	Area lost
Structural form(b)	'000 ha	'000 ha
Woodland	53 800	46 100
Open woodland	14 100	3 400
Low woodland	43 200	14 100
Low open woodland	145 300	2 100

(a) Areas of forest differ from others given in this chapter and the NFI because of differences in the definition of woodlands.

(b) Based on the woodland definition and classification system in Specht et al. (1970) and Auslig (1990).

Source: Auslig 1990.

Native forest area by forest type

Native forest ecosystems can be classified on the basis of forest type or forest community. These may refer to the forest structure or the taxonomic composition of canopy trees, usually by dominant species. Accounting for structure and dominant species, Specht et al. (1995) identified 457 forest communities across the Australian continent. For the purpose of compiling data for the National Forest Inventory, these communities are grouped into eight broad native forest types: Eucalypt, Acacia, Melaleuca, Rainforest, Casuarina, Mangrove, Callitris and Other forest.

Native forest area by forest type *continued*

Eucalypts are by far the most widespread forest type in Australia, making up 81% of the total native forest area (table 3.6). The largest areas of eucalypt forest are in Queensland, Western Australia, the Northern Territory and New South Wales. Medium height eucalypt forests account for 72% of eucalypt forest area. Acacia forests comprise the second largest proportion of Australia's forests (10%), followed by Rainforest (3%) and Melaleuca (2%). Most of the Acacia and Rainforests exist in Queensland, while Melaleuca occurs primarily in Queensland and the Northern Territory. The remaining forest types account for 4% of Australia's native forest estate.

3.6 NATIVE FOREST(a), BY FOREST TYPE — 2001

	New South Wales	*Victoria*	*Queensland*	*South Australia*	*Western Australia*	*Tasmania*	*Northern Territory*	*Australian Capital Territory*	*Australia*
Forest type	*'000 ha*	*'000 ha*	*'000 ha*	*'000 ha*	*'000 ha*	*'000 ha*	*'000 ha*	*'000 ha*	*'000 ha*
Acacia	12	63	7 127	1 826	3 986	73	3 513	—	16 600
Callitris	261	50	387	248	—	1	—	—	948
Casuarina	67	4	140	728	40	1	—	—	982
Eucalypt	25 523	7 358	31 778	7 942	29 390	2 444	28 841	121	133 397
Tall	3 946	2 396	1 073	1	171	1 116	—	29	8 732
Woodland	91	114	1 012	—	—	275	—	—	1 493
Open	3 855	2 282	61	1	171	840	—	29	7 239
Medium	18 288	3 483	28 790	625	20 815	1 266	22 117	84	95 468
Woodland	10 267	721	25 529	582	19 038	1 259	16 432	18	73 847
Open	8 021	2 762	3 261	43	1 777	7	5 685	65	21 621
Low	186	435	1 789	1 206	3 431	62	6 724	8	13 840
Woodland	114	209	1 676	1 206	3 431	62	6 715	3	13 417
Open	72	225	112	—	—	—	8	5	423
Mallee	3 102	1 045	127	6 110	4 973	—	—	—	15 357
Woodland	9	1 045	127	4 841	3 918	—	—	—	9 940
Open	3 093	—	—	1 269	1 055	—	—	—	5 417
Mangroves	3	3	154	20	173	—	445	—	798
Melaleuca	44	90	2 094	1	155	1	1 708	—	4 092
Other(b)	363	132	1 622	23	1 048	19	55	—	3 263
Rainforest	467	16	2 926	—	7	598	318	—	4 332
Total	**26 742**	**7 716**	**46 228**	**10 789**	**34 800**	**3 137**	**34 879**	**121**	**164 411**

(a) All values have been rounded; hence column and row totals may not tally exactly.

(b) Other forest includes mixed species, unknown and minor genera, including Adansonia, Angophora, Brachychiton, Flindersia, Heteroendrum, Leptospermum and Lysiphyllum.

Source: Commonwealth of Australia 2002b.

Native forest area by tenure

Classifying forests according to land tenure contributes to an understanding of the potential use of Australia's forests. It allows inferences to be made about the management regimes imposed upon the forests and is important for understanding the state of forests. The tenure classifications used by the National Forest Inventory are given in box 2. The 'leasehold' and 'private' tenures collectively account for almost 70% of forest ownership (table 3.7). Consequently, a large proportion of the forest estate is privately managed, in conjunction with a variety of uses including sheep and cattle grazing, pasture and cropping. Forests on private and leasehold lands may also be managed specifically for commercial purposes or conservation. Given the difficulty in documenting private land management, the state of forests on privately owned land is poorly understood (NFI 1998).

Native forest area by tenure *continued*

Approximately 7% of Australia's forests are multiple-use forests, which are managed primarily for timber production. Multiple-use forests are particularly important to those states and territories that have an established forest industry — New South Wales, Victoria, Queensland, Western Australia and Tasmania. There is much debate concerning the ecological sustainability of the forest industry in multiple-use forests, which has recently undergone an assessment through the Regional Forest Agreement process. About 12% of Australia's forests are in Nature Conservation Reserves, formally gazetted under state/territory and/or Commonwealth legislation. Issues pertaining to sustainable forest management, Regional Forest Agreements and the conservation of forests in Australia are discussed in more detail later in this chapter.

3.7 NATIVE FOREST(a), BY TENURE(b) — 2002

	NSW	*Vic.*	*Qld*	*SA*	*WA*	*Tas.*	*NT*	*ACT*	*Aust.*
	'000 ha	*'000 ha*	*'000 ha*	*'000 ha*	*'000 ha*	*'000 ha*	*'000 ha*	*'000 ha*	*'000 ha*
Multiple-use forests	1 797	3 308	3 884	5	1 612	1 212	—	2	11 819
Nature conservation reserves	4 899	3 006	3 225	3 933	4 364	926	46	108	20 506
Other Crown land	1 801	175	1 682	373	13 206	98	332	—	17 669
Private land	6 985	1 183	9 182	852	1 502	900	16 694	—	37 299
Leasehold land	9 144	43	28 199	5 227	14 025	—	17 804	11	74 454
Unresolved tenure	2 117	1	54	399	90	—	3	—	2 664
Total	**26 742**	**7 716**	**46 228**	**10 789**	**34 800**	**3 137**	**34 879**	**121**	**164 411**

(a) All values have been rounded; hence column and row totals may not tally exactly.

(b) Refer to box 2 for description of tenure classes.

Source: Commonwealth of Australia 2002b.

Box 2. Classes of tenure

The National Forest Inventory recognises six major tenure classes:

Multiple-use forests (MUF): State forest, timber reserves and other forest areas on public land where timber harvesting is permitted. They are managed by state and territory agencies in accordance with state and territory Acts and regulations.

Nature conservation reserves (NCR): Crown lands that are formally reserved for environmental, conservation and recreational purposes. They include national parks, nature reserves, state and territory recreation and conservation areas, and crown lands reserved to protect water supply catchments.

Private land: Land held under freehold title and is under private ownership. It includes land held under freehold title with special conditions attached by designated Indigenous communities.

Leasehold land: Land under leasehold title and is generally regarded as 'privately managed'. It includes land held under leasehold title with special conditions attached by designated Indigenous communities.

Other Crown land: Crown land reserved for a variety of purposes (e.g. utilities, scientific research, education, stock routes, mining, use by the armed forces, use by Indigenous communities).

Unresolved tenure: No data, or areas where tenure is unknown.

Source: Commonwealth of Australia 2002b.

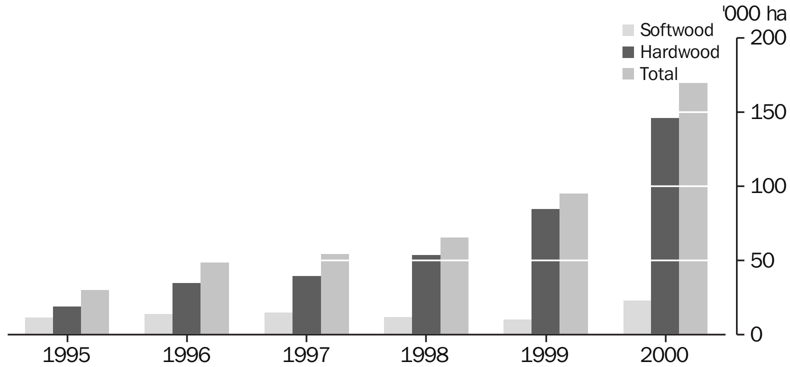
AUSTRALIA'S PLANTATION FOREST ESTATE

Timber harvested from plantations constitutes an important source of wood for the Australian forestry sector. Despite occupying less than 1% of the total forest area in Australia, plantations supply over 50% of wood processing requirements (Burns et al. 1999) and it is expected that forest plantations will be providing 75% of domestic wood supplies by 2010 (Yainshet et al. 2002). By supplementing timber otherwise removed from multiple-use forests, plantations can alleviate the potentially adverse environmental pressures imposed on native ecosystems by the timber industry. Their importance to the timber industry and the environment has seen plantations become a key element in government forest and environmental policy and industry development strategies, both in Australia and overseas (Burns et al. 1999). The National Forest Policy Statement (1992) supports the development of an internationally competitive plantation-based growing and processing industry, which has led to two recent government initiatives designed to expand on an already well established plantation estate.

AUSTRALIA'S PLANTATION FOREST ESTATE *continued*

Plantations for Australia: The 2020 Vision aims to treble the 1994 plantation estate of 1 million ha to 3 million ha by 2020. This policy endeavours to promote a viable plantation processing industry by addressing impediments to investment, raising the understanding of the industry and increasing access to markets. By September 2000, the standing plantation resource had already increased to 1.48 million ha (NPI 2001) and the total area of new plantations being established has been steadily increasing since 1995 (graph 3.8). The *National Farm Forestry Program* encourages the incorporation of commercial tree growing in farming systems for commercial and natural resource management values. In September 2000 there were approximately 67,000 ha of farm forestry plantations, representing around 5% of the total plantation resource, with large industrial plantations making up the remaining 95% (1.4 million ha) (table 3.10).

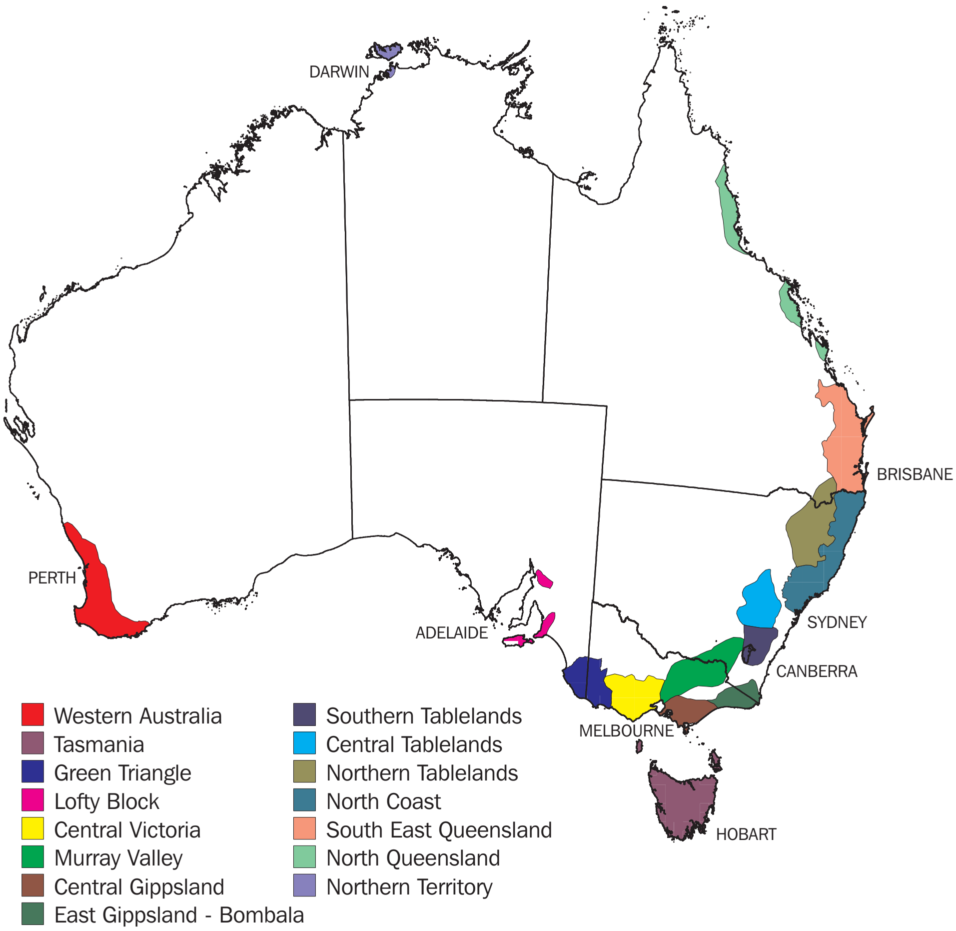
3.8 NEW PLANTATIONS



Source: NPI 2000, Tabular Report.

Information on plantations is compiled in the National Plantation Inventory (NPI) and the National Farm Forestry Inventory according to 15 NPI regions that represent significant economic wood supply zones (map 3.9). Wood flows are not constrained by political boundaries and five of the regions span state or territory borders. Of the NPI regions, Western Australia (21%), Green Triangle (15%), Tasmania and the Murray Valley (each 12%), and South East Queensland (11%) comprise the greatest proportion of the total plantation estate (table 3.10). In terms of states, the largest areas of plantation are in New South Wales, Western Australia and Tasmania, which each support approximately 21% of the plantation resource (NPI 2001).

3.9 NATIONAL PLANTATION INVENTORY REGIONS OF AUSTRALIA



Source: NPI 2001.

3.10 AREA OF PLANTATIONS, BY NATIONAL PLANTATION INVENTORY REGION — SEPTEMBER 2000

	Industrial	*Farm forestry*	*Total*
Region	*ha*	*ha*	*ha*
Western Australia	301 369	12 496	313 864
Tasmania	169 097	16 100	185 197
Green Triangle	218 636	5 548	224 184
Lofty Block	18 983	1 930	20 913
Central Victoria	43 224	6 293	49 517
Murray Valley	173 723	5 731	179 454
Central Gippsland	83 146	6 971	90 117
East Gippsland - Bombala	42 175	773	42 948
Southern Tablelands	24 078	2 504	26 582
Central Tablelands	80 608	—	80 608
Northern Tablelands	15 722	821	16 543
North Coast	54 331	2 481	56 812
South East Queensland	164 462	989	165 451
North Queensland	21 337	2 303	23 640
Northern Territory	6 869	44	6 913
North West Victoria(a)	—	2 001	2 001
Total	**1 417 760**	**66 984**	**1 484 744**

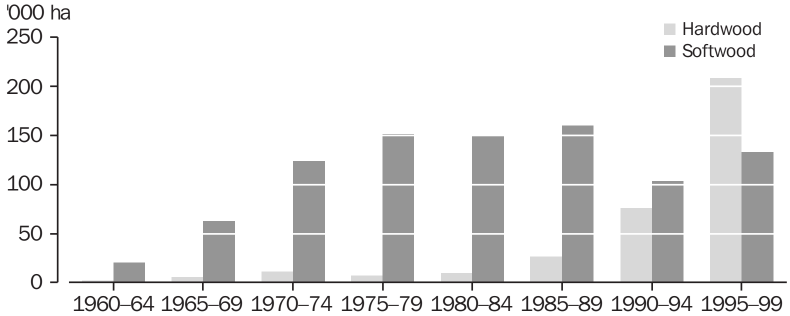
(a) North West Victoria is a Regional Plantation Committee region, additional to NPI Regions.

Source: NPI 2001.

AUSTRALIA'S PLANTATION FOREST ESTATE *continued*

Plantation forests in Australia are dominated by softwood species, which comprise 65% (972,000 ha) of the total standing plantation resource. The remaining area is primarily made up of hardwood plantations (504,000 ha) (NPI 2001). Native eucalypts are the most significant hardwood species, particularly Eucalyptus globulus (Tasmanian blue gum) which makes up 62% of the total hardwood species. Softwood plantations consist mainly of exotic Pinus radiata, which represents 72% of total softwood species (NPI 2001). Although softwoods still make up the majority of the total resource area, their proportion has decreased over time due to increased hardwood plantations since the mid-1990s (graph 3.11). Over the period 1995 to 2000 the hardwood resource increased by 354,500 ha, compared to 155,770 ha for the softwood resource (graph 3.8). The proportion of softwood plantations in this period decreased from 85% of the standing estate in 1995 to 65% in 2000. The rapid hardwood expansion was in large part due to plantings of Eucalyptus globulus (blue gum) for pulpwood production. Blue gums are preferred as they are a very versatile species and produce high quality paper through their high strength qualities, and are also suitable for structural products such as flooring and veneer.

3.11 AVERAGE ANNUAL AREA OF NEW PLANTATION ESTABLISHED(a)



(a) Data include both industrial and farm forest plantations. Mixed species and unknown species are not included. They comprise about 1% of plantations.

Source: NPI 2001.

The environmental impact of a plantation depends, to a large extent, on the previous use of the land and the type of plantation. When hardwood plantations are established on previously agricultural land, such as with farm forestry projects, environmental benefits may arise through: lowering the water table to mitigate salinity; improving the water quality in streams; improving soil structure and fertility; reducing erosion or provision of wildlife habitat; and the subsequent increase in biodiversity. On a global scale, carbon sequestered by appropriately managed plantations may play a significant role in mitigating the greenhouse effect and climate change (see Forests as carbon sinks: economic and ecological values for forests, page 75).

AUSTRALIA'S PLANTATION FOREST ESTATE *continued*

Conversely, if plantations replace native forest, the environmental implications can be adverse. For example, compared to native ecosystems, plantations generally have vastly simplified habitats which support fewer plant and animal species. This is especially relevant to exotic softwood plantations. Consequently, such land conversion usually represents a net loss of biodiversity. In addition, the fragmentation of native forest into a series of remnant patches within a plantation matrix has been shown to reduce the viability of wildlife populations that reside within them (Lindenmayer 2000).

According to the data available to the NPI on previous plantation land use, 21% of the current plantation estate is on former native forest, although the great majority was planted before 1990 (NPI 2001). Recently (especially since 1990), there has been a decline in the establishment of plantations on native forest land and an increase in the area planted on agricultural land (NPI 2001).

ECONOMIC, ECOLOGICAL, SOCIAL AND CULTURAL VALUES OF FORESTS

Australia's forests provide many values to the community: as a source of timber for manufacturing, housing and energy; as a resource for recreational, spiritual and cultural pursuits; as a prime habitat for our flora and fauna; as the catchment area for much of our water supply; as the base for a diverse range of other commercial uses; and as an important component in the set of ecological processes which sustain life (ESDWG 1992). An overview of the complex and interrelated suite of economic, ecological, social and cultural values of forests is presented in table 3.12. Particular aspects of these forest values are explored in this section.

3.12 SUMMARY OF ECONOMIC, ECOLOGICAL, SOCIAL AND CULTURAL VALUES OF FORESTS

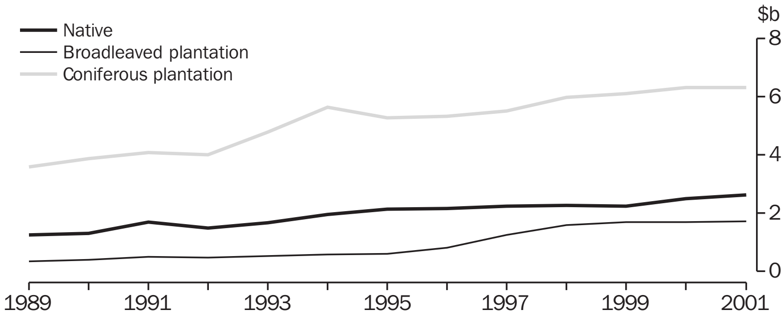
Forest value	*Description*
	ECONOMIC
Timber for forest products	The major commercial contribution of forests in Australia is from wood production for timber and pulp and paper products.
Hardwood for firewood or fuelwood	Hardwood from standing or fallen forest trees is used as firewood or fuelwood by Australia's households and industrial sector.
Honey for beekeeping industry	The beekeeping industry has an overwhelming reliance on native flora. Eucalypts are by far the most important source of nectar and pollen for Australia's apiarists.
Forest catchment for water supply	Forests act as a water supply catchment for industrial and agricultural use. Most major urban centres draw their water from forest based catchments.
Other commercial uses	Such as oils, gums and resins, tannins and dyes, cork, nuts, fruit, flowers, pharmaceutical products and seed.
	ECOLOGICAL
Habitat for nature conservation	Forests provide the suite of resources (food, shelter) and environmental conditions that determine the presence, survival and reproduction of fauna and flora populations.
Maintaining biodiversity	Forest ecosystems make a significant contribution to Australia's exceptional level of ecosystem, species and genetic diversity.
Maintenance of ecological processes	Within forest ecosystems, a wide range of processes relate to the maintenance of productivity and to ecosystem structure and diversity, i.e. formation and maintenance of soils; capture and conversion of energy; nutrient and hydrological cycling; and regeneration.
Maintenance of water quality	Vegetation cover slows run-off to mitigate flooding, reduces erosion and soil loss which reduces water quality, and is important for addressing dryland salinity.
Sinks for atmospheric carbon dioxide (CO_2)	Forest vegetation can accumulate and store CO_2 from the atmosphere. Consequently, it is vital to mitigating rising atmospheric CO_2 levels and global climate change.
	SOCIAL OR CULTURAL
Cultural	Forests help to give Australians a sense of who they are. The forest industry is an important source of employment.
Heritage	Includes ecological, social and cultural attributes identified as being significant to present and future generations.
Educational and scientific	The forest provides information that is of value to society at large. Forests are important for academic research and provide an important educational facility.
Aesthetic and ambience	The visual beauty and scenic qualities of forested landscapes have significant aesthetic and ambient value.
Recreation and tourism	Ranges from relatively passive recreational use (bird watching and photography) through to more active pursuits (bushwalking, rock-climbing, fishing, rafting).
Existence	The forest is of value purely in its own right, to exist as an entity itself.
Bequest	Sense of satisfaction from protecting a forest for the enjoyment of future generations.
Spiritual	People may have spiritual connections with forests resulting from personal experience. Many forest places are sacred to Indigenous people.

Source: ESDWG 1992; NFI 1998.

Economic value of forests

Standing timber resources are an important economic asset for Australia. As part of the National Balance Sheet, the ABS calculated the value of the standing timber asset at end of June 2001 to be $2,625m for native standing timber and $1,729m and $6,325m for broadleaved (hardwood) and coniferous (softwood) plantations respectively (based on Net Present Value; see ABS 2000). Between 1989 and 2001, the estimated value of native forest, broadleaved and coniferous forest increased significantly (graph 3.13). This large resource base provides essential material input into the timber industry. Timber production and the timber industry are discussed in detail later in the chapter.

3.13 VALUE(a) OF STANDING TIMBER



(a) The value of timber resources is estimated in terms of Net Present Value using an index to derive a real rate of discount (see ABS 2000).

Source: Australian National Accounts: National Balance Sheet, 2001 (cat. no. 5241.0.40.001).

The economic value of forests extends beyond standing timber resources in production forests. The beekeeping and firewood industries are heavily reliant on Australia's forests, as discussed below, and carbon stored in certain forests may acquire a market value if it becomes a tradable commodity under an emissions trading scheme (see Forests as carbon sinks: economic and ecological values for forests, page 75).

The beekeeping industry has a gross value of production of just over $60m per year (table 3.14). Bees rely on native flora for food with 70–80% of annual honey production from bees feeding in native flora (Mathison 1988). Eucalypts are by far the most important source of nectar and pollen for Australian apiarists (Briggs & Keith 1996). New South Wales and Victorian honey producers derive at least 70% of the annual honey crop from eucalypts (Somerville & Moncur 1997; NRE & RIRDC Report 2001). Floral resources used by the beekeeping industry are predominantly located on public land (Gibbs & Muirhead 1998). While conserved areas are generally increasing, traditional access for beekeepers to these regions is being questioned on the basis that exotic honeybees may impose adverse impacts upon native bee populations, on insect and bird pollinators, and on animals requiring nesting hollows (Gibbs & Muirhead 1998). A study by Gibbs and Muirhead (1998) concluded that any significant reduction of access to reserved native forest would compromise the viability of the beekeeping industry.

3.14 NUMBER OF REGISTERED HIVES AND HONEY PRODUCTION — 1998

	Registered hives	*Honey production*	*Value of honey production*	*Value of total production(b)*
State	*no.(a)*	*tonnes*	*$m*	*$m*
New South Wales	209 049	14 635	22.2	26.8
Queensland	78 857	5 520	8.4	10.1
Victoria	73 057	5 115	7.7	9.4
South Australia	59 700	4 180	6.3	7.6
Western Australia	36 837	2 580	3.9	4.7
Tasmania	9 184	645	1.3	1.5
Australia	**466 684**	**32 675**	**49.8**	**60.1**

(a) Includes commercial operators with a minimum of 200 hives.

(b) Total production includes honey, beeswax, queen and package bees and pollination services.

Source: Gibbs & Muirhead 1998.

Economic value of forests *continued*

Firewood collectors harvest fallen timber and some live or dead standing timber from Australia's forests for use as a relatively inexpensive source of household energy (Driscoll et al. 2000). In 2000, it was estimated that between 4.5 and 5.5 million tonnes of firewood were burned in Australian households (table 3.15), and when industrial fuelwood consumption is included, the total amount of firewood extracted from forests was between 6 and 7 million tonnes. River Red Gum, Jarrah, Red Box and Yellow Box are particularly sought after trees for use as firewood. Over half of the firewood removed was consumed in New South Wales and Victoria, and despite containing only one-third of households in Australia, rural regions consume over two-thirds of the firewood (table 3.15).

3.15 AVERAGE ANNUAL HOUSEHOLD CONSUMPTION OF FIREWOOD(a)

	Household firewood use	*Proportion of households using firewood*	*Total firewood used*
	tonnes/year	*%*	*million tonnes*
Capital city	2.25	18.6	1.82
Rest of State	3.67	34.7	3.30
New South Wales	2.65	22.3	1.42
Victoria	2.69	25.8	1.21
Queensland	1.31	18.9	0.33
South Australia	4.64	25.5	0.41
Western Australia	3.70	29.2	0.57
Tasmania	5.81	66.8	0.72
Australian Capital Territory	1.88	22.3	0.05
Northern Territory	—	—	0.03

(a) Excludes industrial use of firewood (nationally about 1.5 million tonnes in 2000).

Source: Driscoll et al. 2000.

Old and dead trees and fallen timber provide habitat and food for a range of animals, including birds and insects (ANZECC 2001). Firewood is often collected from old, dead and fallen trees and consequently its removal poses a threat to forest biodiversity. The recent Action Plan for Australian Birds identifies 21 species that are threatened by firewood collection (Garnett & Crowley 2000). Inland forests and woodlands in lower rainfall zones are identified as ecological communities most threatened by firewood collection, because they comprise popular firewood species and have been most extensively cleared for agriculture. Over half of the total firewood harvest is privately collected (Driscoll et al. 2000). The National Approach to Firewood Collection and Use was commissioned in 2000, with the aim of ensuring that 'all firewood collection is ecologically sustainable and not a major cause of loss and degradation of remnant and woodland ecosystems or the habitats of threatened species' (ANZECC 2001).

Ecological value of forests

The Register of the National Estate lists some forest areas because of their significance to natural heritage. The criteria used to assess natural heritage include a range of ecological values such as: importance in exhibiting rich biodiversity; importance for rare, endangered or uncommon flora, fauna or ecosystems; importance for education; being representative of particular ecosystems; and being exceptionally aesthetically pleasing. Table 3.16 presents the number of natural places on the Register of the National Estate which include the words 'forest', 'woodland' or 'rainforests' in a summary statement of their important heritage values. Seven of Australia's 14 World Heritage Properties have natural heritage values associated with forest landscapes: Kakadu National Park, Lord Howe Island Group, Tasmanian Wilderness, Central Eastern Australian Rainforest Reserves, Wet Tropics of Queensland, Fraser Island and the Greater Blue Mountains Area.

3.16 NATURAL PLACES ON REGISTER OF THE NATIONAL ESTATE THAT INCLUDE FOREST, RAINFOREST OR WOODLAND IN STATEMENT OF SIGNIFICANCE(a)(b) — 2001

State	*Interim listed(c)*	*Registered*	*Total*
New South Wales	33	179	212
Victoria	132	82	214
Queensland	6	170	176
South Australia	2	63	65
Western Australia	87	65	152
Tasmania	8	92	100
Northern Territory	2	13	15
Australian Capital Territory	—	3	3
External Territories	—	3	3
Total	**270**	**670**	**940**

(a) This table does not include places listed for their cultural values.

(b) Not all forest and woodland with heritage significance will include the words 'forest', 'rainforest' or 'woodland' in their statement of significance.

(c) Places listed as interim have been publicly proposed for entry in the Register of the National Estate and are awaiting any objections, considering objections or seeking other data before making a decision on whether the place should be entered in the Register proper.

Source: Register of the National Estate, 2001.

Australia's forests are home to many species which form a great variety of ecological communities (or ecosystems). Forests account for 457 of the 910 plant communities occurring in Australia (Specht et al. 1995). The major ecological communities of Australia — including forests — have been defined, mapped and described in the Interim Biogeographic Regionalisation for Australia (IBRA) (Thackway & Creswell 1995). A provisional estimate of forest dwelling vertebrate species and higher (vascular) plant species for each state is presented in table 3.17. Based on these data (NFI 1998), about 54% of Australia's vertebrate species and approximately 76% of its higher plant species occur in forests (NFI 1998). More than 2,800 of the 3,000 Australian tree species are unique to Australia (Commonwealth of Australia 2001).

3.17 PLANT AND ANIMAL SPECIES OCCURRING IN FORESTS(a)

	NSW	*Vic.*	*Qld*	*SA*	*WA*	*Tas.*	*NT*	*ACT*
Amphibians	54	36	49	na	15	7	30	na
Birds	281	253	303	na	150	77	198	na
Fish	—	—	4	na	12	—	—	na
Mammals	96	94	104	na	29	27	87	na
Reptiles	73	102	122	na	45	14	134	na
Total vertebrates	**504**	**485**	**582**	**na**	**239**	**125**	**449**	**na**
Higher plants	na	2 959	7 830	na	2 639	1 043	1 691	na

(a) Varying collection methods and differences in the definition of forest dwelling species may affect the consistency of results across states and territories.

Source: NFI 1998.

Social/cultural value of forests

Cultural heritage encompasses the qualities and attributes of places that have aesthetic, historical, scientific or social value for past, present or future generations (Australia ICOMOS Burra Charter Article 1.2). These values may be seen in a place's physical features or through intangible qualities such as an individual's or community's association with or feelings for a place (SF NSW 2000). Indigenous peoples have lived in and used forested areas for thousands of years as hunting grounds, as places for ceremony and learning, and as a source of bush tucker, medicines and raw materials. More recently, non-Indigenous settlers have used the forest as an important source of contemporary cultural meaning (NFI 1998). The cultural significance of Australia's forest estate varies significantly between community groups and between different levels of community — local, regional and national. Cultural values are difficult to identify and assess, particularly quantitatively. The role of the forestry sector as a source of employment is discussed later.

An example of a forested landscape that encompasses a diverse range of cultural values is the Greater Blue Mountains World Heritage Area, located about 60 kilometres west of Sydney. It has significant aesthetic value, as its wilderness landscape consists of dramatic yellow sandstone escarpments, spectacular gorges, canyons and caves and a diverse and beautiful range of distinctive blue sclerophyll vegetation. The Blue Mountains are associated with Aboriginal occupation, and their custodianship over the land, which spans at least 14,000 years. The area contains about 700 known Aboriginal occupation sites and rock shelter paintings, as well as rock platform engravings. More recently, the Blue Mountains have provided an important recreation facility, particularly for Sydney residents, and support a thriving tourism industry. Bushwalkers take advantage of an extensive walking track system which traverses much of the region, and sites such as the Jenolan Caves and the Three Sisters at Katoomba are popular tourist destinations.

Places of cultural significance within forests may be recognised under Indigenous and historic listings on the Register of the National Estate. Readers interested in exploring the cultural heritage values of Australia's forests are advised to contact the Commonwealth Department of Environment and Heritage or search the Register of the National Estate database at <http://www.ahc.gov.au>.

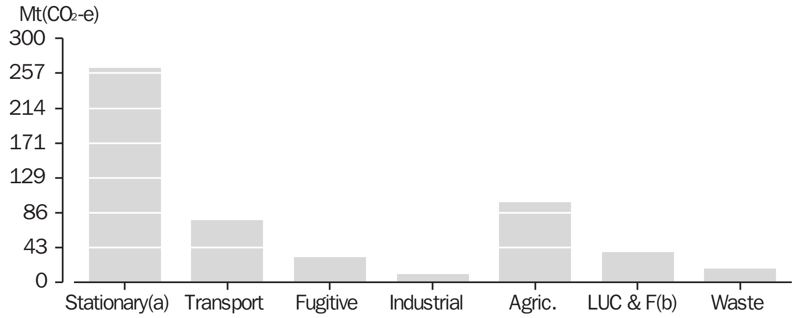
FORESTS AS CARBON SINKS: ECONOMIC AND ECOLOGICAL VALUES FOR FORESTS

Terrestrial ecosystems, particularly forests, have the potential to accumulate and store carbon dioxide (CO_2) from the atmosphere. Consequently, they play a vital role as mitigators of rising atmospheric CO_2 concentrations and global climate change. Furthermore, carbon in certain planted forests may acquire an economic value if it becomes a tradeable commodity under an emissions trading scheme.

Rising atmospheric CO_2 concentrations, climate change and the international response

Since the Industrial Revolution, global concentrations of CO_2 and other greenhouse gases in the atmosphere have risen significantly. The Intergovernmental Panel on Climate Change (IPCC) reported that, between 1850 and 1998, atmospheric CO_2 concentrations have increased by approximately 28%, from about 285 to 366 parts per million (IPCC 2000b). Fossil fuel consumption and, to a lesser degree, tropical deforestation have been identified as primarily responsible for the escalating atmospheric CO_2 and greenhouse gas concentrations. In 2000, Australia's net greenhouse gas emissions totalled 535.3 million tonnes of carbon dioxide equivalent (CO_2-e), predominantly arising from emissions from the energy sector (AGO 2002; graph 3.18).

3.18 GREENHOUSE GAS EMISSIONS BY SECTOR — 2000



(a) Stationary energy.
(b) Land Use Change and Forestry.

Source: AGO 2002.

Increased atmospheric CO_2 and greenhouse gas concentrations may have caused changes in global climate and weather patterns, and may continue to do so into the future (IPCC 2000a).

The 'ecological value' of carbon in forests

Given their ability to accumulate and store (or sequester) atmospheric CO_2, forests play an important role in mitigating the greenhouse effect and climate change. Forest vegetation absorbs CO_2 from the atmosphere as part of the growing process, where it is stored as living vegetation biomass, including standing timber, branches, foliage and roots; and in dead biomass including litter, woody debris and soil organic matter. As such, these forest carbon pools are valuable as atmospheric CO_2 sinks.

Biomass and carbon storage in Australian forests

Estimation of carbon stocks in Australian forests is limited by scarce and inconsistent data concerning carbon storage and a poor understanding of key carbon cycle processes. Available data are probably biased toward certain forest types, and some ecosystem components are particularly under-represented. For instance, most studies have investigated only the above-ground components of forests and little consideration has been given to the below-ground component. The Australian Greenhouse Office has set up research initiatives such as the National Carbon Accounting System and the Cooperative Research Centre for Greenhouse Accounting to improve measurement and predictions of stocks and fluxes in Australian vegetation, and to develop a comprehensive framework for reporting storage and emissions of carbon dioxide.

Estimates have been made of the above-ground biomass and carbon storage of Australia's forests and woodlands, classified according to the Carnahan (1976) structural classification scheme (table 3.19). On the basis of this analysis, the total forest ecosystem biomass for Australia's forests and woodlands is estimated to be approximately 26.3 billion tonnes, while the total carbon pool is approximately 13.1 billion tonnes. Given their large extents, open medium forest (29%) and medium woodland (43%) dominate storage in the carbon pool. It should be noted that these estimates constitute only broad, preliminary estimates and do not include below-ground carbon, which may make a substantial contribution to the forest and woodland carbon pool.

3.19 ESTIMATED TOTAL FOREST AND WOODLAND ECOSYSTEM BIOMASS AND CARBON POOL(a) — 1997

Forest type	*Forest and woodland area(b)*	*Above-ground biomass*	*Total forest ecosystem biomass*	*Total forest ecosystem carbon pool*
	'000 hectares	*tonnes/hectare*	*million tonnes*	*million tonnes*
Closed tall forest	1 639.8	450	738	369
Closed medium forest	1 958.5	356	697	349
Closed low forest	1 029.0	300	309	155
Open tall forest	5 476.9	279	1 528	764
Open medium forest	28 094.7	272	7 642	3 821
Open low forest	1 415.9	200	283	142
Open, medium, mallee, forest	234.9	39	9	5
Open, low, mallee, forest	3 952.2	39	154	77
Tall, woodland	1 068.1	200	214	107
Medium woodland	76 075.0	150	11 411	5 706
Low woodland	27 312.9	100	2 731	1 366
Medium mallee woodland	870.0	39	34	17
Low mallee woodland	6 706.7	39	262	131
Plantations	1 042.6	244	254	127
Total	**156 877.2**	**2 707**	**26 266**	**13 136**

(a) Estimates of above-ground carbon storage are generally derived from above-ground biomass densities. Given that approximately 50% of biomass is carbon, the carbon density may be calculated by assuming a conversion factor of 0.5. The total above-ground biomass may be roughly approximated by multiplying the area of each structural forest and woodland class by the above-ground biomass estimates.

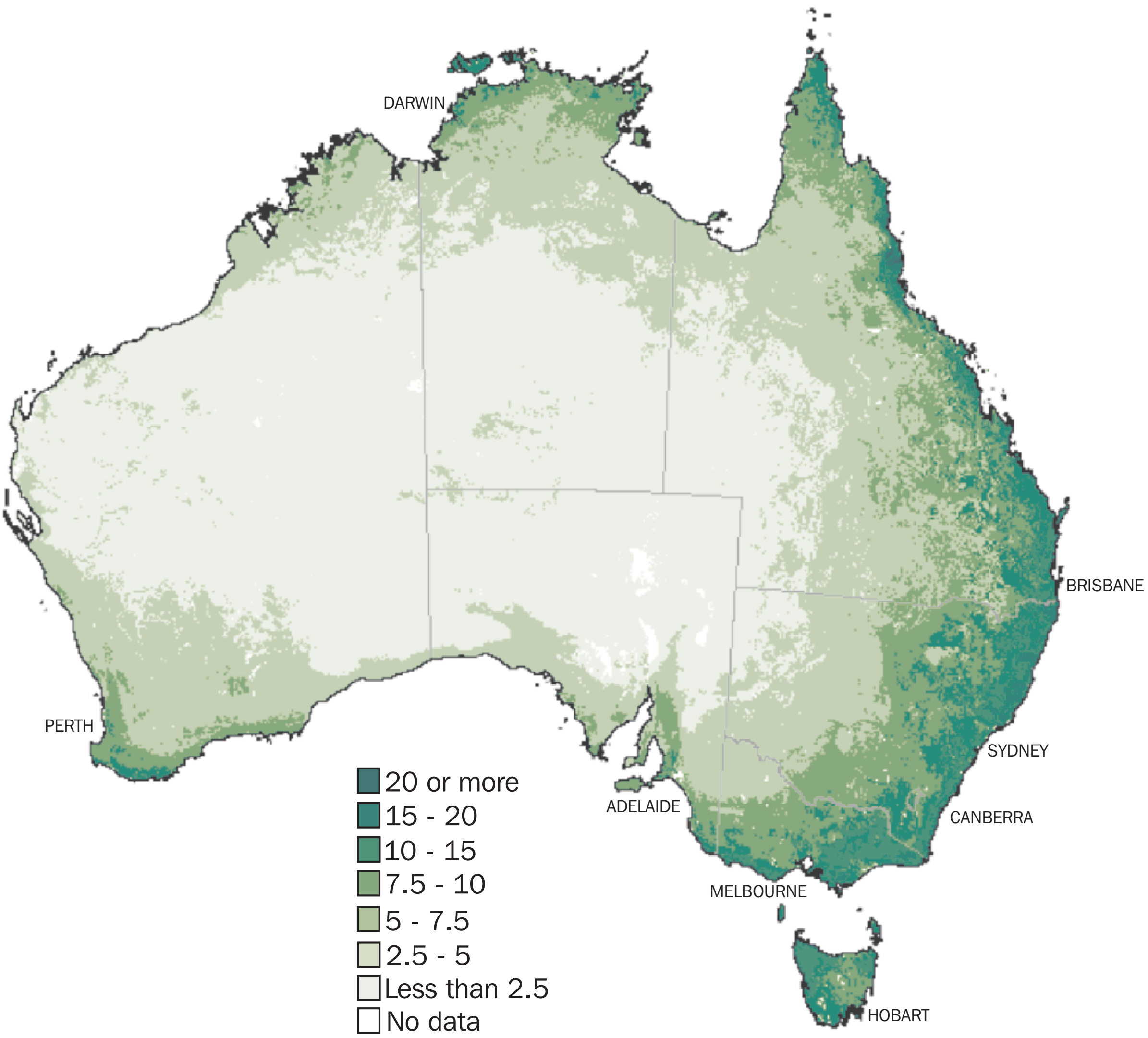
(b) This analysis uses an old definition of forests; hence the area of forest differs from contemporary NFI data presented in this chapter.

Source: Australia's First Approximation Report for the Montreal Process, June 1997.

Carbon sequestration in Australian forests

Net Primary Productivity (NPP) is a common measure of the rate of carbon sequestration by a forest, equal to the difference between carbon gained by plant photosynthesis and the carbon lost by plant respiration. Computer simulation models enable the spatial prediction of NPP. Based on geographically referenced information on environmental factors such as solar radiation, water and nutrient availability, humidity, temperature and certain vegetation attributes, these models can estimate the variation of NPP over landscapes, regions or the entire continent. A computer simulation model was applied to the whole surface of Australia to give a complete map of NPP for the Australian continent (map 3.20). In this model the highest NPP occurs in the forested wet tropics and New South Wales North Coast regions, while the lowest NPP occurs in the Little Sandy and Simpson–Strezlecki desert regions. Estimates of NPP by other models for the entire Australian continent range from 1.6 to 3.2 billion tonnes of carbon per year (Kirschbaum 1999; Roderick et al. 2001).

3.20 NET PRIMARY PRODUCTIVITY FOR AUSTRALIA AS PREDICTED BY SIMULATION MODEL, Annual average (1982–90)

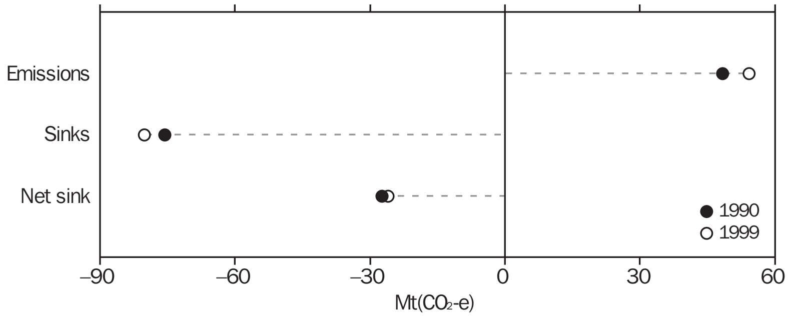


Source: Australian Greenhouse Office, National Carbon Accounting System.

Emissions and sinks from forest management

Forestry is both a sink (absorber) and producer of CO_2-e emissions, the net effect being that forestry absorbs more than it produces. Forestry contributes to CO_2-e emissions through the decay of harvested timber products and the decay of unburnt woody debris. In 1999 around 53 Mt of CO_2-e was emitted from forestry, while around 76 Mt of CO_2-e was absorbed by growing forests (AGO 2002). The net effect of forestry was a sink of around 23 Mt of CO_2-e. This is slightly less than in 1990 when it was a net sink of around 25 Mt of CO_2-e (graph 3.21).

3.21 CO_2-e EMISSIONS FROM FORESTRY(a)(b)



(a) Forestry = forest and other woody biomass stocks.
(b) Does not include emissions from Land clearing or Other (see NGGI 2002).
Source: AGO 2001a and 2002.

Emissions trading and carbon credits: The 'economic value' of carbon in forests

The United Nations Framework Convention on Climate Change (UNFCCC) was formed in 1992 in response to concern over global climate change (see <http://www.unfccc.int>). An additional instrument, the Kyoto Protocol, was established in principle in 1997. Australia has not ratified the Kyoto Protocol. The Protocol sets out emissions targets for countries and includes provisions that allow countries to offset emissions by taking into account carbon sequestered in greenhouse sinks. These carbon sinks could be incorporated into an emissions trading system. This trading system is one of three proposed 'flexibility mechanisms', which will promote affordable emission abatement activities.

Emissions trading refers to the buying and selling of emissions units by countries that have emission abatement targets. Emissions trading would be based upon emissions permits — a tradable commodity — that would provide the holder with authorisation to emit a specified amount of greenhouse gas, most likely expressed as one tonne of CO_2-e. Carbon sinks could be incorporated into an emissions trading system by issuing a 'carbon credit' (or 'removal unit' or RMU) for each tonne of CO_2-e sequestered in certain managed forests. Such credits would be tradable commodities and could be used interchangeably with emissions permits.

Emissions trading and carbon credits: The 'economic value' of carbon in forests *continued*

The Kyoto Protocol does not incorporate the contribution of forest sinks on a comprehensive basis. Only specified sinks associated with afforestation, reforestation and deforestation since 1990 are taken into account. In addition to these 'Kyoto forests', the Kyoto Protocol also recognises the activities of forest management, cropland management, grazing land management and revegetation. As such, the emergence of a market for carbon sequestered in trees will have significant implications for forestry and rural sectors. The financial incentive to invest in Kyoto forests and additional greenhouse sink activities may provide the stimulus for environmental plantings and commercial forestry plantations. Plantations may be established primarily for the sale of carbon credits only, or commercial forestry activities may use carbon credits to supplement returns from timber harvesting.

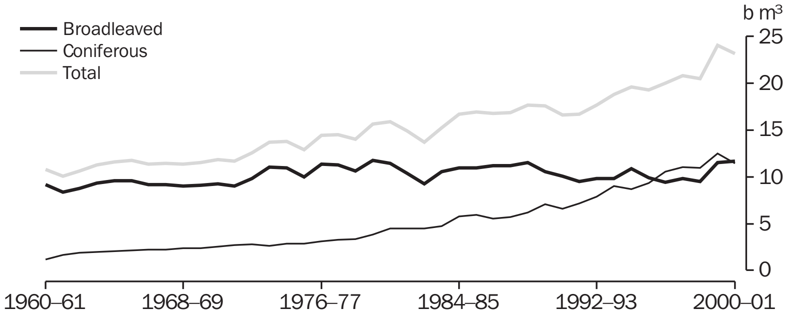
TIMBER PRODUCTION IN AUSTRALIA'S FORESTS

Wood and paper products (forest products) are essential to the everyday lives of Australians, and range from sawn timber used for housing and construction, to wood based panels such as plywood and particleboard, to paper and paper products including newsprint, writing paper and packaging. These products are either imported or produced from timber removed as roundwood from Australia's native and plantation forests. Furthermore, forest products collectively comprise an important export commodity for Australia. The import and export of forest products is an important issue within the forestry sector, particularly the role of woodchips and the trade deficit in forest products. Much of the debate about the use of forests has concerned assessing the socioeconomic benefits of the forestry sector relative to the potentially adverse changes to forest ecosystems caused by logging. This debate is especially relevant in rural communities currently dependent on the forestry sector for employment and economic development. These issues provide the basis for discussion of the forestry sector in Australia presented in this section.

Removal of timber from Australia's forests and its environmental impacts

In 2000–01, approximately 24.2 million cubic metres (m^3) of roundwood were removed from Australia's forests (ABARE 2002). In 2000–01, about 42% of the total roundwood removed was logged from commercially productive native broadleaved forests (hardwood; 10.2 million m^3). The remaining volume was supplied from the coniferous (softwood; 13 million m^3) and broadleaved plantation estate (hardwood; 1 million m^3 (ABARE 2002)). The contribution of coniferous (softwood) plantations to the timber industry has increased steadily since the 1960s, and is primarily responsible for the increasing volume of timber removed from Australia's forests over time (graph 3.22).

3.22 REMOVALS OF ROUNDWOOD(a)

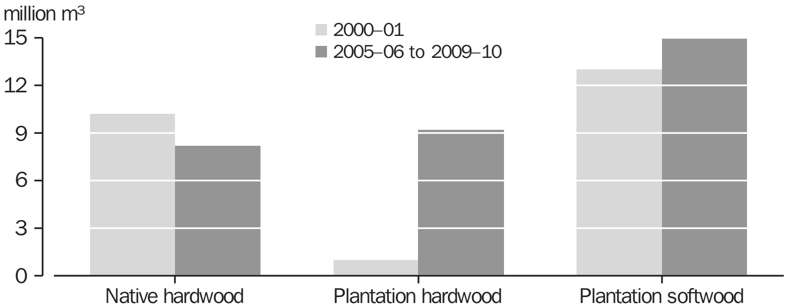


(a) Gross Roundwood Equivalent (GWE) of industrial log removals. Excludes log removals for firewood.

Source: ABARE 2001.

The trend in graph 3.22 reflects a gradual restructuring of the forestry industry, where timber removed from native forest ecosystems has been supplemented by an expanding softwood and hardwood plantation resource (refer to the section *Australia's plantation forest estate*). Given Commonwealth and state government initiatives such as *Plantations for Australia: The 2020 Vision* and the *Farm Forestry Project*, this trend is expected to continue with increasing contributions from a rapidly expanding hardwood plantation estate. Annual wood flows from hardwood plantations are expected to rise significantly from 1 million m^3 in 2000–01 to an average of 9.2 million m^3 in the latter half of the current decade, while removals from native forests are projected to decline from 10.2 million m^3 to 8.2 million m^3 (graph 3.23).

3.23 AVERAGE ANNUAL ROUNDWOOD REMOVALS — 2000–01 AND 2005–06 TO 2009–10(a)



(a) Projected roundwood removals for the period 2005–06 to 2009–10 from Ferguson et al. 2002.

Source: Ferguson et al. 2002; Yainshet et al. 2002.

Much of the debate about forest use has focused on the potential environmental impacts of timber harvesting in native forests managed for wood production and whether these impacts are damaging to the values of the forest estate (RAC 1992). This issue was central to the recent Regional Forest Agreement process, discussed later in this chapter. The potential impacts of timber harvesting are wide ranging (table 3.24), complex in nature and vary enormously in the spatial extent and the time taken for their implications to become apparent. Consequently, the magnitude and importance of these impacts is difficult to assess and evidence of their implications remains limited (RAC 1992).

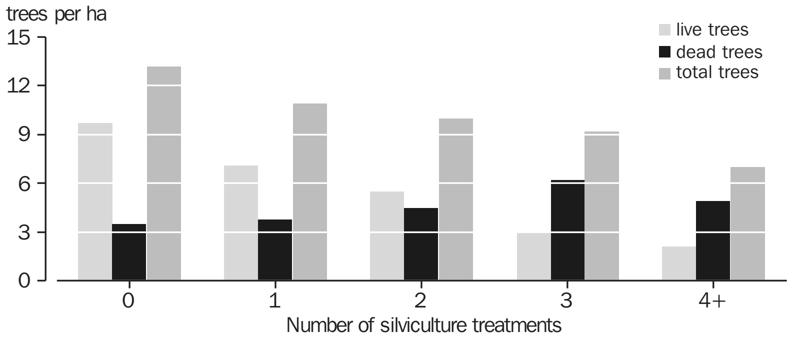
3.24 POTENTIAL IMPACTS OF WOOD PRODUCTION ACTIVITIES

- Compaction of soil from the action of harvesting machinery
- Loss of soil nutrients through wood removal
- Regeneration and fuel reduction burning
- Erosion from roads and tracks
- Increased sediment loads in forest streams
- Changes in forest hydrology
- Changes to forest structure following clearfelling
- Changes in vegetation composition through fuel reduction burning
- Facilitation of weed and feral animal invasion through the creation of logging roads and temporary clearings following clearfelling
- Reduction in habitat of forest-dwelling fauna

Source: RAC 1992.

Clearfelling and associated fire regimes result in major changes in plant species composition and stand structure (Florence 1996), which in turn may have detrimental effects on an array of plants and animals (Mackey et al. 1998). For example, logging operations can significantly change the distribution and abundance of hollow-bearing trees that provide habitat for a wide array of vertebrate and invertebrate species. Tree hollows tend to occur in mature, senescent and dead trees, and often take over 100 years to form. Forests are often logged on rotation times shorter than the period required for hollows to form, consequently reducing the number of hollow bearing trees in harvested forest ecosystems (Gibbons & Lindenmayer 2001). Studies consistently show that hollow-bearing trees are present in greater number in unlogged stands than in those subject to silvicultural treatments (Lindenmayer et al. 1990; Gibbons 1999; graph 3.25). This has important implications for populations of hollow-dependent species such as Leadbeaters Possum, Greater Glider and Mountain Brushtail Possum (Gibbons & Lindenmayer 2001). For example, Lindenmayer et al. (1991) found that arboreal marsupials were rare or absent from areas of forest which supported limited numbers of hollow-bearing stems.

3.25 NUMBER OF HOLLOW-BEARING TREES, Range of forest types, South-east Queensland



Source: Ross 1999.

Imports and exports of forest products

The most conspicuous feature of Australia's international trade of forest products is the \$2b trade deficit (table 3.26). The deficit is primarily due to Australia's dependance on imported pulp and paper products, which currently account for around 70% of the imports bill for forest products. Currently, it is cheaper to import paper and paper products given our relatively high costs of production and high environmental protection standards. In the long-term, domestic processing of paper and paper products in Australia is expected to increase, given the recent construction of several pulp and paper mills and the rapid expansion of the plantation estate (Yainshet et al. 2002). However, with no major expansion of domestic production capacity anticipated in the medium term, paper and paper product imports are expected to remain an important component of Australia's trade in forest and forest products.

3.26 FOREST PRODUCTS, IMPORTS, EXPORTS AND TRADE BALANCE — 2001

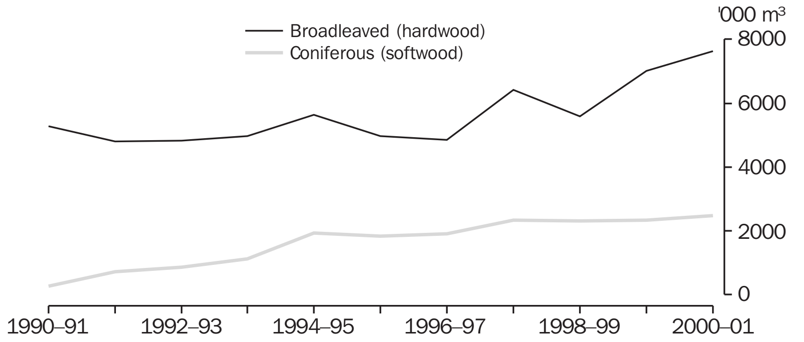
	Units	*Imports*	*Exports*	*Balance(a)*
	VOLUME			
Roundwood	'000 m^3	1.3	1 094.2	1 092.9
Sawnwood	'000 m^3	718.5	86.5	–632.0
Railway sleepers	'000 m^3	—	23.8	23.8
Wood based panels	'000 m^3	285.1	518.6	233.5
Paper and paperboard	kt	1 409.8	530.1	–879.7
Wastepaper	kt	41.2	246.1	204.9
Pulp	kt	303.4	17.8	–285.6
Woodchips	kt	3.1	5 004.1	5 001.0
	VALUE			
Roundwood	\$m	0.9	66.8	65.9
Sawnwood	\$m	427.7	58.9	–368.8
Railway sleepers	\$m	—	9.0	9.0
Miscellaneous forest products	\$m	461.5	71.2	–390.3
Wood based panels	\$m	151.6	205.4	53.8
Paper and paperboard	\$m	2 088.0	528.8	–1 559.2
Paper manufactures	\$m	377.5	83.8	–293.7
Wastepaper	\$m	8.8	39.7	30.9
Pulp	\$m	316.6	4.6	–312.0
Woodchips	\$m	1.4	743.8	742.4
Total	**\$m**	**3 834.1**	**1 811.9**	**–2 022.2**

(a) Negative value denotes a trade deficit where imports exceed exports.

Source: ABARE 2002.

Economically, woodchips are Australia's most important forest product export, accounting for 41% of the value of total forest product export trade (table 3.26). Australia sells almost 95% of its export woodchips to Japan, the balance being shipped predominantly to South Korea and Taiwan (ABARE 2002). Since 1990, woodchip exports have risen (graph 3.27), with increasing contributions from the softwood and hardwood plantation estate. Woodchips are produced from sawmill residues and pulplogs. Pulplogs are obtained as thinnings from plantations and from clearfelling, or 'integrated harvesting', of native forests to salvage both quality timber for sawlogs and pulplogs for woodchips (RAC 1992).

3.27 QUANTITY OF WOODCHIPS EXPORTED(a)



(a) Green tonne equivalent of bone dry tonnes.

Source: ABARE 2001.

Australia's export woodchipping industry has prompted intense and often highly publicised debate between the forest industry and conservation groups, and was heavily scrutinised during the Regional Forest Agreement process. Forest industry groups maintain that the industry is sawlog driven, with woodchips providing an opportunity to market residual roundwood that would otherwise be largely a waste product of logging activity. They argue that maintenance of the export woodchip trade is crucial for the development of hardwood plantations in Australia (RAC 1992) and that clearfelling is often the most appropriate silvicultural regime for many types of eucalypt ecosystems that rely on the associated post-harvest burn for regeneration (Florence 1996).

Conservation groups argue that logging operations are largely pulplog (i.e. woodchip) driven because of the important source of revenue they provide. These groups regard this as unacceptable on the grounds that ecological forest values are compromised for a relatively low-value resource. They argue that clearfelling of native forest during integrated harvesting operations generally has a greater impact on the environment than the selective logging of native forests for sawlogs (RAC 1992).

The wood and paper product manufacturing industries and employment

The forestry sector comprises the forest and logging and the wood and paper manufacturing industries. The sector collectively contributed just over $4.5b to the gross domestic product (GDP) in 1996–97, representing approximately 1% of total GDP (ABS 2001c). The forestry sector is particularly important in providing economic development and employment in rural regions. In 1999–2000 the forestry sector had a turnover of over $15b and spent approximately $2.6b on wages and salaries, of which the wood and paper manufacturing industries contributed a significant proportion (table 3.28).

3.28 WOOD AND PAPER PRODUCT MANUFACTURING INDUSTRIES, SUMMARY OF OPERATIONS — 1999–2000

	Forestry & logging	*Wood & paper product manufacturing*	*Total*
	$m	*$m*	*$m*
Wages and salaries(a)	332.1	2 497.3	2 829.4
Turnover	1 447.3	15 693.5	17 140.8
Industry Value Added	681.0	5 226.3	5 907.3

(a) Excludes the drawings of working proprietors.

Source: ABS data available on request, Economic Activity Survey.

The number of persons employed in the forestry sector has fluctuated between 60,000 and 95,000 persons since the 1980s (ABS Labour Force Survey) and currently stands at approximately 77,900 (table 3.29). This represents just under 1% of Australia's total workforce. About 89% of the forestry sector workforce is employed in the manufacturing and processing of forest products. The forestry sector is particularly important in Tasmania, where it makes up 2.7% of that state's total workforce.

3.29 EMPLOYMENT(a) IN FORESTRY SECTOR — 1999–2000

	Forestry & logging		*Wood & paper manufacturing*		*Total*	
	Employed	*Total workforce*	*Employed*	*Total workforce*	*Employed*	*Total workforce*
	'000(b)	*%*	*'000(b)*	*%*	*'000(b)*	*%*
New South Wales	2.14	0.07	22.41	0.75	24.55	0.82
Victoria	*0.68	0.03	18.38	0.83	19.06	0.86
Queensland	*0.99	0.06	10.99	0.66	11.98	0.72
South Australia	0.90	0.13	7.75	1.16	8.65	1.29
Western Australia	1.89	0.21	5.66	0.61	7.55	0.82
Tasmania	1.99	1.01	3.44	1.74	5.43	2.74
Northern Territory	**0.07	0.08	**0.21	0.22	0.28	0.30
Australian Capital Territory	**0.12	0.07	*0.29	0.17	0.40	0.25
Australia	**8.78**	**0.10**	**69.12**	**0.78**	**77.89**	**0.87**

(a) All values have been rounded; hence column and row totals may not tally exactly.

(b) Figure derived by averaging the employment estimate for each quarter in 1999–2000.

Source: Data available on request, ABS Labour Force Survey.

The forestry sector is an important source of employment and economic development for many rural communities. The proportion of the working population employed in the sector is indicative of that population's financial dependence on it (its 'forest-dependency'). On a regional scale, 186 towns have a forest-dependency above 5% (NFI 1998). Of these towns, 35 have a forest-dependency of more than 20% and 5 have a forest-dependency greater than 50% (NFI 1998). Regions that are heavily reliant on the forestry sector include: the Orbost and Cann River regions in Victoria; the Grafton, Taree, Eden, Gloucester and Bombala regions in New South Wales; the Huon Valley region in Tasmania; and the Mornington region in Western Australia (DFA 1999a).

The wood and paper product manufacturing industries and employment *continued*

Forest-dependent communities exhibit certain characteristics, including relatively low education and training levels, narrow employment experience and opportunities, low household income of workers and the concentration of the communities in small rural townships (DFA 1999b). As a consequence of their limited resources to make adjustments to employment and lifestyles, these individuals and communities are highly vulnerable to changes in the local forest industry (DFA 1999b). Consideration of the social implications of changing the forest industry was particularly important during the Regional Forest Agreement (RFA) process, and resulted in the completion of several social impact assessments.

ECOLOGICALLY SUSTAINABLE FOREST MANAGEMENT

Ecologically sustainable forest use is a major objective for those concerned with the management of Australia's forest resources. The Ecologically Sustainable Development Working Group (1991) defined ecologically sustainable forest use as

> ...optimising the tangible and intangible social and economic benefits which forests can provide to the community, with the goals of maintaining the functional basis of forested land, biodiversity and the options available for future generations.

To achieve ecologically sustainable forest use, the challenge for forest managers is to strike a reasonable balance between the economic, ecological, social and cultural values of forests for current and future generations.

The Montreal Process: measuring ecologically sustainable forest management

The Montreal Process, established in 1994, is being used as a tool to assist in the measurement and monitoring of Australia's progress toward sustainable forest management. The Montreal Process was established with the specific purpose of developing and implementing internationally agreed criteria and indicators for sustainable management of the world's temperate and boreal forests. The Montreal Process includes twelve countries on five continents, including Australia, which account for 90% of the world's temperate and boreal forests, and 45% of the world trade in forest products.

The group has developed a set of seven criteria (categories of forest values to be maintained) and 67 indicators (measurable aspects of these criteria). The seven criteria include vital ecosystem functions and attributes (biodiversity, productivity, forest health, the carbon cycle and water protection), socioeconomic benefits (timber, recreation and cultural values) and the laws and regulations that constitute the forest policy framework (box 3). The indicators have been divided into three groups — Category A which are largely implementable now, Category B which require some development and Category C which require longer term research and development. Australia's *First Approximation Report for the Montreal Process*, which reports on Category A indicators, was released in 1997 (Commonwealth of Australia 1997). Australia's Country Report to the Montreal Process is in preparation and is expected to be available in late 2003.

Box 3. The Montreal Process: criteria and indicators for the conservation and sustainable management of temperate and boreal forests

The Montreal Process identified seven broad criteria important for sustainable forest management. These are:

1. Conservation of Biological Diversity
2. Maintenance of Productive Capacity of Forest Ecosystems
3. Maintenance of Ecosystem Health and Vitality
4. Conservation and Maintenance of Soil and Water Resources
5. Maintenance of Forest Contribution to Global Carbon Cycles
6. Maintenance and Enhancement of Long-term Multiple Socioeconomic Benefits to Meet the Needs of Societies
7. Legal, Institutional and Economic Framework for Forest Conservation and Sustainable Management.

Source: Commonwealth of Australia 1997.

Regional Forest Agreements

Australia's National Forest Policy Statement (1992) provides the policy framework for the future management of Australia's public and private forests, and outlines a vision for the ecologically sustainable management of Australia's forests. To implement this policy, the governments negotiated 20 year bilateral RFAs between the Commonwealth and the states and territories. The key objectives of RFAs are to establish a world class conservation reserve system (discussed later), to provide certainty for forest industries and forest-dependent communities, and to provide continuous improvement in ecologically sustainable management of the entire forest estate. The RFAs are based on scientific Comprehensive Regional Assessments (CRAs) of the environment, heritage, social and economic uses and values of forests. The RFA and CRA initiatives were undertaken with reference to sustainablity indicators based on those developed as part of the Montreal Process. By mid-2000 all the CRAs were completed, and by April 2001 Australia had ten RFAs in place (table 3.30).

There is some debate regarding the degree to which the RFA process has met its objectives.

3.30 REGIONAL FOREST AGREEMENTS, BY REGION AND DATE SIGNED

State	*Region*	*Date RFA was signed*	*Total area of region*
Queensland	South East CRA region	RFA not signed(a)	6 100
New South Wales	North East (Lower)	31 March 2000	5 800
	North East (Upper)	31 March 2000	4 000
	Southern RFA region	24 April 2001	4 513
	Eden	26 August 1999	800
Victoria	East Gippsland	3 February 1997	1 200
	Gippsland	31 March 2000	2 676
	North East	23 August 1999	2 300
	Central Highlands	27 March 1998	1 100
	West	31 March 2000	5 762
Tasmania	Tasmania	8 November 1997	6 800
Western Australia	South West	4 May 1999	4 256

(a) The Commonwealth Government and the state government completed a Comprehensive Regional Assessment for South-East Queensland, but did not sign a Regional Forest Agreement.

Source: Commonwealth of Australia 2002a.

FOREST CONSERVATION IN AUSTRALIA

Threatening processes in Australian forests

A number of threatening processes directly or indirectly jeopardise the health and vitality (integrity) of forest ecosystems. These include: cropping, grazing, housing and mining; timber harvesting; impact of exotic species; altered fire regimes; and climate change. The main threatening processes to forest species, forest communities and forest ecosystems are listed in table 3.31. Impacts vary enormously in their spatial extent and the time taken for their consequences to become apparent (RAC 1992). The processes presenting the greatest immediate threats are clearing and fragmentation of habitat, although the impacts of wood production are particularly pertinent in multiple use forests.

3.31 PROCESSES THREATENING FOREST ECOSYSTEMS

Primary removal(a)	*Secondary(b)*	*Tertiary indirect(c)*
Clearing for grazing	Exotic plant invasions	Climate change
Collecting	Feral grazing	'Dieback'
Dryland clearing for crops	Fire regime	Fertiliser
Feral predation	Firewood collecting	Herbicides
Fragmentation of habitat	Native grazing	Pesticides
Hunting	Native plant invasions	Salinity
Tree plantations	Stock grazing regime	Soil structure
Road construction	Timber harvesting	Water table change

(a) Primary threats refer to direct removal of species, habitats or communities.

(b) Secondary threats are those factors which, if managed appropriately, might not be threatening.

(c) Tertiary effects are those that indirectly threaten whole systems.

Source: Silvertsen & Clarke 2000.

In recognition of the potential negative impacts of the aforementioned threatening process on Australia's forest biodiversity, the Commonwealth Government and the state and territory governments have endeavoured to protect Australia's forest ecosystems through forest conservation. The general aim of forest conservation is to ensure that forest ecosystems and the natural processes that sustain them remain intact for their own sake and for the benefit and enjoyment of future generations (NFI 1998). This implies preservation of the suite of economic, ecological, social and cultural values that are intrinsic to forest ecosystems. Forest conservation is an important component of ecologically sustainable forest management.

Across Australia, approximately 26.8 million ha of native forest are protected and conserved in reserves, representing some 16% of our remaining native forest estate (table 3.32). This compares favourably with a global average of 8% reserved (Commonwealth of Australia 2001). Australia's protected forest estate is made up of a number of tenures and management intents. About 12% of the native forest estate is in Nature Conservation Reserves, formally gazetted under state or territory and/or Commonwealth legislation (i.e. National Parks and Flora Reserves (see table 3.7)). The remaining conserved area occurs under tenures which are not principally managed for conservation, but may afford some protection to many conservation values. The Australian Capital Territory and Victoria have a relatively high proportion of forested land in conservation reserves.

3.32 PROTECTED NATIVE FOREST — 2001

	Units	*NSW*	*Vic.*	*Qld*	*SA*	*WA*	*Tas.*	*NT*	*ACT*	*Aust.*
Area of protected forest(a)	'000 ha	5 720	5 189	3 665	3 960	4 364	1 261	2 500	108	26 766
Percentage of total native forest	%	21	67	8	37	13	40	7	89	16

(a) Given that very little is known about management intent on private native forests, those informally managed for conservation are not included in the protected forest areas.

Source: Commonwealth of Australia 2002b.

Threatening processes in Australian forts *continued*

In 1992 the National Forest Policy Statement advocated the development of a comprehensive, adequate and representative (CAR) reserve system for Australia's forests. The national CAR reserve system aims to safeguard biodiversity, old growth, wilderness and other natural and cultural values of the forests. Comprehensiveness aims to secure diversity across forest communities; adequacy is based on the reserved area being of sufficient size to maintain the viability and integrity of native forest populations, species and communities; and representativeness seeks to ensure that the diversity within a native forest community is reserved across its range (Commonwealth of Australia 2001).

Establishing a CAR reserve system is one of the key objectives of the Regional Forest Agreement process. The process adopted nationally agreed criteria — known as the JANIS criteria — to identify the areas of the forest that needed protection under the CAR reserve system (JANIS 1997). The criteria specify the reservation of a proportion of the past extent of forest ecosystems and current distribution of rare or depleted ecosystems, and the protection of old-growth and forested wilderness, and require the protection of adequate high-quality habitat for forest species, particularly those considered endangered (NFI 1998). Development of these CAR reserves is confined largely to RFA regions with forests intensively managed for timber production. Consequently, the process does not address a CAR reserve system for the entire forest estate.

The RFA process added 2.9 million ha to the existing forest reserve estate, giving RFA regions a total of 10.4 million ha of forest in conservation reserves (table 3.33). This increased the reserved forest area in RFA regions by about 39%. The RFAs increased old-growth forest protection across the ten RFA regions by approximately 42% from 2.4 million ha to 3.4 million ha (table 3.34). As a consequence, approximately 68.3% of Australia's old growth forests in RFA regions have been reserved.

3.33 AREA IN RESERVES, BY RFA REGION

State	*RFA region*	*Pre-RFA area in reserves* '000 ha	*Post-RFA area in reserves* '000 ha	*Increase in reserves* %
Western Australia	South-west WA	932.6	1 047.2	12.3
Victoria	East Gippsland	573.6	581.1	1.3
	Central Highlands	177.6	293.9	65.5
	North East	394.8	591.5	49.8
	Gippsland	501.8	780.5	55.5
	West	466.4	629.3	34.9
New South Wales	Eden	160.4	266.1	65.9
	Upper North East	243.7	705.0	189.2
	Lower North East	747.0	1 367.0	83.0
	Southern	1 003.1	1 401.0	72.0
Tasmania	Tasmania	2 304.6	2 746.7	19.2
Total		**7 505.7**	**10 409.4**	**38.7**

Source: Commonwealth of Australia 2002a.

3.34 AREA OF OLD GROWTH IN RESERVES, BY RFA REGION

State	RFA region	Pre-RFA area of old growth in reserves	Post-RFA area of old growth in reserves	Increase to old growth reserved by RFA
		'000 ha	'000 ha	%
Western Australia	South-west WA	184.9	232.8	25.9
Victoria	East Gippsland	150.0	152.8	1.9
	Central Highlands	14.1	22.0	56.3
	North East	98.0	147.5	50.5
	Gippsland	84.6	139.0	64.3
	West	69.3	110.4	59.2
New South Wales	Eden	47.0	69.6	48.0
	Upper North East	127.0	371.1	192.2
	Lower North East	532.9	738.9	38.7
	Southern	407.0	562.6	72.3
Tasmania	Tasmania	682.0	848.7	24.4
Total		**2 396.8**	**3 395.5**	**41.7**

Source: Commonwealth of Australia 2002a.

SUMMARY

Australia's forests provide many values to the community. For example, forests are:

- a source of timber for manufacturing, housing and energy
- used for recreational, spiritual and cultural pursuits
- habitat for our flora and fauna
- catchments for much of our water supply
- a base for a diverse range of other commercial uses and
- an important component in the set of ecological processes which sustain life.

Forests can also accumulate and store carbon dioxide (CO_2) from the atmosphere, playing a vital role as mitigators of rising atmospheric CO_2 concentrations and global climate change.

Australia has 164 million ha of forest. There are many different types of native forest and Australia is one of 12 'mega-diverse' countries, with ecosystems of exceptional variety and uniqueness. Clearing of native vegetation remains the single greatest threat to terrestrial biodiversity, particularly for forest ecosystems. Plantations occupy 1.5 million ha, less than 1% of the total forest area of Australia, but they supply over 50% of our wood.

Wood and paper products (forest products) are essential to the everyday lives of Australians, and include sawn timber, wood based panels and paper and paper products. These products are either imported or produced from timber removed from Australia's native and plantation forests. Forest products are also an important export commodity for Australia. The potential impacts of timber harvesting are wide ranging, complex and vary enormously in their extent and the time taken for their implications to become apparent. Consequently, the magnitude and importance of these impacts is difficult to assess.

SUMMARY *continued*

Ecologically sustainable forest use is a major objective for those concerned with the management of Australia's forest resources. To achieve ecologically sustainable forest use, the challenge for forest managers is to strike a reasonable balance between the economic, ecological, social and cultural values of forests for current and future generations.

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CHAPTER 4 MINING AND THE ENVIRONMENT

INTRODUCTION

Australia enjoys many natural advantages that contribute to a thriving minerals sector. It is geologically diverse, hosting a large variety of mineral deposits, substantial geological information to aid exploration activities, a critical mass of capital, expertise and infrastructures, and a mature economy and stable political environment. It also features an extensive land area to accommodate and support mining and its associated impacts on the environment.

Australia is one of the leading mineral resource nations in the world. It has the largest identified reserves of lead, nickel, tantalum, mineral sands, zinc and uranium. It continues to dominate world production of bauxite, industrial diamonds, lead, mineral sands. It is the second largest world producer of nickel, zinc and uranium, the third largest producer of lithium and is among the top five world producers of recoverable black and brown coal, gold, iron ore and silver (GA 2001a).

However, the complexity of the environmental issues and consequences of mining, both locally and globally, have attracted public attention and political controversy. Unregulated disposal of wastes during the early development of the mineral industry has left a legacy of unrehabilitated wastes, polluted rivers and degraded land. Activities such as uranium mining adjacent to the Kakadu National Park World Heritage Property have added to the controversy. A range of environment protection measures are in place, and Australia has developed significant and world renowned capabilities in environmental research, impact reduction and land rehabilitation.

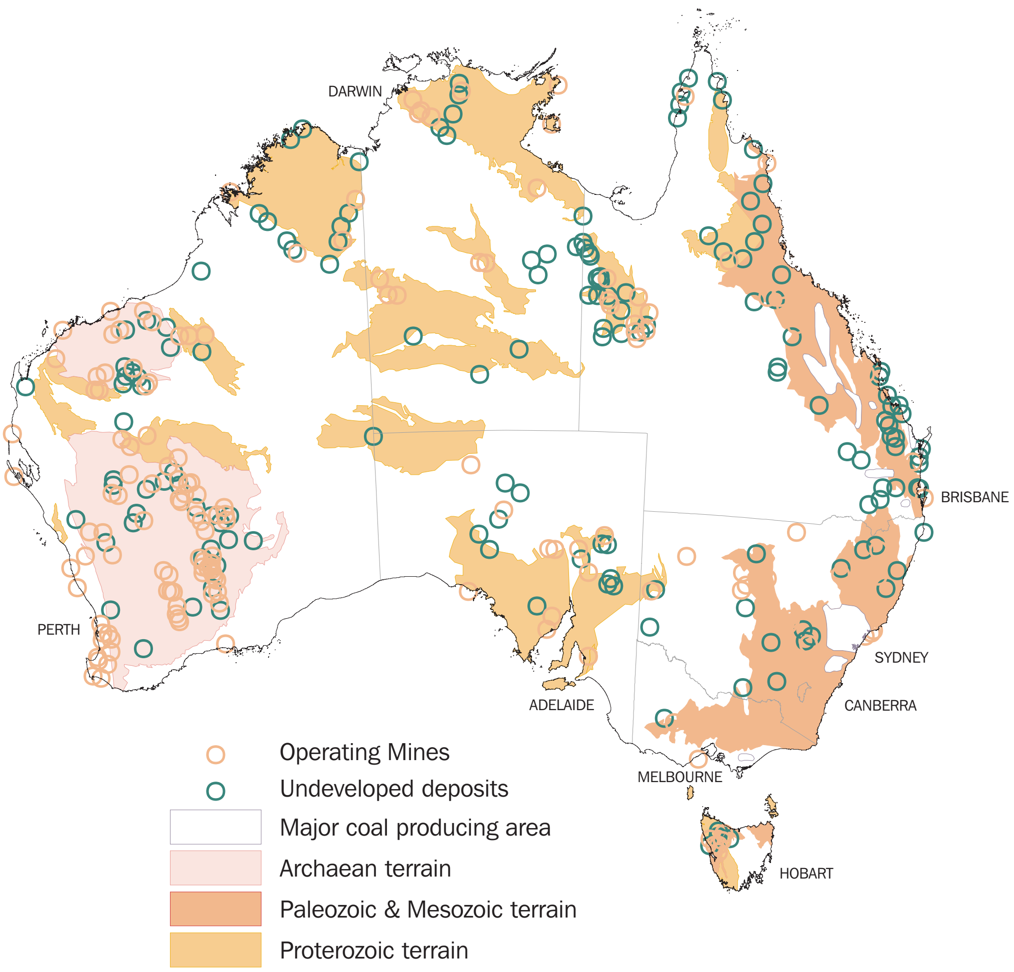
In this publication, the mining industry refers to both the mining of minerals as well as fossil fuels (coal, gas and oil). This is in line with the Australian and New Zealand Standard Industrial Classification (ANZSIC) which includes these under the one industry division (Division B — Mining).

The chapter begins with an overview of mineral and fossil fuel resources in Australia. It then covers economic and social aspects of the mining industry, including its evolution through the last century. There is further information on the structure of the industry, employment, exports and mining-related tourism. The second part of the chapter focuses on the environmental impacts of mining. This includes resource depletion, land disturbance, mining activities giving rise to air and water pollution as well as energy consumption and greenhouse gas emissions. Finally, there is a section on environmental management, which is important to the success and long-term prosperity in the mining sector. The topics covered include environment protection, environmental impact assessment, performance bonds, multiple land use, the voluntary Australian Minerals Industry Code for Environmental Management (MCA 2000) and environmental technologies.

MINERAL AND PETROLEUM RESOURCES

Australia is well endowed with mineral and petroleum resources. Australia ranks as one of the world's leading mineral resource nations with over 70 types of economically significant mineral deposits. Undeveloped mineral deposits and existing mines are shown in map 4.1. For a detailed account of the contribution of subsoil assets to Australia's wealth, see the Appendix.

4.1 MINERAL DEPOSITS AND MINES



Source: Geoscience Australia.

Australia has the largest known economic reserves of bauxite, lead, mineral sands, nickel, tantalum, uranium and zinc; the second largest reserves of brown coal; and the third largest reserves of copper and industrial diamonds, lithium and gold. Other minerals of worldwide economic importance are black coal, iron ore, manganese, silver, and vanadium (table 4.2).

4.2 IDENTIFIED MINERAL RESOURCES, SELECTED MINERALS, AUSTRALIA — 2001

		Economic demonstrated resources			*Production*		
Commodity	*Units*	*Australia*	*World*	*Ranking*	*Australia*	*World*	*Ranking*
Bauxite	Mt	4 400.0	25 000.0	1st	50.0	100.0	1st
Black coal (recoverable)	Mt	42 600.0	770 000.0	6th	301.0	3 500.0	4th
Brown coal (recoverable)	Mt	37 700.0	189 000.0	2nd	66.0	900.0	3rd
Copper	Mt	24.1	340.0	3rd	0.8	12.9	4th
Diamond (industrial)	Mc	96.1	580.0	3rd	—	58.6	1st
Gold	t Au	4 959.0	48 959.0	3rd	296.4	2 445.0	3rd
Iron ore	Mt	13 600.0	135 600.0	4th	168.0	1 010.0	3rd
Lead	Mt Pb	14.6	64.0	1st	0.7	3.0	1st
Lithium	kt Li	157.0	3 400.0	3rd	81.9	13.3	1st
Manganese ore	Mt	128.0	1 871.0	4th	1.6	21.7	5th
Mineral sands							
Illmenite	Mt	196.0	671.0	1st	2.2	7.2	1st
Rutile	Mt	22.0	49.3	1st	0.2	0.4	1st
Zircon	Mt	28.0	69.3	1st	0.4	0.9	1st
Nickel	Mt Ni	20.0	58.2	1st	0.2	1.2	3rd
Silver	kt Ag	32.1	280.0	4th	2.1	17.9	4th
Tantalum	kt Ta	29.0	32.3	1st	0.6	0.6	1st
Uranium	kt U	654.0	1 570.0	1st	7.6	34.8	1st
Vanadium(a)	kt V	188.0	10 000.0	—	0.3	42.0	—
Zinc	Mt Zn	33.0	190.0	1st	1.4	8.0	2nd

(a) Australia has limited reserves of Vanadium when compared internationally.

Source: GA 2001a.

Australia also has extensive areas of petroleum-bearing sedimentary basins, much of which are not fully explored. For over 25 years, the majority of Australia's commercial oil production has been in the Bass Strait region off the coast of Victoria. Recent significant discoveries of oil and condensate deposits on the Northwest Shelf off the coast of Western Australia made this area the principal centre of oil production. Other commercial reserves were located in Browse, Carnarvon, and the Bonaparte and Cooper basins. During 2001 there were 35 petroleum discoveries, of which 14 were made offshore. The most significant oil finds were at Audacious in the Ashmore/Cartier area of the Timor Sea and at Cliff Head in the Perth Basin. However, these are not considered large oil discoveries in comparison to what is needed for sustained oil production in Australia (GA 2002a). In 2000–01, total expenditure on mineral and petroleum exploration was estimated at $1.7b, an increase of 23% ($328m) from 1999–2000. Petroleum is the most sought commodity, accounting for over 55% of total exploration expenditure in the last three years. In 2000–01 the industry spent over $1b in petroleum exploration expenditure (60% of the total) (ABS 2002c). These and other resources, while extensive, are non-renewable, meaning that they are finite resources which, once used, cannot be re-created (Yencken & Wilkinson 2000).

MINERAL AND PETROLEUM RESOURCES *continued*

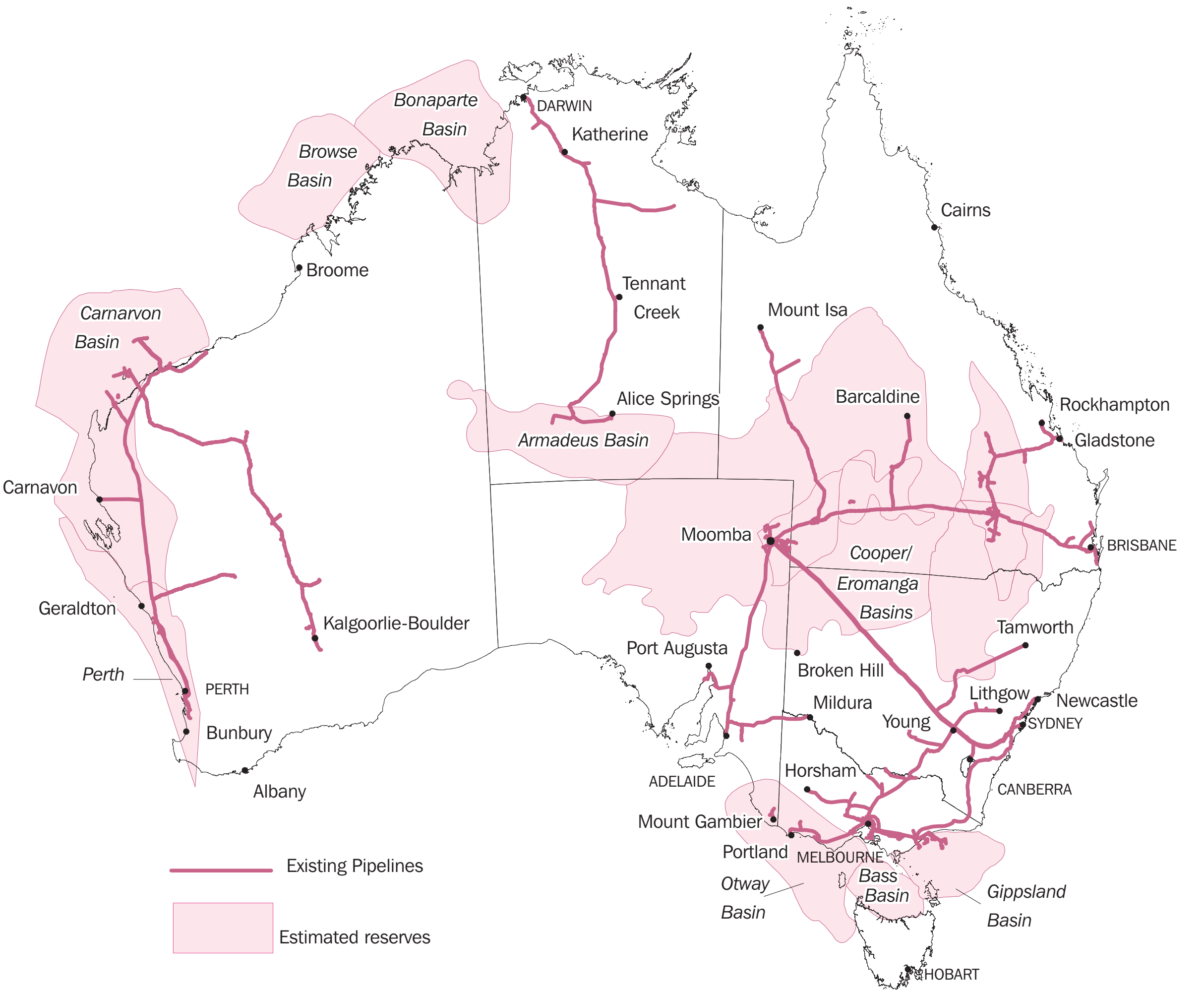
Table 4.3 indicates that Australia's petroleum reserves at 1 January 2000 were estimated at 265 GL of oil, 344 GL of condensate, 350 GL of liquefied petroleum gas and 3,246 billion cubic metres (b m^3) of Sales Gas. With recent discoveries of additional gas resources, Australia is slowly emerging as a major provider of liquefied natural gas (LNG); it currently accounts for 8% of the world's LNG trade and 9% of the Asia Pacific trade (DME 2001). Map 4.4 shows the location of Australia's main gas resources.

4.3 AUSTRALIA'S PETROLEUM AND GAS RESOURCES — 1 JANUARY 2000

		Demonstrated resources		
	Units	*EDR*	*SDR*	*Total DR*
Oil	GL	227	37	265
Condensate	GL	282	62	344
Liquefied petroleum gas	GL	262	88	350
Sales gas	b m^3	2 219	1 027	3 246

Source: GA 2002a.

4.4 GAS RESOURCES, Australia



Source: The Australian Gas Association 2000.

THE AUSTRALIAN MINING INDUSTRY

The mining industry has been fundamental to Australia's economic and social prosperity (box 1). It has been the major source of export income for Australia, accounting for 39% of the total value of export income and contributing 4% of gross domestic product (GDP) in each of the last five years. It has provided most of the nation's domestic mineral resource requirements, and has been a basis for decentralisation and development of growth centres in regional and remote areas in Australia. From the late 18th century, the discovery and extraction of minerals have been key factors in the evolution of the Australian economy.

Box 1. Evolution of the mining industry in Australia

1790–1900

Coal was the first mineral discovered in Australia in 1791; it was the first mineral to be exported, in 1800. Metal mining started with silver-lead in 1841, succeeded by copper and iron ore, but it was the discovery of gold in 1851 that gave impetus to the metals sector of the industry and discoveries of other metals such as tin. A transition from an agricultural and pastoral economy to mining began with the growth of service industries to cater for the increasing population and growing commercial activities.

1900s–1930s

Metal mining, with its associated smelters and refineries, was well established. Gold was the main mineral commodity, accounting for 75% of the total value of metal mining. Many towns were established and ports, railways and other support facilities were developed to service the needs of the industry. Petroleum exploration began with the discovery of natural gas in 1900.

The mining industry continued to prosper in the early decades of the century. However, the collapse of metal prices after the end of the First World War resulted in closure of several mines and a fall in the value of mineral exports in lieu of increasing competition. Coal production fell by 33% as petroleum products replaced coal in industry and railways.

1930s–1950s

Mining played a minor role in the Australian economy. The need for new reserves of many minerals was the major concern of the industry. A series of discoveries of new mineral deposits (i.e. uranium) in the late 1940s changed the structure of the industry and elevated Australia to a major mineral exporting country. Such discoveries were made possible with the development of geo-chemical and exploration methods suited to Australian conditions.

1950s–1970s

The period was characterised by industry expansion, and growth in production and exports of various commodities, particularly iron ore and coal. Mining again became a major element in the economic and social life of the country, providing wealth, self sufficiency in minerals and world recognition as a mineral nation. The first commercial oilfield was discovered in 1961 and came into production in 1964. By the late 1960s Australia was a major world supplier of black coal, bauxite, iron ore, nickel, manganese, titanium and zirconium.

1950s–1970s *continued*	The industry began to be affected by an increasing public concern for the quality of environment, that led to increasing controls on the discharge of potentially polluting emissions, including environmental legislation.
1970s–1990s	The rate of growth of the mining industry in Australia began to slow down, brought about by increasing competition from other countries. Nonetheless, many new mines and oil and gas fields were established. Gold was still the most prominent mineral with the development of efficient gold recovery technologies. Land access was the main issue affecting the industry. The granting of title to extensive tracts of land to Indigenous people resulted in prolonged negotiations, additional mining expenditure costs and uncertainty of the mineral exploration process. Fly-in/fly-out arrangements were adopted to service remote areas.
1990s to present	Industry output increased steadily for much of the 1990s in line with increased investments, low inflation and continual advances in technology. Export values and volumes continued to rise despite the onset of the economic crisis in East Asia (1998), as exporters drew down stocks and successfully diverted products to alternative markets, only to fall again in the early part of 1999. Improving efficiency and safety of operations, and movement towards 'globalisation' are the main themes in the modern mining industry. Environmental management has been an integral component of any mineral exploration and mine development plan. Rehabilitation arrangements are inherent in development proposals and form an integral part of environmental management throughout the mining cycle. *Source: 'A century of mining in Australia', Year Book Australia, 2001 (cat. no. 1301.0), p. 679.*

Structure of the mining industry

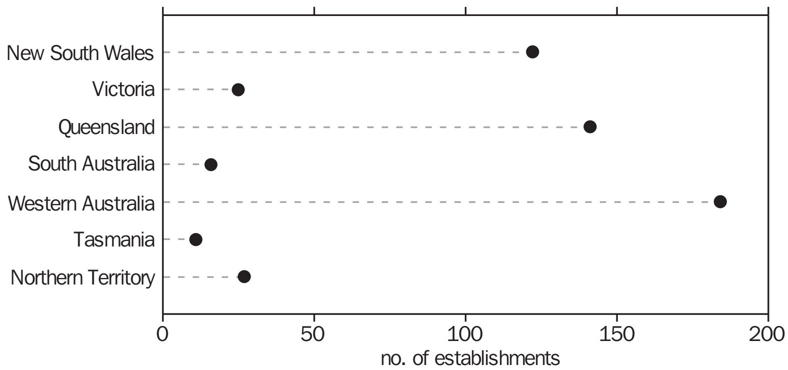
The Australian mining industry is composed of several hundred small, medium and large companies, mostly owned and operated by the private sector (DISR 1999). At June 2000 there were 529 establishments actively engaged in mining operations, with 45% of the establishments concentrating on metal ore mining, 34% on coal mining and the remaining 21% for oil and gas extraction (table 4.5). Gold extraction continues to be the main focus of metal mining, accounting for 55% (129 establishments) of the total number of establishments engaged in metal mining in 1999–2000. Western Australia continued to have the largest number of mining establishments with 184 followed by Queensland and New South Wales (graph 4.6).

4.5 MINING ESTABLISHMENTS, BY INDUSTRY SUBDIVISION

Industry	*1998–99*	*1999–2000*
Coal mining	189	182
Oil and gas extraction	102	111
Metal ore mining		
Iron ore	24	27
Bauxite	10	9
Copper ore	21	20
Gold	129	129
Mineral sands	14	13
Silver-lead-zinc	14	16
Other	24	22
Total metal ore mining	236	236
Total mining	**527**	**529**

Source: Mining Operations, Australia, 1999–2000 (cat. no. 8415.0).

4.6 MINING INDUSTRY DISTRIBUTION, By state — 1999–2000



Source: Mining Operations, Australia, 1999–2000 (cat. no. 8415.0).

Table 4.7 illustrates the highly concentrated structure of the mining industry. The 12 largest enterprise groups in the industry accounted for more than half of the turnover (52%) and valued added (55%) and almost half (49%) of the total employment in mining in 1998–99. The top 100 enterprise groups, which operated 55% (289 establishments) of the total number of establishments in mining, accounted for 94% of the total turnover, 99% of value added and 87% of the employment. The remaining contributions to industry turnover (6%), employment (13%) and value added (1%) were shared among the remaining 246 enterprise groups (240 establishments).

4.7 MINING INDUSTRY CONCENTRATION — 1998–99

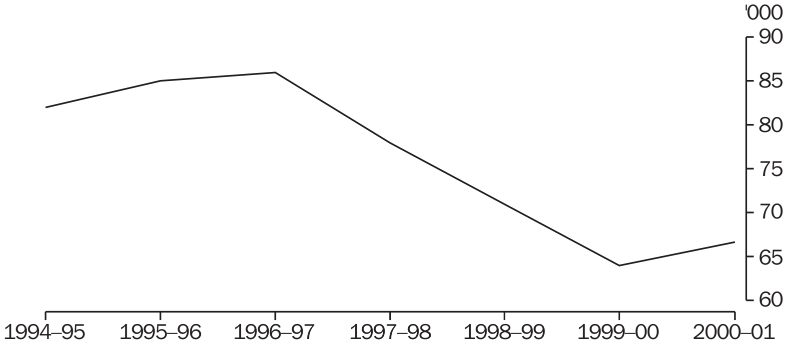
	Establishments at 30 June 1999		*Employment at 30 June 1999*		*Turnover*		*Value added*	
Enterprise groups	*no.*	*%*	*no.*	*%*	*$m*	*%*	*$m*	*%*
Largest 12	104	20	23 000	49	19 682	52	13 164	55
Largest 25	148	28	31 618	67	26 289	70	17 758	74
Largest 50	216	41	37 031	78	31 577	84	21 140	88
Largest 100	289	55	40 948	87	35 406	94	23 831	99
Largest 200	409	77	44 539	94	37 427	100	24 796	100
All enterprise groups (346)	529	100	47 300	100	37 524	100	24 119	100

Source: Australian Mining Industry, 1998–99 (cat. no. 8414.0).

Employment and regional development

While employment in mining industries slowly increased during the mid-1990s, it fell substantially over the next few years, from 86,000 in 1996–97, to about 65,000 in 1999–2000, a fall of 24% (graph 4.8). The decrease is attributed to the restructuring and downsizing, and the application of new technologies, by companies attempting to remain competitive in the light of low commodity prices. The shift from direct to contract employment and the closure of several mines have also contributed to the fall in employment.

4.8 MINING EMPLOYMENT



Source: Business Operations and Industry Performance, Australia, 1998–99 and 2000–01 (cat. no. 8140.0).

Metal ore mining has been consistently the largest employer within the mining industry, employing 23,057 people at the end of June 2001 (table 4.9). Within the metal ore mining industry, gold and iron ore mining are the largest employers, employing 8,096 and 4,525 people respectively.

Services to mining employed 13,823 people, or 20.7% of total mining employment. The coal industry accounted for 36.7% of total mining employment (17,256 persons), whereas the oil and gas extraction industry accounted for 14.3% of total mining employment (table 4.9).

4.9 MINING INDUSTRY EMPLOYMENT — AT 30 JUNE 2001

Description	*no.(a)*
Coal mining	17 256
Oil and gas extraction	6 714
Metal ore mining	
Iron ore mining	4 525
Copper ore mining	3 864
Gold ore	8 096
Mineral sand mining	1 679
Silver-lead-zinc ore mining	2 265
Other metal ore mining(b)	2 628
Total metal ore mining	*23 057*
Total coal mining, oil and gas extraction and metal ore mining	47 027
Other mining	5 827
Services to mining	13 823
All mining — June 2001	**66 677**

(a) Includes working proprietors.

(b) Includes nickel ore mining and metal ore mining n.e.c.

Source: Mining Operations, Australia, 2000–01 (cat. no. 8415.0).

Some 16,000 full-time equivalent contractors were reported to be engaged in the mining industry in 2000–01 (MCA 2002). Contract mining expenses in 1999–2000 were estimated at $2.9b, representing 18% of the industry's total operating expenses ($16.4b) for that year (ABS 2001d). Gold, coal and iron ore mining are the largest users of contract labour, accounting for 70% of contract expenses in 1999–2000 (ABS 2001c).

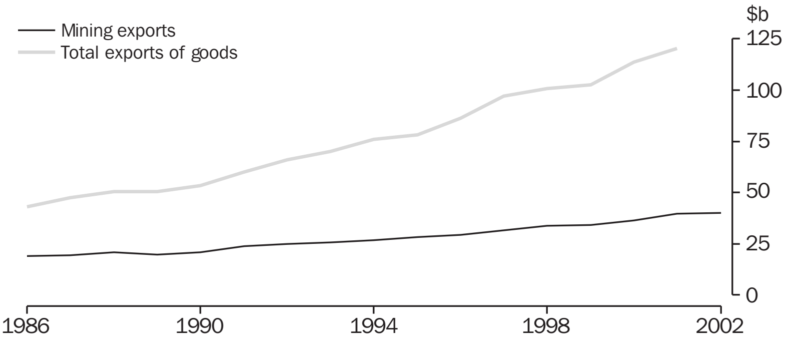
Although direct employment in the mining industry is relatively small (averaging less than 1% of total employment in the economy), many businesses in other industries depend upon the mining industry for their survival. Some of these businesses include suppliers of vehicles, equipment and chemicals, computer equipment developers and suppliers, caterers and contracting firms. During 1999–2000, 278,625 people were employed in mining-related industries including the metal product, non-metallic product, petroleum, coal and chemical manufacturing products sectors. This figure was four times greater than direct employment within the mining industry.

Mining and mineral processing have played a continuing and significant role in the development of regional and remote areas in Australia. Infrastructure development — not only railways and ports, but also infrastructure available for public benefit such as streets, houses, schools, hospitals and recreational facilities — has been one of the preconditions of any mining lease, thereby providing to the community a share of the benefits from resource exploitation.

Exports

The mining industry is one of Australia's most important export industries, although its share of total exports has decreased over recent decades. In 1986 mining exports were valued at $19b (44% of total exports) and in 2002 they were worth $40b (33% of total exports) (graph 4.10).

4.10 MINING EXPORTS(a)



(a) Chain Volume Measure (Reference year is 2000–01).

Source: ABS data available on request, National Accounts.

The biggest mineral commodity export earner in 2000–01 was coal, earning $10.8b, followed by petroleum oils and oils obtained from bituminous minerals, earning $7.6b (table 4.11).

4.11 VALUE OF EXPORTS, MAJOR MINERAL COMMODITIES

	Value of exports 1999–2000	*Value of exports 2000–01*	*Change 1999–2000 to 2000–01*	*Share of total exports 2000–01*
	$m	*$m*	*%*	*%*
Crude ores and concentrates(a)				
Iron ore concentrates and agglomerates (excluding roasted iron pyrites)	3 817	4 903	28	4.1
Copper ores and concentrates	777	1 037	33	0.9
Nickel oxide sinters	105	126	20	0.1
Alumina (aluminium oxide)	3 397	4 394	29	3.7
Uranium and thorium ores and concentrates	366	497	36	0.4
Zinc ores and concentrates	682	978	43	0.8
Ores and concentrates of molybdenum, niobium, titanium etc.	349	367	5	0.3
Mineral fuels, lubricants and related materials				
Coal, whether or not pulverised but not agglomerated	8 323	10 829	30	9.1
Petroleum oils and oils obtained from bituminous minerals, crude	4 878	7 640	57	6.4
Gas, natural and manufactured	2 601	3 504	35	2.9

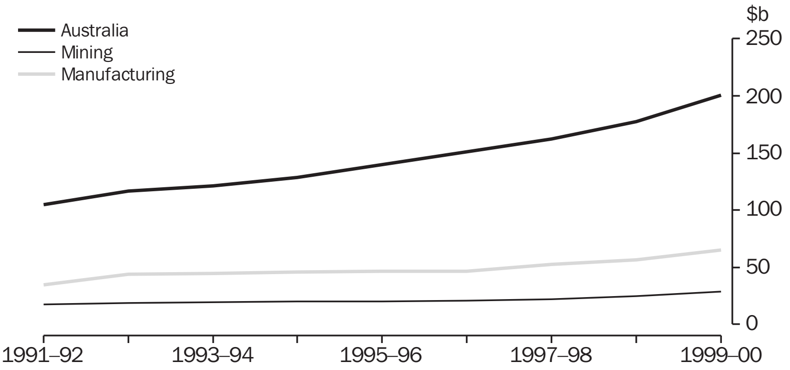
(a) Excludes commodities subject to a confidentiality restriction.

Source: International Merchandise Trade, Australia, September Quarter 2000 to June Quarter 2002 (cat. no. 5422.0).

Direct foreign investment

The level of direct foreign investment (DFI) in Australia has been on the rise in the last decade, increasing at about 10% per annum. In 1999–2000, the level of DFI in mining reached $29b (15% of the total DFI), second behind the manufacturing sector, which recorded $65b in DFI (34%) (graph 4.12). Compared to 1998–99, DFI in mining experienced an increase of 15% ($3.8b), mainly due to increases in investment in exploration, particularly for petroleum and gas.

4.12 DIRECT FOREIGN INVESTMENT IN AUSTRALIA



Source: ABS data available on request, Foreign Investment Survey.

MINING-RELATED TOURISM

Not all the value of mining to Australia is directly related to extracting and selling minerals and fossil fuels. Historical mining towns embody elements of the European heritage of Australia. They represent the legacy of mining booms in the nineteenth century that made them part of the cultural heritage of the nation. Historical mining sites are important tourist attractions. In 1997–98, mining-related tourism in Australia contributed $18m to the economy in terms of industry gross value added (ABS 1998). Although the amount represents a relatively small share of the total tourism contribution to the economy, it created a significant effect in employment generation and the development of non-metropolitan regions where most historical mining sites are located (Cegielski et al. 2001).

The Register of the National Estate (RNE) of the Australian Heritage Commission lists 132 sites that are of historical significance to mining and mineral processing activities. Victoria has the most sites listed in the RNE (38), followed by South Australia (30) and Queensland (22) (table 4.13).

4.13 HISTORICAL MINING SITES, REGISTER OF NATIONAL ESTATE — JUNE 2001

	no.
New South Wales	19
Victoria	38
Queensland	22
South Australia	30
Western Australia	7
Tasmania	3
Northern Territory	10
Australian Capital Territory	—
External territories	3

Source: Australian Heritage Commission 2001.

POTENTIAL IMPACTS OF MINING ON THE ENVIRONMENT

Mining is a resource-intensive industry which typically creates disturbance to the environment. This section describes potential impacts of mining, many of which can be observed at historical mine sites. The section also describes advances that have been made over the past decade or more in environmental management for mining.

POTENTIAL IMPACTS OF MINING ON THE ENVIRONMENT *continued*

The broad range of extractive operations involved in the industry have various impacts on the environment before, during and after mining operations. The extent and nature of the impacts can range from minimal to significant depending on a range of factors associated with each mine site. These factors include: the characteristic of the orebody; the type of technology employed in mining and processing of minerals; and the sensitivity of the local environment affected by the mining activities. Table 4.14 summarises the environmental impacts related to various stages of mining. These impacts need to be put in the context of risk: some adverse environmental effects will arise as an inevitable consequence of a particular type of mining operation, while other impacts will only result in the case of system failures, human error or negligence, and can be minimised by sound management.

4.14 ENVIRONMENTAL EFFECTS OF MINING

Stages	*Indicative activities*	*Potential impacts*
Pre-development	Mineral and petroleum exploration (airborne or ground based) involving geological, geophysical and or geo-chemical surveys over anomalies; surface drilling, sampling, trenching, road/trail construction	Soil, habitat and fauna disturbances; ground and water pollution; localised noise pollution
Development	Stripping of overburden, shaft sinking, haulage way construction, installation of mining and material handling facilities and equipment; construction of beneficiation facilities and mill plants; construction of offices, access roads, community housing facilities including power and water	Resource depletion; visual impacts; air pollution; water pollution; noise pollution from blasting and operation of earthmoving equipment; and loss of flora and fauna
Production (actual mining and milling)	Stripping of wastes, ore extraction (blasting, drilling, material handling and back-filling); crushing, grinding, mineral processing, tailings disposal and loading of concentrates for shipping; drilling for oil; on-site oil refining	Land disturbance and visual impact; land subsidence; air pollution; water pollution; noise pollution; and loss of flora and fauna; oil spills to land and water
Post-development (mine closure and rehabilitation)	Recontouring of pit walls and waste dumps, covering of reactive materials, — dismantling of buildings/plants, revegetation, ongoing environmental quality monitoring	Seepage of toxic solutions and hydrocarbons into ground and surface water; contamination from acid mine drainage; loss of flora and fauna; wind borne dust; revegetation failure; slope and tailings impoundment failure; oil spills to land and water

Source: Derived from Down & Stocks 1977, Dale & Stock 1983 and Australia's Environment: Issues and Trends, 2001 (cat. no. 4613.0).

Rate of resource use

The rate of depletion and discovery of natural resources is a major issue concerning the mining industry. Minerals, oil and gas are finite resources, and their consumption today poses a threat of scarcity to future generations (WCED 1987). Table 4.15 illustrates the estimated resource life of major minerals and petroleum in Australia based on current rates of production and measured resources. It is possible that stocks of crude oil, for example, will be exhausted in 11 years if the current rate of production is maintained and there is no discovery of new reserves (ABS 2001b). However, advances in exploration and mining technologies have so far enabled the rate of discovery of new reserves to keep pace with the rate of production, allowing for changes in the estimated resource life of mineral, oil and gas stocks. Modern technology has been a contributing factor to the efficient recovery of minerals, and the consequent fall in the cost of finding additional reserves of base metals in particular. It is also important to emphasise that resource scarcity is lessened by recycling and/or substitution.

4.15 MINERALS AND PETROLEUM, PRODUCTION AND ESTIMATED RESOURCE LIFE — 30 JUNE 2000

Mineral or fossil fuel	*Units*	*Measured resources*	*Annual production*	*Estimated resource life(a) years*
Metallic minerals				
Gold	t	5 018	295.93	17
Iron ore	Mt	15 500	160.0	100
Bauxite	Mt	3 800	50.0	83
Copper	Mt	22.2	0.75	36
Mineral sands				
Ilmenite	Mt	180.9	1.97	85
Rutile	Mt	19.8	0.20	94
Zircon	Mt	26.3	0.36	64
Uranium	Kt	571	8.22	91
Coal				
Black coal	Gt	44.4	0.23	205
Brown coal	Gt	37.7	0.24	611
Oil and gas				
Crude oil	GL	266	29.59	11
Natural gas	b m^3	1 494	31.23	49
Condensate	GL	192	7.85	26
LPG	GL	184	4.35	46

(a) 5 year lagged moving average of resource life.

Source: Australian National Accounts: National Balance Sheet (cat. no. 5241.0.40.001).

Land disturbance

Mining affects the environment and associated biota through the removal of vegetation and topsoil, the displacement of fauna, and increases the potential for the release of pollutants into the air, land and water. Extensive mining operations, such as open-cut extraction of coal, bauxite and manganese, as well as sand mining in coastal heathlands, have caused long-term changes to biodiversity, despite attempts by the industry to effectively rehabilitate these impacts. The major controversies over mining priorities coincide with sites of high biological diversity or cultural significance, while the major impacts of mining are associated with the infrastructure that provide access to remote areas of Australia surrounding prospecting leases and mining towns (State of the Environment Advisory Committee 1996).

The discovery of mineral deposits comes after the conduct of exploration activities. Whilst exploration activities require access to large areas of land, they often do not lead to subsequent mining development. Exploration for minerals using state of the art techniques is currently undertaken in ecologically sensitive areas with negligible impact. According to state and territory mines and lands departments, Australia has a total of over 953,128 km^2 covered by mineral exploration permits. In 2001, oil and gas exploration permits covered 1,241,863 km^2 for onshore areas and 1,575,786 km^2 for offshore areas (GA 2003c).

Although some mines are extensive, the total area of land directly affected by mining in Australia represents less than 0.01% of the country’s landmass (table 4.16).

4.16 LAND TENURE — 1993(a)

Tenure type	NSW '000 km²	Vic. '000 km²	Qld '000 km²	SA '000 km²	WA '000 km²	Tas. '000 km²	NT '000 km²	ACT '000 km²	Aust. '000 km²
Private land	714.4	155.3	1 567.0	576.8	1 105.0	27.2	673.0	0.9	4 819.6
Aboriginal and Torres Strait Islander land	1.5	—	42.2	189.6	325.5	—	536.0	—	1 094.8
Public land	—	—	—	—	—	—	—	—	—
Native reserve	38.1	30.6	54.2	203.7	155.0	13.5	27.8	1.2	524.1
Aboriginal freehold-National Park	—	—	—	—	—	—	10.8	—	10.8
Vacant crown land	1.4	—	0.6	8.3	863.3	4.3	82.8	—	960.7
Other crown land	6.4	2.0	13.9	0.8	42.7	2.5	12.3	—	80.6
Forestry reserve(b)	34.6	36.4	40.1	1.0	20.9	15.1	—	0.1	148.2
Water reserve	2.8	1.5	0.3	0.2	5.3	0.9	—	—	11.0
Defence land	0.4	0.4	3.8	3.6	6.6	0.3	3.5	—	18.6
Mining reserve	—	0.3	4.3	—	0.4	—	—	—	5.0
Mixed category lands	2.0	1.1	0.8	—	0.8	4.0	—	0.2	8.9
Total public land	85.7	72.3	118.0	217.6	1 095.0	40.6	137.2	1.5	1 767.9
Total all tenures	**801.6**	**227.6**	**1 727.2**	**984.0**	**2 525.5**	**67.8**	**1 346.2**	**2.4**	**7 682.3**

(a) This is the latest information available from AUSLIG. Some changes have occurred since, particularly in the composition of public land tenures.

(b) The area available for timber production is about half this as some areas cannot be harvested for practical reasons.

Source: Australia's Environment: Issues and Trends, 2001 (cat. no. 4613.0).

The impact of mining on the landscape is generally influenced by the methods of mining used, including surface, underground or in situ leaching (ISL). The option to use these methods is fundamentally determined by the depth of the orebody and volume of overburden to be removed to expose the mineral ore. Surface mining is used when the orebody is near the surface and little overburden needs to be removed, and deep seated ore bodies are extracted by underground methods. Surface, underground and ISL all have different impacts on the environment. For example, surface mining:

- involves the clearing of native vegetation
- creates the potential for erosion
- may impact upon water quality and groundwater levels
- may affect air quality by releasing dust and other airborne contaminants.

The impacts of underground mining and oil and gas extraction are typically less disruptive and are confined to a relatively small surface area. Extraction activities do not entail the removal of overburden and produce minimal volume of waste rocks that are stored underground. In most cases, waste rocks, together with mill tailings, are used as filling materials for mined out areas.

Land disturbance *continued*

Nevertheless, the removal of subsurface material by underground mining creates a high potential for ground movement and draining of underground water resources (Tujan & Guzman 1998). For example, notable effects of ground subsidence have been evident in longwall coal mines in Queensland and New South Wales, and subsidence has created impacts on surface water and groundwater. Ground subsidence in the Hunter Valley and Bowen Basin regions has resulted in ground deformation, disruption of water flows, increased salinity and the release of methane gas.

ISL is a method that does not have the same profile as open-cut and underground methods. It is a process whereby boreholes are drilled into the mining site and water-based chemical solvents (either an acid or alkali) are used to dissolve the desired mineral. The metalliferous fluid is pumped to the surface through different boreholes for processing. The benefits of this mining extraction method are its low capital and operating costs compared to open-cut or underground mines. There are also advantages in much less ground disturbance, with no open pits, shafts, tunnels, earthmoving equipment or grinding and crushing facilities, and the minimisation of waste, such as rock overburden. Sometimes called solution mining, ISL presents risks to the environment through contaminating groundwater and aquifers. This contamination may also spread through connected groundwater, creating a pollution plume. Currently, Australia has one operational ISL mine (Beverley, South Australia) and another is being established (Honeymoon, South Australia) (SACME 2001).

Wastes

Inherent in any mining and mineral processing operations is the generation of wastes. Many of the environmental problems traditionally associated with mining industry wastes were the results of mining practices which are no longer used.

Wastes from mining activities are mostly in the form of waste rocks — overburden, interburden and the unwanted materials. They contain low or nil concentrations of the material desired. Waste rocks may contain sulphide minerals, potentially resulting in acid mine drainage (see the discussion of acid mine drainage below). Normally, waste rocks are stockpiled adjacent to or near the excavation area, often to be used later as backfill during reclamation. Mineral processing produces wastes in grain sizes of fine sand, silt and clay fractions. Referred to as mine tailings, this type of waste contains significant concentrations of chemical reagents, and minerals not amenable to recovery at the time of initial mining (Down & Stocks 1977).

Poorly managed tailings disposal has a negative impact on the health of humans and the environment. Potential environmental impacts of tailing disposal range from contamination of groundwater, surface water, soil, and air, to damage to vegetation, wildlife and other biota (Hancock 1993). Box 2 discusses the tailings wastes from uranium mining.

Wastes *continued*

Information on the amount and location of wastes from mining and mineral processing is generally limited. In most cases, waste rocks are often excluded from reporting of wastes, given their alternative use as backfill materials during reclamation. The Australian Cooperative Research Centre (CRC) for Waste Management and Pollution Control Ltd has estimated the amount of wastes processed and disposed of in various regions of Australia as reported by State Environment and Protection Agencies and Waste Authorities. Table 4.17 shows the quantity of manifested hazardous waste which was processed and disposed of by mining activities in New South Wales in 1992, 1993 and 1994.

4.17 HAZARDOUS MINING WASTE GENERATED IN NEW SOUTH WALES

	1992	*1993*	*1994*
Waste type	*Kilolitres/yr*	*Kilolitres/yr*	*Kilolitres/yr*
Acids	80	100	95
Alkalis	(a)	(a)	50
Inorganic chemicals	(a)	548	284
Waste oil	51	17	28
Washwater	1	262	9
Inert waste	(a)	5	(a)
Miscellaneous	(a)	387	35
Total	**132**	**1 319**	**502**

(a) Data not collected.

Source: CRC for Waste Management & Pollution Control Ltd 2002.

Box 2. Uranium mill tailings wastes in Australia

The characteristics of uranium mill tailings wastes are unique compared to other mining wastes, the key factor being their radioactivity. Although milling removes 90% of uranium, decay products also present in the ore retain some 85% of their radioactivity. The main radionuclides that are cause for concern are thorium-230 (which has a half-life of 75,000 years) and radium-226 (half life of 1,600 years). Each element has different chemical properties, requiring comprehensive measures to ensure long-term containment of the tailings. Radium-226 breaks down into radon-222, a highly radioactive gas that is a threat to workers and the public. Although a rehabilitated mill tailings deposit may be secure chemically and physically, higher radiological exposure risks may result from high levels of gamma radiation and radon emanation (Mudd 2000a).

Waste rock dumps also present dangers. As uranium ore and associated waste rock can contain high levels of heavy metals, they may cause surface water or groundwater contamination. Given the often close proximity of tailings and waste dumps, their combined effects in terms of leaks present a substantial ecological concern. The engineering and rehabilitation requirements of waste rock dumps are often less than those for tailings dumps, so that long-term security of waste rock dumps is less assured. In 2000, Australia had ten sites containing uranium tailings, with several other sites containing exposed ore and/or waste rock (Mudd 2000b).

The effects of tailings are not limited to currently operating mines. Old mining sites also present dangers from tailings dumps that have either been inadequately designed and constructed, or affected by weathering causing breaches in the dumps. One example was the deposits located at the Upper South Alligator River (Northern Territory, north of Katherine). This river is particularly important as it forms part of Stage III of the Kakadu National Park World Heritage area. The Upper South Alligator River area had two mills: one at Rockhole and the other at Moline. The small uranium deposits were mined between 1959 and 1964. A number of surveys were conducted as the area was considered for inclusion in Kakadu National Park. The research found an unacceptable risk from gamma radiation and radon. The Rockhole tailings were adjacent to the main tourist road to Gunlom Falls, and nearly 25% of the Moline tailings had eroded into the Mary River. As the numbers of visitors increased to the Gunlom Falls area, a Hazard Reduction Works program was conducted during the early 1990s. The works involved the use of five shallow dump pits to contain the contaminated radiative materials. Annual inspections still draw attention to erosion problems and find new hot spots of radioactive contamination (Mudd 2000a). It must also be emphasised that the area has high to very high natural radioactivity (GA 2002b).

Water pollution

Water is an integral component of virtually all mining activities. Water plays a significant role in the mining and recovery of many minerals, including gold, tin, wolfram and zircon. In mineral processing, water is used in wet screening, flotation, gravity and heavy media separation processes and in leaching solutions. Water is also used as a slurrying medium to transport ores between various stages of processing or in the transport of waste products to impoundment dams; and in cooling equipment such as crusher bearings, pumps and compressors. Other uses include dust control, general washing purposes, domestic and sanitation purposes.

Compared to other sectors, the mining industry has been a relatively small consumer of water: in 1996–97, 570 GL or 3% of the net water use in Australia (table 4.18). The agricultural sector is the largest net user of water, accounting for 70% (15,522 GL) of the net water use in Australia in 1996–97 (see Chapter 2, Agriculture and the environment). About 95% (544 GL) of total water use by mining was extracted directly from the environment and the remaining 5% from the mains supply.

4.18 SUPPLY AND USE OF WATER IN THE MINING INDUSTRY — 1996–97

	Mining	*All sectors*	*Mining's share of total*
	ML	*ML*	*%*
Supply			
Mains supply	4 905	11 525 533	< 0.1
In stream discharge	—	46 517 638	—
Total	*4 905*	*58 043 171*	—
Use			
Self-extracted	544 746	68 703 371	8.0
Mains use	30 376	11 525 533	0.2
Total	*575 122*	*80 228 904*	*0.7*
Net water use (use less supply)	**570 217**	**22 185 733**	**3.0**

Source: Water Account for Australia, 1993–94 to 1996–97 (cat. no. 4610.0).

Mining has the potential to affect water in different ways:

Acid mine drainage (AMD) — This occurs when large quantities of excavated rock containing sulphide minerals interact with water and oxygen to create sulphuric acid. The resulting acid is carried off into the intermediate streams, rivers, lakes and groundwater from the minesite by rainwater or surface drainage. Given the release of significant concentrations of sulphuric acid, AMD can adversely impact upon water quality and aquatic life.

AMD is one of the main environmental issues of mining. In a survey of 317 Australian mines in 1997, 116 sites were found to generate significant amounts of potentially acid-generating wastes, 54 of which had produced acid-wastes of more than 10 million tonnes (Harries 1997). The highest impact comes mostly from historic and abandoned mines at Mount Morgan mines in Queensland, Captain's Flat in New South Wales, Rum Jungle mine in Northern Territory, and the still operating mine at Mount Lyell in Tasmania (Hamblin 2001).

Heavy metal contamination and leaching — This occurs when metals (i.e. arsenic, cobalt, copper, cadmium, lead, silver and zinc) contained in an excavated or exposed rock are leached out and carried downstream by flowing water, particularly accelerated in the low pH conditions created by AMD.

In 1971, the Finnis River (NT) was assessed to be highly polluted by heavy metals, acidification and radiation caused by the operations of Rum Jungle Mine. Average release of metals into the river was estimated at 130 tonnes of copper, 100 tonnes of manganese, 40 tonnes of zinc and 13,000 tonnes of sulphates in a year. Recent surveys of the same river reveal that the macro-invertebrates in the waterways have continued to diminish downstream of the mining activities (ACMER 2001).

Water pollution *continued*

Processing chemical pollution — Spilling, leaking or leaching of chemical agents (e.g. cyanide, sulphuric acid) from the minesite into nearby water bodies. In 1994, a massive leak from the tailing retention system of the Olympic Dam mine was reported. For over four years, about 3 million cubic metres of highly acidic liquid containing a mixture of heavy metals and radionuclides had leaked through the limestone deposit (ANAWA 2003).

Erosion and sedimentation — Erosion of cleared land surface and dumped waste material can lead to sediment loadings into the adjacent water bodies, particularly during rainfall. Strip and open-pit mining naturally breaks up the terrain and exposes vast areas of land to wind and rainfall, making it highly susceptible to erosion (Hancock 1993).

Air pollution

Air pollutants, either in gaseous or particulate form, are potential hazards to health. Dust particles with diameters below 10 mm can penetrate into human lungs, while particles in the size range of 0.1–2 mm can cause impairment of vision. Incidences of health damage attributed to dust emissions from mining and mineral processing are evident in mining towns such as Mount Isa and Port Pirie. Studies indicate that the level of lead content in the blood of local residents has increased from their very long exposure to lead-bearing dusts which have been accumulated in the soils of residential areas (Hancock 1993).

Gaseous pollutants can impact on ecosystems. For example, the area around the Mt Lyell mine, has been severely affected by the fumigation of gases from copper smelting activities in the region from 1896 to 1969. Sulphuric acid mist and rain, which bring about devastation of vegetation in the area, have been a common problem in the region (Farrell & Kratzing 1996).

The majority of air emissions from the mining industry include dust, oxides of nitrogen, sulphur dioxide and carbon monoxide. Of emissions reported to the National Pollutant Inventory (NPI) (1999–2000), the mining industry was responsible for approximately 73% of particles, 76% of chromium (VI), 14% of sulphur dioxide and 18% of nitrogen dioxides. Dust emissions were mostly sourced from the production of coal, iron ore and gold. Table 4.19 quantifies the main emissions in 1999–2000. It must be emphasised that the National Pollutant Inventory does not cover all industries and it is not an exhaustive listing of pollutants. It has also relied on estimates of emissions rather than measurements.

4.19 SELECTED AIR EMISSIONS(a), MINING INDUSTRY — 1999–2000

Substance	Total mining	Total NPI	Mining's share of total NPI
	tonnes	*tonnes*	*%*
Oxides of nitrogen	109 711	607 028	18
Chromium (VI)	13	17	76
Carbon monoxide	46 826	615 878	8
Sulphur dioxide	201 384	1 483 824	14
Dichloromethane(b)	—	420	—
Cadmium compounds	1	11	10
Particulate matter (10 microns)	243 008	334 847	73
Sulphuric acid	17	130	13
Xylenes	1 444	2 611	55
Arsenic compounds	41	447	9

(a) The ten pollutants given highest priority by the NPI in terms of human health hazard and environmental hazard.

(b) Emissions of dichloromethane from the mining industry are 0.011 tonnes.

Source: Derived from NPI database.

Energy consumption and greenhouse gas emissions

The mining industry has been a relatively small consumer of energy in Australia, accounting for about 2% to 5% of the national energy consumption over the last 25 years. The electricity generation, transport and manufacturing industries are the major consumers of energy in Australia, accounting for almost 80% of the nation's total energy consumption.

Since 1973–74, the mining industry has displayed the fastest growth in energy consumption in the economy: 6.4% a year between 1973–74 and 1997–98 (table 4.20). This significant growth in energy consumption was mainly attributed to the development of the LNG industry in the late 1980s, the increasing demand for natural gas, increased production of petroleum products and the expansion of several mining activities, especially for gold, iron ore, nickel, mineral sands and black coal (ABARE 2001b).

4.20 ENERGY CONSUMPTION, BY SECTOR

Sector	Consumption 1997–98	Sector share 1997–98	Annual growth 1973–74 to 1997–98
	PJ	*%*	*%*
Electricity generation	1 359.0	28.3	4.2
Transport	1 210.7	25.2	2.4
Manufacturing	1 197.0	24.9	1.1
Residential	384.6	8.0	2.1
Mining(a)	263.8	5.5	6.4
Commercial and services	205.7	4.3	3.7
Agriculture	68.8	1.4	2.4
Construction	46.9	1.0	2.5
Other	73.6	1.5	0.7
Total energy consumed in Australia	**4 858.3**	**100.0**	**2.6**

(a) Vertically integrated operations.

Source: ABARE 2001b.

Energy consumption and greenhouse gas emissions *continued*

Natural gas has been the major source of energy used in mining industries, accounting for 55% of total mining consumption; petroleum accounted for 23%, electricity for 19% and coal and coke for 4%. The use of natural gas by the mining industry has almost tripled between 1986–87 and 1997–98, whereas the use of coal and coke has remained steady (table 4.21).

4.21 MINING INDUSTRY ENERGY CONSUMPTION AND PRODUCTION, BY FUEL TYPE

	1986–87	*1992–93*	*1997–98*
Energy source	*PJ*	*PJ*	*PJ*
Natural gas	50.2	103.1	146.3
Petroleum(a)	27.7	42.4	61.3
Electricity	24.2	37.9	47.8
Coal(b) and coke	22.6	19.7	22.8
Energy produced(c)	18.8	13.3	14.9
Net energy consumed by the mining industry	**106.0**	**190.1**	**263.8**

(a) Includes LPG, diesel, fuel oil, petroleum products n.e.c.

(b) Brown coal, black coal, and coal by-products.

(c) The mining industry produces electricity and brown coal briquettes.

Source: ABARE 1999.

The mining industry is among the top seven direct greenhouse gas emitters in Australia, accounting for 4% of the total energy-related CO_2 emissions per annum in the period from 1992–93 to 1997–98. It ranked fourth behind the electricity supply industry, which accounted for nearly half (48%) of the total emissions from 1992–93 to 1997–98 (ABS 2001c).

Table 4.22 shows the emissions produced by the mining sector relative to fuel combustion activities and fugitive emissions from fuel. CO_2 comprises easily the largest component of greenhouse gas emissions derived from stationary combustion, accounting for 99% of the total emissions of carbon dioxide equivalents, with CH_4 and N_2O accounting for the remainder. Emissions from fugitive sources are mostly CH_4 (80%), of which 75.4% arises from coal mining (surface and underground). CO_2 (21%) and N_2O (less than 1%) comprise the remainder of fugitive emission from oil and gas production. In 1999, total fugitive emissions were estimated at 30.8 Mt CO_2-e, representing 6.7% of the total net emissions in Australia, 4.4% higher than in 1990, but 2.7% lower than in 1998.

4.22 MINING SECTOR CO_2-EQUIVALENT EMISSIONS — 1999

	CO_2-equivalent emissions			
	CO_2	CH_4	N_2O	Total
Greenhouse gas source and sink categories	Gg	Gg	Gg	Gg
1. Fuel combustion activities	*11 982.0*	*27.1*	*15.5*	*12 024.6*
a. Manufacture of solid fuels and other energy industries	10 571.0	25.4	12.4	10 608.8
Coke ovens	1 387.0	0.4	6.2	1 393.6
Briquetting	4.0	—	—	4.0
Coal Mining	1 455.0	1.7	3.1	1 459.8
Oil and gas production and field processing	7 058.0	21	3.1	7 082.1
Natural gas transmission	499.0	1.7	—	500.7
Gas production and distribution	168.0	0.6	—	168.6
b. Mobile equipment	1 411.0	1.7	3.1	1 415.8
2. Fugitive emissions	*6 482.0*	*24 335.0*	*22.0*	*30 839.0*
a. Solid fuels (coal mining)	Not estimated	18 341.0	na	18 341.0
b. Oil and natural gas	6 482.0	5 994.0	22.0	12 498.0
Total national energy emissions	**332 860.0**	**26 753.0**	**4 952.0**	**364 566.0**

Source: National Greenhouse Gas Inventory 1999.

ENVIRONMENTAL MANAGEMENT

Public concern about the quality of the environment in the 1980s led to increased controls and regulations relating to activities that have an impact on the environment. The environmental impacts of long-standing mines created a demand for governments to take greater responsibility to formulate and enforce environmental standards, and to encourage rehabilitation of the mine site upon completion of mining, and for mineral companies to control or limit their impacts on the environment.

Environment protection

Environment protection is now an integral part of any mine or exploration development plan, in consultation with the community and the government, prior to the issue of mining leases. Environment protection includes all activities aimed at the prevention, reduction or elimination of pollution or any degradation of the environment. It includes waste management and protection of biodiversity, landscape, air and climate (MCA 2002). Protection mechanisms are backed by environmental legislation from the states and, increasingly, the Commonwealth. The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* provides the Commonwealth with powers to intervene in or oversee state approval processes for projects which may significantly impact on matters of national environmental significance (Ameef 2002).

The mining industry is involved in managing risks to the environment associated with mining activities. For example, the industry is working with research organisations to identify and manage risks to the environment arising from Acid Mine Drainage (AMD; see the Water Pollution section earlier in this chapter). Australian Nuclear Science and Technology Organisation research into the impacts of AMD at the Rum Jungle uranium mine has led to an improved understanding of oxygen in the process. The waste dumps are now capped with clay, sandy loam and gravelly sand to reduce the amount of oxygen and water penetrating the heaps. The dumps were also contoured and revegetated to control water run-off and erosion (ANSTO 2002).

Environment protection *continued*

The industry is also undertaking steps to control erosion. One way to manage erosion during exploration is to restrict access of vehicles to designated tracks, thereby limiting impacts to the stability of soil structure. During mineral extraction, establishing contour banks and grading the slopes of mined areas contains water erosion. Short-term use of grasses and vegetation are also used as a temporary measure to maintain soil stability (Hinds 1999). In areas undergoing rehabilitation, such as at bauxite mines in south-west Western Australia, the process of ripping allows control of water run-off (Ward et al. 1996). This process involves using ground rippers that break up soil compaction in a pit floor allowing water to infiltrate the soil quicker and allow vegetation to establish more quickly. The Mt Leyshon gold mine in north Queensland controls erosion from water run-off though the use of graded banks and rock-lined channels (Orr 1996). Techniques such as this are critical for managing erosion of overburden and tailings dumps.

The importance of high standards of environmental management and performance to the future of the industry is demonstrated through the Australian Minerals Industry Code for Environmental Management (the Code). Launched in 1996, the Code incorporates the principles of sustainable development, partnerships with the community, and the development of an environmentally responsible culture (MCA 2000). The Code does not cover petroleum, oil and gas mining.

As at 1 January 2002, 43 companies had committed themselves to the 2000 Australian Minerals Industry Code for Environmental Management, covering over 300 operations (35 are outside Australia). This represents around 50% of all mining establishments in Australia, accounting for over 85% of production (Ameef 2002).

By signing to the 2000 Code, the signatories and its workforce commit to excellence in environmental management through the adoption of the following principles:

- accepting environmental responsibility for all actions
- strengthening relationships with the community
- integrating environmental management into the way they work
- minimising environmental impacts of activities
- encouraging responsible production and use of products
- continually improving environmental performance
- communicating environmental performance.

An essential feature of the 2000 Code is the provision for enhanced public reporting and the verification of the industry's environmental practices measured against the implementation of the Code's principles. A company's performance is assessed in key areas covering energy use and efficiency, water consumption, land rehabilitation, air emissions, biodiversity, and the incidence and severity of environmental issues. At least 45 company environmental reports have now been released since the Code was initiated in 1996.

Environment protection *continued*

In 2000–01 the total national expenditure for environmental protection by the mining industry was $391m (table 4.23), comprising current expenditure of $284m, and capital expenditure of $107m. Management of solid and liquid waste and air emissions were the largest environmental expenses by the mining industry, representing 55% ($214m) of total expenditure (ABS 2002).

Current expenditure generally refers to activities related to the intermediate consumption of environmental products and services. Current expenditure accounted for 73% ($284m) of total environment protection expenditure. Of this, the two highest contributors were minesite rehabilitation ($98m) and solid waste management ($54m). Administration of environment protection accounted for the remaining $48m (17%) of current expenditure. The metal ore mining subdivision ($154m) reported the highest environment protection current expenditure in the mining industry. Metal ore mining had major current expenditure on minesite rehabilitation ($50m) and reducing air emissions ($34m). Coal mining was a significant contributor to minesite rehabilitation ($36m) current expenditure.

Capital expenditure in the mining industry for 2000–01 was $107m. Metal ore mining ($72m) accounted for the highest capital expenditure estimates in the mining industry. Of this, solid waste management accounted for $48m and liquid waste accounted for $12m.

4.23 ENVIRONMENTAL PROTECTION EXPENDITURE, BY MINING INDUSTRY SUBDIVISION

	1996–97	*2000–01*						
	Total	*Minesite rehabilitation*	*Solid waste*	*Liquid waste(a)*	*Air emissions*	*Other*	*Administration*	*Total*
Current expenditure	*$m*	*$m*	*$m*	*$m*	*$m*	*$m*	*$m*	*$m*
CURRENT EXPENDITURE								
Coal mining	58.5	35.8	21.2	6.3	4.0	5.8	9.4	82.4
Oil and gas extraction	21.9	1.8	3.3	6.3	9.5	3.5	7.8	23.5
Metal ore mining	103.9	50.2	24.6	11.4	34.1	7.7	26.4	154.4
Other mining	31.2	9.9	4.7	0.9	1.5	2.0	4.4	23.5
Total	**228.1**	**97.7**	**53.8**	**24.8**	**40.5**	**19.0**	**48.0**	**283.8**
CAPITAL EXPENDITURE								
Coal mining	44.4	np	3.4	4.4	np	np	. .	11.6
Oil and gas extraction	10.4	np	0.4	0.8	np	np	. .	14.5
Metal ore mining	69.2	4.4	47.7	11.6	4.7	3.0	. .	71.5
Other mining	15.7	1.2	2.6	0.4	4.7	0.3	. .	9.2
Total	**140.8**	**7.4**	**54.2**	**17.3**	**23.1**	**4.9**	**. .**	**106.8**

(a) Includes waste water.

Source: Environment Protection, Mining and Manufacturing Industries, Australia, 2000–2001 (cat. no. 4603.0); Environment Protection Expenditure, Australia, 1995–96 and 1996–97 (cat. no. 4603.0).

Environment protection *continued*

In 2000–01, most mining environmental current expenditure was directed to minesite rehabilitation, including activities such as the restoration of landscapes ($98m), whereas most capital expenditure was directed to solid waste management ($54m) (table 4.24).

4.24 ENVIRONMENTAL PROTECTION EXPENDITURE, BY ENVIRONMENTAL DOMAIN — 2000–01

Domain	Businesses with expenditure(a)	Expenditure	Proportion of total environment protection expenditure	Proportion of total expenditure for all mining businesses
	no.	$m	%	%
CURRENT EXPENDITURE				
Minesite rehabilitation	426	97.7	34.4	0.3
Solid waste	297	53.8	19.0	0.2
Liquid waste(b)	254	24.8	8.7	0.1
Air emissions	203	40.5	14.3	0.1
Other	192	19.0	6.7	0.1
Total	**520**	**(c)283.8**	**83.1**	**0.7**
CAPITAL EXPENDITURE				
Minesite rehabilitation	100	7.4	6.9	0.2
Solid waste	95	54.2	50.7	1.1
Liquid waste(b)	90	17.3	16.2	0.4
Air emissions	87	23.1	21.6	0.5
Other	43	4.9	4.6	0.1
Total	**229**	**106.8**	**100.0**	**2.2**

(a) Businesses may be involved in more than one domain activity, hence the count of businesses may not sum to the total.

(b) Includes waste water.

(c) Includes administration expenditure of $48m.

Source: Environment Protection, Mining and Manufacturing Industries, Australia, 2000–2001 (cat. no. 4603.0).

The mining industry has developed expertise in environmental management, to ensure that environmental protection is achieved in planning and operating resource developments. This expertise has been built up across a wide variety of climatic and geographical conditions in Australia and overseas. Australian companies are widely viewed as among the best in the world in terms of best practice with environmental management (GA 2002b).

The principles and practices of minesite rehabilitation, particularly restoring natural ecosystems and the re-establishment of native flora, were enhanced by the release of the *Best Practice Environmental Management in Mining Handbook — Rehabilitation and Revegetation* publication by the Environment Protection Agency in 1995 (EPA 1995).

Environmental technologies

Environmental technologies used in the mining sector can be defined as the use of hardware, systems and services that provide a 'net environmental benefit' (EA 2000). The application of environmental technologies in Australian mining is firmly established and increasingly recognised internationally in developing best practice and practical solutions. The nature of mining in Australia involves coping with remoteness, environmental extremes, large resources and concentration of minerals requires the ongoing development of highly efficient mining and transport systems capable of handling and processing large tonnages over long distances. New processes have also been brought into production to treat ores not previously thought economic to extract. The development of science and technology has allowed mining on greater scales than previously imagined. Australia is a world leader in earth science software used to process, visualise and interpret remotely sensed scientific data from satellites and aircraft, and link them with ground-based information. Over 60% of the world's mines use software created by Australian companies, and AUSTMINE figures show exports worth $1.2b of mining-related intellectual property in 1998–99; this was ahead of industries such as the wine industry which has exports worth $900m (ABS 2001a).

Environmental technologies are essential to achieving environmental best practice by controlling environmental impacts, and are vital to overall integrated management approaches and systems. The incentives for developing the use of environmental technologies in mining include the community's demands for environmental sustainability, the wide variety in commodities mined and in how they are processed, the vast range of climatic, soil and natural environment conditions, environmental standards adopted by government regulations and progressive industry practices, and well established research, development, education and training systems.

Examples of the applications of mining technologies include:

- Ecosystem monitoring — the measurement of success in rehabilitation of a mine site goes beyond simply restoring a site to its pre-mining appearance and works towards ensuring that habitats are regenerated. The effectiveness of monitoring is also aided by the use of remote sensing technologies such as satellite photography. Remote sensing allows for the detection and monitoring of environmental impacts.
- Information management — the amount of environmental information associated with monitoring can be vast, which requires systems to store, process and present these data. The ability to analyse data more readily allows for better environmental decision making.
- Reuse of waste materials — reduces the need for new materials as well as the amount of landfill required.
- Training — develops environmental awareness, and is also important in promoting environmental responsibility so that staff know how to reduce risks of environmental impacts and respond to situations such as spills.

Environmental technologies *continued*

- Wastewater management — reducing the need to dump used water allows the environment to accept less quantities of water as well as reducing water requirements of mining sites.
- Pollution control — control of atmospheric, water and even noise pollution. This involves efforts such as reducing greenhouse gas emissions through using carbon scrubbing technology, as well as treating contaminated water with filtration systems.
- Dust suppression — important in controlling dust, keeping soil stability and allowing plant germination and growth, thereby controlling erosion (EA 2000).

The application of environmental technologies in the mining sector has contributed substantially to limiting environmental impacts in the planning, exploration, operational, closure, remediation and rehabilitation stages of mining operations. The continuing evolution of technology will allow for greater capabilities in managing the environmental impacts of mining. Table 4.25 shows the proportion of Australian mining industry establishments which use environmental monitoring or rehabilitation technologies.

4.25 PERCENTAGE OF ESTABLISHMENTS WITH ENVIRONMENTAL TECHNOLOGIES, BY TYPE AND INDUSTRY SUBDIVISION — JUNE 1994

Technology type	*Coal mining* %	*Oil and gas extraction* %	*Metal ore mining* %	*Other mining* %	*Services to mining* %	*Total mining* %
Air quality monitoring	62	27	62	31	9	35
Meteorological monitoring	36	36	33	7	7	18
Water quality monitoring	72	73	79	41	15	46
Biological monitoring	21	55	43	8	7	18
Rehabilitation design	73	45	72	65	25	55

Source: Environment Protection Expenditure, Australia, 1992–93 and 1993–94 (cat. no. 4603.0).

Environmental Impact Assessment (EIA)

Environmental Impact Assessment (EIA) is a mechanism for managing the process of integrating environmental factors into project planning and decision making, consistent with the principles of ecologically sustainable development. It is institutionalised primarily to provide information on the biophysical, social, and other related consequences of proposed developments. It is an instrument for planning the wide range of resource use, development, and conservation initiatives at its utmost consideration to achieve sustainability (Gibson 1993).

The level at which an EIA is assessed depends on a range of factors: the nature of the proposal; its complexity; the local environment; its expected effects; and the controversy that will be or has been generated. Project proposals that are likely to be of any local and regional interest, and where potential environmental impacts are few or easily managed, are required to produce a public environmental report (PER). This provides details of the proposal including potential environmental impacts and proposed management techniques.

Environmental Impact Assessment (EIA) *continued*

Project proposals that may attract wide public interest and/or deal with complex issues of environmental significance are often required to produce an Environmental Impact Statement (EIS). The impacts identified will require detailed evaluation, be the subject of extensive community advice and review, and require comprehensive environmental management programs.

Between 1975 and 1999, 177 EIS proposals were directed under the administrative procedures of the *Commonwealth Environment Protection Act 1974*. Almost 40% (70) of the proposals came from the mining industry. Uranium projects accounted for 26% (18) of the submissions, and oil and gas and minerals for close to 20%. The greatest number of submissions occurred between 1975 and 1984, when several proposals for the development of uranium and coal projects were subjected to EIS.

Performance bonds

Performance bonds are monetary guarantees to perform a required standard of post-mining rehabilitation. Either in the form of cash or bank guarantee, they provide the government with a form of 'insurance' or guarantee that there will be sufficient funds to cover the clean-up and rehabilitation of a completed or abandoned mining project, and subsequently to minimise the risks that the government and the community would have to bear the costs of rehabilitation. The bonds are refunded over time as rehabilitation progresses to the extent where environmental damage has declined (Allen et al. 2001).

Performance bonds are commonly used as an administrative and environmental management tool. As an administrative tool, a performance bond is one of the preconditions required by a state mining authority prior to issue of any mining lease. As an instrument for environmental management, it is used to influence the behaviour of the permitees to act responsibly and to encourage the efficient use of natural resources.

With the stringent requirement for rehabilitation of areas affected by mining operations, the value of performance bonds held by governments has increased significantly. At June 2000, the performance bonds held by state and territory governments were valued at $1.1b, approximately 3.3% of the gross value of mineral production for Australia in the same year (table 4.26).

4.26 VALUE OF REHABILITATION BONDS — JUNE 2000

	Value of bonds
	$m
New South Wales	230
Victoria	57
Queensland	474
South Australia	51
Western Australia	240
Tasmania	13
Northern Territory	62
Australia	1 127
Total value of mine production	34 229

Source: Australian Mining Industry, 1998–99 (cat. no. 8414.0); Allen et al. 2001.

Performance bonds *continued*

The calculation of the bonds is relative to the sensitivity of the environment and the nature of the mining activity. The amount is set normally to the level of cost to be incurred on rehabilitation of perceived damages, and is based on average costs per hectare of land disturbed by different mining activities. Table 4.27 provides a comparison of the determinants of bond calculations in several states and the Northern Territory. The level of bonds or securities is reviewed periodically to determine if there are significant changes in the plan (requiring a recalculation of the bond), and to allow refunds of some of the bond monies during mining operations. The frequency of the review process depends on the complexity of the mining project. The process also assists in avoiding situations where deposits are set too low (and made worse by inflationary pressures), requiring some rehabilitation to be subsidised by state governments (Ameef 2002).

4.27 ACTIVITIES DETERMINING BOND CALCULATIONS — 2000

Mining activity	*New South Wales*	*Queensland*	*Western Australia*	*Northern Territory*
	$'000 per ha	*$'000 per ha*	*$'000 per ha*	*$'000 per ha*
High risk structures, tailings storage facilities and waste dumps with acid mine drainage	33–55	30–40	10–15	20–30
Normal tailing storage facilities and high waste dumps	10–20	20–30	10	10–20
Low waste dumps and special heaps	9–15	10–20	8	5–10
Plant sites, camp infrastructure	5–8	5–10	5	10
Roads and hardstand	—	2	3	5
Adits, shafts etc. (each)	15–25	—	—	5–10

Source: Allen et al. 2001.

Multiple resource use

The mining industry is just one of a number of land users in Australia. Increasingly the mining industry has had to justify its need to access land against the needs of other land users, including Indigenous interests, agricultural and forestry industries, human settlements, and conservation areas (Hancock 1993). Managing competing interests in land has become a major issue for industry, the community and all levels of government.

The compatibility of one resource use with other resource uses has been widely promoted by the mining industry as a partial solution to land resource conflict (Cox, in ABARE 1997). Compatibility exists when such a combination offers long-term benefits to the populace and exceeds the benefits of an exclusive resource use. The mining of bauxite in the Jarrah forests of the Darling Ranges (Western Australia) and uranium mining in an area excised from the Kakadu National Park (Northern Territory) provide examples of coexistence. These projects have been in operation for over 35 years and 20 years respectively (GA 2002b).

Multiple resource use *continued*

The potential also exists for resources to be used sequentially. For example, a number of rehabilitated mine sites have become part of protected areas after mining has ceased. Successful rehabilitation of a number of mineral sands mines in the coastal areas of New South Wales has led to the inclusion of the sites in the Myall Lakes, Crowdy Bay and Bundjalung National Parks.

Where ecological and mineral potentials coincide, multiple land use arrangements have been introduced in some states and the Northern Territory to allow exploration and mining activities in certain areas (Mining Working Group 1991). This is carried out by creating special reserves, with the aim of protecting conservation values while allowing other uses of land such as exploration and mining operations. The other approach is through a legislative provision which allows for approvals of mineral exploration and mining operations within established conservation areas.

SUMMARY

Australia hosts one of the largest and most diversified sub-soil asset bases in the world, including the largest identified reserves of bauxite, lead, mineral sands, uranium and zinc. Additionally, Australia has significant petroleum and natural gas reserves. This competitive advantage has led to the mining industry becoming a significant contributor to Australia's wealth. The mining industry contributes 4% to Australia's GDP, employs over 60,000 people, and accounts for over 46% of exports.

Despite affecting less than 0.01% of Australia's land mass, mining is a resource-intensive activity that creates disturbance to the environment. Mining and exploration disturb the land by removing vegetation and topsoil, generating wastes and pollution, affecting surface and groundwater, and emitting greenhouse gases.

The environmental consequences of mining have attracted public attention and political controversy. This has led to increased regulation of mining activities and resulted in the mining industry identifying and addressing environmental issues. The industry's desire to actively management the environment is demonstrated by the introduction of an environmental code in 1996, its high level of expenditure on environmental protection (almost $400m in 2000–01), and its contribution to resolving land use conflict. Environmental management is important to the success and long-term prosperity of the mining sector.

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CHAPTER 5 WASTE AND WASTE MANAGEMENT IN AUSTRALIA

INTRODUCTION

Substantial quantities of waste are generated from human consumption and activities related to the construction, operation, maintenance and renewal of human settlements (Newton et al. 2001). Australia currently consumes more resources and produces more waste than at any time in its history. In terms of sustainability, high resource consumption and increasing outputs of wastes are important features of Australian society and are related to the nation's growing population and increasingly high standard of living. Without changes to consumption patterns and other behavioural changes, these trends look set to continue into the future.

Resource inputs and their transformation and consumption, waste generation and waste disposal are integral to the life of any society. Pressures on the environment imposed by human populations are intricately linked to these processes. Under the principles of ecologically sustainable development, non-renewable resources should be used prudently and efficiently, with care that the same function is available to future generations. Sink functions should not be used beyond their assimilative capacities. In this context, increasing resource use and emission of wastes to ecological sinks are important issues to be addressed in working towards ecologically sustainable development in Australia.

This chapter focuses on flows of waste in Australia. The chapter initially provides an overview of material flows, waste streams and waste emissions, and the pressures they impose on the environment. This is followed by a more detailed discussion of particular waste streams, namely: emissions of certain substances to land, water and air; solid wastes and their disposal at landfills; radioactive wastes; and litter and debris in coastal areas — and their associated environmental impacts. The chapter concludes with an outline of recent trends in waste management and waste minimisation (i.e. reuse, recovery and recycling), and their cost.

MATERIAL FLOWS AND WASTE STREAMS

The term 'waste' has numerous meanings and interpretations. In this chapter, waste is broadly defined as any substance that may be emitted, discharged or deposited into the environment to cause or potentially cause adverse environmental change. Waste emanates from material flows in the economy, that is, the extraction or harvesting of raw material inputs, processing and manufacturing activity to transform materials and produce goods. Waste is a by-product of these processes and of the final consumption of the material outputs.

MATERIAL FLOWS AND WASTE STREAMS *continued*

Waste generated by a community can be broadly divided into distinct 'waste streams', which follow these material flows in the economy. Waste streams are important concepts used to identify the amount, composition and disposal of waste at various points within the economy. The flow of a wood product through the economy is a good example. Timber is initially harvested from a forest, and processed into sawn-timber products in a sawmill, which are subsequently used to construct various components of houses and other buildings. Any timber products not consumed (e.g. discarded forest material, off-cuts from the mill or unused timber at the building site) are considered waste and are generally incinerated or disposed of in other ways. Further waste may be generated during the harvesting, transport and milling phases through wastewater, air pollution and greenhouse gas emissions.

Numerous waste streams have been identified for Australia. These streams incorporate flows of solid, liquid and gaseous materials (including hazardous and radioactive substances) emitted as waste to our land, water and atmosphere. Wastes generated in human settlements are usually recorded for three waste streams: municipal waste (domestic and council); commercial and industrial waste; and building and demolition waste. These waste streams are particularly relevant to solid and liquid wastes generated in urban areas. Organic wastes from human settlements are increasingly treated as a separate waste stream. Other waste streams may be used to define waste flows for specific parts of the economy such as the agriculture, energy and mining industries.

Hidden flows are an important component of material flows in the economy, which comprise waste streams that are rarely recognised or measured. Hidden flows are associated with processes which produce direct material inputs and waste outputs. However, because they are not traded in the monetary economy, they are not recorded in economic statistics, and are generally ignored. Wastes associated with hidden material flows are not handled by the waste management industry. This hidden component of total material flows in Australia may be very high, emphasising the importance of integrating hidden flows into commonly recorded waste streams.

Material flows in the Australian economy

A broad indicator of environmental pressure in Australia is material flows in the economy. Material flow refers to the extraction, transformation and end use of different materials to create the products needed to support and sustain a city, nation or society (Poldy & Foran 1999, Yencken & Wilkinson 2000). This description encompasses production cycles from start to finish (i.e. the extraction or harvesting of raw material inputs, processing and manufacturing activity to purify materials and produce goods, the final consumption of the material outputs, and the disposal of wastes). Total material flow is made up of direct material input and hidden flows. The direct material input, consisting of primary inputs such as agricultural, mineral and energy commodities as well as imported goods and materials, is the direct object of commerce, and its flows are systematically recorded in monetary terms in the economic statistics (and sometimes — but less systematically — in physical terms).

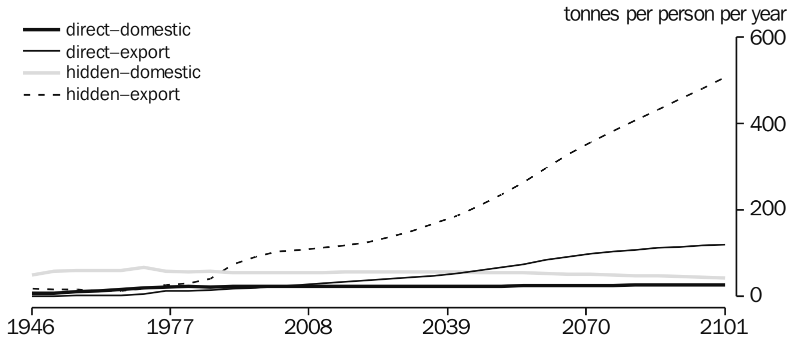
Material flows in the Australian economy *continued*

Hidden flows are material flows unavoidably associated with the processes which produce the direct material input. However, because they are not traded in the monetary economy, they are not recorded in the economic statistics, and are generally ignored (Poldy & Foran 1999, Yencken & Wilkinson 2000). Hidden flows include the removal of overburden in mining, acid run-off into rivers and streams, groundwater contamination from tailings dams and storage ponds, material removed during the construction of roads, buildings and other infrastructure, and effects of agriculture, such as soil erosion, chemical contamination, salinity and weed infestation. These flows impose significant environmental costs despite the fact that they are not formally recorded in the standard economic accounts. This hidden component of the total material flow is very high.

The estimated actual Australian material flow is 200 tonnes per person per year and is projected to grow very quickly (Poldy & Foran 2001). Most of the projected increasing total flow is associated with exports and consists of the exported commodities themselves and the even larger hidden flows necessarily associated with them (graph 5.1). More specifically, overburden removal in the metal and energy mining industries accounts for much of the increase (graph 5.2).

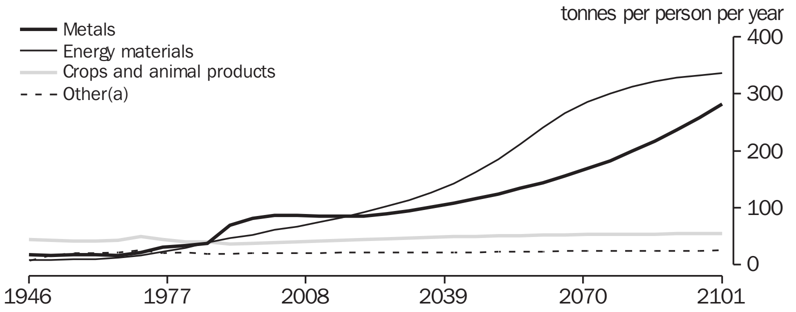
For these projections, Australia's population is assumed to stabilise at about 25 million by 2050, and it is assumed that population and primary commodity exports are not tightly coupled: if population rises then the material flow per person drops because the same volume of material is spread over more people (Poldy & Foran 1999). Conversely, a lower population means a higher total material flow per person. In other words, Australia's high material flow per person is a feature of the materially intensive structure of the Australian economy.

5.1 ESTIMATED ACTUAL AND PROJECTED MATERIAL FLOW PER PERSON, Direct and hidden flows



Source: Poldy & Foran 2001.

5.2 ESTIMATED ACTUAL AND PROJECTED MATERIAL FLOW PER PERSON, Main types of material



(a) Includes construction materials and excavation.

Source: Poldy & Foran 2001.

WASTE EMISSIONS TO LAND, WATER AND ATMOSPHERIC SINKS

Outputs from each waste stream are discharged in either solid, liquid or gaseous form to various land, water and atmospheric 'sinks'. These waste emissions have potentially deleterious effects on the environment and human health, in particular, those wastes deemed 'hazardous'. This section identifies some of the many solid, liquid and gaseous wastes, and some of the potential impacts of these wastes upon the environment. It then discusses the types and amounts of certain polluting substances being emitted to the land, water and air, as reported to the National Pollutant Inventory (NPI). Several issues are dealt with in more detail in later sections.

Overview of solid, liquid and gaseous wastes and their environmental impacts

Solid waste generally refers to waste generated by the three identified waste streams from human settlements identified earlier: municipal (domestic and council); industrial and commercial; and building and demolition. Solid wastes include paper, plastics, metal, glass and organic materials; discarded manufacturing and packaging materials; and rubble and building off-cuts. The waste produced by these sectors is generally transported to landfill or is incinerated. Solid wastes are also generated by other industry sectors, such as mining and agriculture, and are generally managed on-site. Solid waste generation and the environmental implications of its disposal at landfill are discussed further in the section *Solid waste generation and disposal.*

Overview of solid, liquid and gaseous wastes and their environmental impacts *continued*

Stormwater, wastewater and treated sewage are discharged from human settlements into rivers, lakes, wetlands, estuaries, groundwater and coastal waters. These water-based emissions may contain high levels of nutrients (phosphorus and nitrogen), organochlorines (including pesticides and herbicides), hydrocarbons (i.e. oil), heavy metals and dissolved salts, which often reduce water quality and adversely affect aquatic ecosystems. For example, the excessive quantities of nitrogen and phosphorus (nutrient enrichment) in inland waterways may give rise to algal blooms and eutrophication under appropriate conditions, and contaminated inland waterways have resulted in decreased diversity of aquatic plant and animal life (SoE 1996). Wastewater is water which has been used for some purpose and would normally be treated or discarded, and often contains significant quantities of pollutants. Thomas et al. (1997) found that the majority of wastewater in 1994 was disposed to coastal waters (72%); inland waters received 17% of the wastewater; while land disposal was used for 10% of the total (table 5.3).

5.3 WASTE WATER DISPOSAL METHOD, BY VOLUME — 1994

Disposal method	*Units*	*Coastal waters*	*Inland waters*	*Land*	*Direct reuse*	*Total*
Australian Capital Territory	ml	—	32 969	30	1	33 000
New South Wales	ml	443 137	138 293	28 198	8 710	618 338
Northern Territory	ml	9 090	1 100	1 250	—	11 440
Queensland	ml	240 320	31 810	30 660	1 220	304 010
South Australia	ml	93 478	1 548	6 819	2 881	104 726
Tasmania	ml	35 000	14 390	—	910	50 300
Victoria	ml	326 580	74 071	82 191	958	483 800
Western Australia	ml	76 765	875	12 790	3 382	93 812
Total	*ml*	*1 224 370*	*295 056*	*161 938*	*18 062*	*1 699 426*
Percentage of total	%	72.1	17.4	9.5	1.1	100.0

Source: Thomas et al. 1997 cited in Newton et al. 2001.

The main air pollutants emitted from Australian settlements to the atmosphere are carbon dioxide, nitrogen oxides, carbon monoxide, sulphur oxides and volatile organic chemicals. All except carbon dioxide are potentially toxic to humans and are particularly problematic in urban areas, where air pollution (e.g. smog) is one of the main environmental concerns of metropolitan populations in Australia (ABS 1998a). Human induced emissions of carbon dioxide and other greenhouse gases into the atmosphere have increased dramatically in the last century (see the section *Greenhouse gas emissions*). Increasing atmospheric concentrations of these gases have been linked to global climate change; this is one of the most pertinent global environmental problems.

Overview of solid, liquid and gaseous wastes and their environmental impacts *continued*

Hazardous waste emissions to land, water and the atmosphere are particularly detrimental to the environment and human health. Hazardous waste includes substances which are explosive, flammable, poisonous, toxic, infectious or ecotoxic (have an adverse impact on the general environment, including impacts on wildlife). Potentially hazardous wastes of domestic origin include paints, detergents, solvents, used car batteries and motor oils. *The Hazardous Waste (Regulation of Exports and Imports) Act 1989* (with substantial amendments in 1996) was established to 'regulate the export and import of hazardous wastes to ensure that hazardous waste is disposed of safely so that human beings and the environment, both within and outside Australia, are protected from the harmful effects of the waste'. Radioactive waste is a particularly important type of hazardous waste, of which Australia is accumulating relatively small quantities. Radioactive waste requires special treatment in its handling, storage and disposal (see the section *Radioactive waste*).

The National Pollutant Inventory (NPI)

Established in 1998, the NPI is designed to provide reliable and consistent data on the types and amounts of certain substances being emitted to the land, water and air of Australia, through a database of estimated emissions. The NPI provides information on both point sources (facilities like manufacturing sites) and aggregated emissions from diffuse or mobile sources (such as households and transport). From over 400 initial substances considered harmful to the environment and human health, a priority list of 90 substances was developed. They include metals such as cadmium, copper, lead, mercury and zinc, volatile organic compounds, acids (hydrochloric, nitric, phosphoric, sulphuric), as well as substances like fluoride, ammonia, arsenic and chlorine (for more information on the types, uses and impacts of the listed substances consult the NPI web site <http://www.npi.gov.au>).

Industrial facilities emitting volumes of the listed substances above a certain threshold are currently required to estimate and report their emissions of all 90 listed substances to air, land and water. Prior to July 2001, emissions of only 36 listed substances were reported. Estimates are also made for emissions from smaller industrial facilities and everyday household activities, such as driving to work and mowing the lawn.

The National Pollutant Inventory (NPI) *continued*

The NPI is a developing initiative, and comparisons between industry sectors and domains (land, water and air) must be made with caution. The data do, however, provide an indication of the levels of pollution and their source. Data for 1999–2000 indicate that the overwhelming majority of emissions of substances measured by the NPI were to the air (table 5.4). Of the total emissions of 3.24 Mt recorded by the NPI, emissions to air accounted for over 97% (3.13 Mt), with emissions to water and land accounting for about 3% (0.11 Mt) and less than 1% (0.002 Mt) respectively. The metal product manufacturing industries (i.e. aluminium, iron and steel) contributed the highest proportion of recorded air emissions (42%), followed by the electricity and gas supply sector (30%) and the metal ore mining sector (13%). Sulphur dioxide, carbon monoxide and oxides of nitrogen comprised the most significant substances emitted to the atmosphere in terms of quantity and their potential effect on human health and the environment. For both emissions to water and land, the greatest supply was from the water supply, sewerage and drainage services sector, with 49% of recorded emissions to water, and 42% of recorded emissions to land.

5.4 POLLUTANT EMISSIONS TO LAND, WATER AND THE AIR — 1999–2000(a)

	Air emissions		*Water emissions*		*Land emissions*	
Sector	*tonnes*	*%*	*tonnes*	*%*	*tonnes*	*%*
Agriculture	15 344.9	0.5	—	—	—	—
Coal mining	132 258.1	4.2	7.0	—	0.5	—
Oil and gas extraction	84 598.2	2.7	408.1	0.4	40.8	2.4
Metal ore mining	398 769.8	12.8	19 484.7	17.6	520.0	30.8
Other mining	10 076.7	0.3	63.7	0.1	—	—
Food, beverage & tobacco manufacturing	56 851.4	1.8	2 604.1	2.3	23.1	1.4
Textile, clothing, footwear & leather manufacturing	626.5	—	—	—	—	—
Wood & paper product manufacturing	19 862.3	0.6	1 306.4	1.2	0.5	—
Printing, publishing & recorded media	2 915.9	0.1	—	—	—	—
Petroleum, coal, chemical & assoc. product manufacturing	72 772.4	2.3	30 710.9	27.7	1.7	0.1
Non-metallic mineral product manufacturing	51 784.8	1.7	—	—	73.6	4.4
Metal product manufacturing	1 316 372.9	42.1	1 719.6	1.5	108.8	6.4
Machinery & equipment manufacturing	4 394.7	0.1	—	—	—	—
Electricity & gas supply	940 091.5	30.1	14.2	—	—	—
Water supply, sewerage & drainage services	616.7	—	54 379.1	49.0	717.7	42.5
General construction	124.1	—	—	—	0.2	—
Basic material wholesaling	11 386.2	0.4	4.4	—	14.5	0.9
Accommodation, cafes & restaurants	85.4	—	—	—	—	—
Rail transport	5.8	—	—	—	—	—
Services to transport	4 969.5	0.2	1.7	—	—	—
Storage	—	—	—	—	—	—
Defence	965.7	—	—	—	—	—
Health services	647.0	—	—	—	—	—
Personal services	104.5	—	—	—	—	—
Other services	1 723.4	0.1	280.4	0.3	189.1	11.2
Total	**3 127 348.3**	**100.0**	**110 984.4**	**100.0**	**1 690.4**	**100.0**

(a) In the years 1999–2000 and 2000–01, facilities were only required to report on 36 substances. From July 2001 this increased to 90 substances.

Source: NPI 2001.

SOLID WASTE GENERATION AND ITS DISPOSAL

National-scale monitoring and measurement of solid waste streams is more comprehensive than the monitoring of liquid and gaseous waste streams (with the possible exception of greenhouse gas emissions, addressed in the next section). This is particularly relevant to solid waste flows within urban areas. Australia is one of the world's highest solid waste producers per capita, this waste emanating primarily from the municipal (domestic and council) waste stream. The majority is deposited at landfill sites. This section discusses the quantity and composition of solid waste, its disposal, and some of the key environmental implications of landfill operations.

Quantity and composition of solid waste

Solid wastes are generally classified into the three waste streams identified earlier: municipal (domestic and council); commercial and industrial; and construction and demolition. The overall solid waste composition for Australia's major cities is shown in table 5.5. The average waste composition for Australia's metropolitan areas is approximately 40% domestic waste (from domestic households and councils), 23% commercial and industrial waste, and 37% construction and demolition waste. However, there is substantial variation across these urban centres, which reflects the diverse range of economic activity and waste generating processes (i.e. material flows) across Australian cities.

5.5 COMPOSITION OF SOLID WASTE(a), SELECTED REGIONS — 2000

	Inner Sydney	*Sydney metro*	*Melbourne*	*Brisbane*	*Perth metro*	*Tasmania*	*Australian Capital Territory*	*Average*
	%	%	%	%	%	%	%	%
Municipal	14	36	34	51	28	50	40	40
Commercial & industrial	26	23	32	17	17	26	24	23
Construction & demolition	60	40	34	32	55	24	36	37

(a) Percentages by weight.

Source: SOE 2001.

Solid waste disposal

'The primary pressure from waste generation is the need for disposal, and the consequent environmental impacts' (Newton et al. 2001). In Australia, solid wastes from the municipal, commercial and industrial, and construction and demolition streams, and some hazardous wastes, are sent primarily to landfills. Some landfills are general dumps or tips, while others are specially engineered to store and contain specific types of waste for long time periods. In 1990 landfilling accounted for 96% of municipal solid waste disposal, with 1% incinerated, and the remaining 3% recycled. At present, landfills account for over 95% of solid waste disposal in some states and territories (Newton et al. 2001).

Solid waste disposal *continued*

In the mid to late 1990s Australia was the second largest producer of municipal (domestic and council) solid waste per person among Organisation for Economic Cooperation and Development (OECD) countries, with only the United States producing more waste per person (OECD 1998). Based on 1996–97 data, the average Australian contributed 690 kilograms (kg) of solid waste to the municipal waste stream, which was well above the OECD average of 500 kg per year. Approximately 58% of municipal waste was made up of domestic or household waste, such as garden wastes, paper, glass, plastic and food wastes. Australia's per capita disposal of household wastes of 400 kg per year was among the highest ten in the OECD.

In 1996–97, landfills received 21.2 million tonnes of solid waste from all waste streams (table 5.6), equating to a disposal rate of around 1.146 tonnes per person, or 3.14 kg per person per day. This places Australia among the top 10 solid waste generators within the OECD (OECD 1999). Among Australian states and territories, the per capita rate of waste generation ranges from approximately 800 kg per year in the Australian Capital Territory to almost 1,400 kg per year in Western Australia.

Of the 21.2 million tonnes of solid waste disposed of at landfills in 1996–97, almost 11 million tonnes was disposed of at privately operated landfills, and 10.5 million tonnes at government landfills. Landfill operations varied markedly across the states and territories. Private New South Wales landfills received 5.1 million tonnes of solid waste, compared to 2.1 million tonnes at government landfills. In contrast, private Queensland landfills received 1.1 million tonnes of solid waste, while government landfills received three times that amount (3.3 million tonnes).

5.6 QUANTITIES OF SOLID WASTE — 1996–97

	NSW	*Vic.*	*Qld*	*SA*	*WA*	*Tas.*	*NT*	*ACT*	*Aust.*
Solid waste received and disposed of at landfills	*'000 tonnes*	*'000 tonnes*	*'000 tonnes*	*'000 tonnes*	*'000 tonnes*	*'000 tonnes*	*'000 tonnes*	*'000 tonnes*	*'000 tonnes*
Privately operated landfills	5 073.5	3 105.6	1 119.2	620.7	833.3	np	np	—	10 757.0
General government operated landfills	2 097.2	1 914.5	3 309.6	713.6	1 595.8	456.7	140.1	236.0	10 463.5
Total	**7 170.7**	**5 020.1**	**4 428.8**	**1 334.3**	**2 429.1**	**np**	**np**	**236.0**	**21 220.5**

Source: Waste Management Industry, Australia, 1996–97 (cat. no. 8698.0).

Most of the hazardous wastes generated by Australian households are sent to landfills. Disposal through the usual garbage collection service from the household (for subsequent delivery to landfill sites) was the most commonly used method for disposing of most hazardous wastes in 2000 (table 5.7). This form of disposal was the most common for particular items including household batteries, oven cleaners, fluorescent tubes or globes, metal cleaners, garden chemicals, pharmaceuticals, and paint products. For example, 93% of households disposed of household batteries in the usual garbage collection.

5.7 HOUSEHOLD DISPOSAL OF HAZARDOUS WASTES, ITEMS DISPOSED BY METHOD(a) — MARCH 2000

Method of disposal	Garden chemicals	Paint products	Metal cleaners	Oven cleaners	Fluorescent tubes/ globes	Household batteries	Car batteries	Motor oil	Pharma-ceuticals
	%	%	%	%	%	%	%	%	%
With usual garbage collection	71.2	52.1	76.7	90.4	81.7	93.0	5.4	7.2	53.5
Special service from house	7.6	10.6	6.8	3.1	4.5	0.7	10.2	3.0	0.5
Dump — general area	6.7	14.9	6.5	3.3	6.0	2.8	5.1	4.9	1.0
Dump — special area	7.8	15.3	5.0	0.7	1.6	1.1	17.9	17.5	0.4
Central collection point	3.0	3.2	*1.2	*0.3	0.8	0.7	8.0	5.8	2.1
Poured down the drain	*0.4	*0.6	*0.2	*0.1	—	—	—	*0.3	23.9
Taken to a business or shop	1.2	1.0	*0.7	*0.1	2.2	0.9	46.2	43.3	23.5
Buried them	*0.8	0.9	*1.4	*0.5	0.8	0.5	*0.2	2.3	1.0
Other	3.8	4.0	2.5	2.1	2.9	0.6	7.7	16.7	2.0

(a) Column totals do not equal 100% because more than one method of disposal may be specified.

Source: Environmental Issues: People's Views and Practices, 2000 (cat. no. 4602.0).

Australia's heavy reliance on landfills has advantages and disadvantages. Landfills have low operating costs compared to expensive waste reprocessing systems and can be located relatively close to the urban areas they serve. However, the dominant use of landfills has serious risks and implications. There is pressure on land use, land prices, disposal costs and other spillover effects related to transportation of wastes and disposal of landfills (Newton et al. 2001). Some specific pressures include:

- surface water and groundwater contamination from untreated leachate and sediment loads
- air emissions of methane and carbon dioxide which contribute to the greenhouse effect, as well as other gases which can be corrosive, toxic or emit strong or offensive odours
- litter escaping from the site
- decreased local amenity and aesthetics
- a breeding place for vermin and pests such as rats and insects
- increased community opposition to the siting and opening of new landfills, especially those handling and storing hazardous materials
- increasing fees and charges which can result in a higher level of illegal dumping outside prescribed landfill areas
- the wastage of potentially reusable and recoverable materials.

Litter and debris on coastlines and beaches

It is estimated that around seven billion tonnes (SoE 1996) of solid waste (i.e. litter and debris) enter the world's oceans annually, with plastics accounting for the greatest percentage. Globally, 80% of this marine debris is considered to be derived from land-based sources (SoE 1996). About 85% of Australia's population live within 50 kilometres of the coast (SoE 2001). Consequently Australia's coastline and beaches contain many forms of litter and debris. Although urban beaches contain the most litter and waste, even the most remote coastal and island beaches are not free from litter. For example, along coastal areas and beaches in Tasmania, surveys have found on average 300–400 debris items per kilometre, while some areas of the Antarctic have recorded an average of 80–100 debris items per kilometre (Wace 1995).

Litter comes from rubbish left by beach-goers or is washed there. The latter comes from land litter washed from catchments and stormwater drains, from ships' garbage, from fishing gear discarded by anglers and fishing boats, and from remote sources across the ocean. There is scant nation-wide information on the amount or composition of debris and litter in coastal areas of Australia. Surveys of beaches near Brisbane, Sydney and Melbourne found that most litter came from streets and garbage dumps, and reached beaches via streams and drains (Wace 1995). A survey of New South Wales beach litter in 1996 found that 73% of it comprised land sourced plastics, 14% other land sourced materials and 13% debris from fishing (Herfort 1997).

Coastal litter has important implications for the amenity of coastal areas and poses significant risks to human and wildlife populations such as:

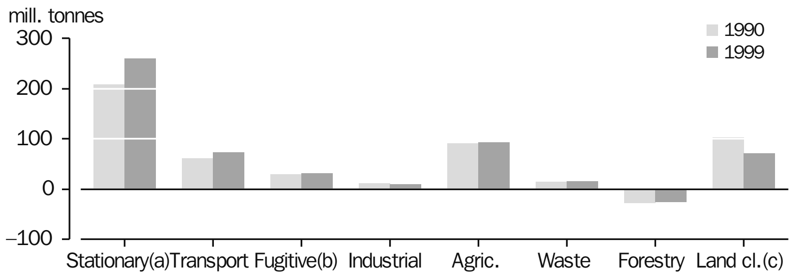
- reducing the aesthetics and natural amenity of beaches — domestic waste in particular (plastic bottles and bags, decomposing organic waste) is unsightly, can generate offensive odours, and have an adverse effect on tourism in coastal areas
- causing injury — some litter, such as broken glass, knives, fishing hooks, syringes and needles, can cause cuts and infection to beach-goers. Floating litter may injure board riders and swimmers
- endangering marine wildlife — many thousands of marine mammals, turtles and seabirds die each year from swallowing plastic bags and other objects, or get entangled and trapped in discarded fishing gear (SoE 1996)
- facilitating migration of marine organisms — if drifting waste (such as plastics and glass bottles) is colonised by organisms (such as seastars, snails and mussels), they can be carried over long distances to potentially infest new environments.

GREENHOUSE GAS EMISSIONS

The National Greenhouse Gas Inventory (NGGI) reports on human-induced greenhouse gas emissions from five sectors: Energy (Stationary energy, Fugitive emissions from fuel, and Transport), Industrial processes, Agriculture, Land use change, and Forestry and waste (graph 5.8). Australia's net greenhouse gas emissions for 1999, not including emissions from land clearing, were 458.2 million tonnes of carbon dioxide equivalents (CO_2-e). Net greenhouse gas emissions in 1990 were 390.3 Mt in 1990, which represents a 17.4% increase during the period 1990 to 1999. The Energy sector accounted for 79.6% (364.6 Mt CO_2-e) of total net national emissions in 1999 and the Agriculture sector 20.5% (93.8 Mt CO_2-e). The Forestry sector constituted a net sink of 25.9 Mt CO_2-e, which was discussed in Chapter 3, Forests and forestry. Emissions from waste are discussed in the next section.

Australia is currently undertaking a range of activities to reduce greenhouse gas emissions. Details of these activities and additional information on Australia's greenhouse gas emissions can be found at the Australian Greenhouse Office web site <http://www.greenhouse.gov.au>.

5.8 GREENHOUSE GAS EMISSIONS (CO_2-e), By sector



(a) Stationary energy.
(b) Fugitive emissions from the production and distribution of coal and gas.
(c) Estimated emissions from land clearing. These assessments should be treated as indicative only due to high uncertainties in emissions estimates.

Source: AGO 2001.

Greenhouse gas emissions from the waste sector

Waste is one of the six sectors defined by the Intergovernmental Panel on Climate Change (IPCC), which represent the main human activities that contribute to the release or capture of greenhouse gases into or from the atmosphere (AGO 2002). In 2000 the National Greenhouse Gas Inventory estimated that 16.7 Mt of CO_2-e, or 3.1% of total net national greenhouse gas emissions, were emitted from the waste sector (table 5.9). The majority of these emissions comprised methane gas (CH_4) generated by the decomposition of organic matter in landfills (14.8 Mt CO_2-e). The remaining greenhouse gas emissions were attributed to wastewater handling (1.8 Mt CO_2-e) and waste incineration activity (0.02 Mt CO_2-e).

Greenhouse gas emissions from the waste sector *continued*

Although the waste sector is a relatively minor source of total greenhouse gas emissions, there is scope for further reductions in emissions. Reducing resource inputs and waste outputs in the production process was identified by Australia's National Greenhouse Strategy as an important means of reducing greenhouse emissions in the Waste sector. Facilities have been set up to capture methane gas from landfill and wastewater, for use as a source of energy or as a fuel, thereby reducing emissions and acting as a substitute for fossil fuels. The Green and Organic Waste Management Strategy is being implemented across Australia to reduce organic waste landfill deposits.

5.9 CARBON DIOXIDE EQUIVALENT (CO_2-e), EMISSIONS FROM WASTE — 2000

Greenhouse gas source and sink categories	*Carbon dioxide* Gg CO_2-e	*Methane* Gg CO_2-e	*Total (includes CO_2)* Gg CO_2-e	*Share of total net national emissions* %
Solid waste disposal on land	ne	14 812	14 812	2.8
Wastewater handling	ne	1 325	1 867	0.3
Waste incineration	16	na	16	—
Other waste	na	na	na	na
Total waste	**16**	**16 137**	**16 695**	**3.1**

Source: AGO 2002.

RADIOACTIVE WASTES

Australia produces and uses radioactive materials, and subsequently generates radioactive wastes. Radioactive waste must be handled, stored and disposed of in ways that are appropriate to its characteristics. It is generally classified on the basis of how much radiation it emits (low, intermediate or high) and the length of time over which it will continue to emit radiation (short-lived or long-lived). Australia produces four types of radioactive waste: three in the low-level and short-lived intermediate-level waste categories; and one in the long-lived intermediate-level waste category (DISR 2000). Australia does not generate high-level waste, which is produced from the reprocessing of spent fuel from nuclear reactors used to generate power.

This section discusses the volume and composition of radioactive waste generated in Australia and the programs initiated to deal with its disposal and storage.

Low-level and short-lived intermediate waste

Most of Australia's radioactive waste consists of low-level and short-lived intermediate-level radioactive waste. Over the past 40 years, Australia has accumulated about 3,200 cubic metres of low-level and short-lived intermediate-level radioactive waste (table 5.10) — about the volume of 50 shipping containers. This waste has emanated from research, and from medical and industrial production and use. It does not include uranium mining wastes, which are disposed of locally at the mine sites. In comparison, Britain and France each year individually produce around 25,000 cubic metres of low-level waste (DISR 2000).

Low-level and short-lived intermediate waste *continued*

Over half of Australia's radioactive waste — 10,000 drums of lightly contaminated soil (1,950 cubic metres) — is the legacy of CSIRO research into the processing of radioactive ores during the 1950s and 1960s (table 5.10). The balance includes items such as laboratory equipment and clothing, paper, glassware, smoke detectors and exit signs. This radioactive waste is accumulating at a rate of about 40–60 cubic metres per year, and it is expected that an additional 500 cubic metres of low-level waste will arise in 2035 when the Lucas Heights Reactor near Sydney is decommissioned.

5.10 LOW-LEVEL AND SHORT-LIVED INTERMEDIATE RADIOACTIVE WASTE — 2001

Source	Typical low & intermediate waste	Estimated current volume m^3
CSIRO	Contaminated soil from research into treatment of radioactive ores 40 years ago	1 950
ANSTO	Clothing, paper and glassware	1 080
States/territories	Industrial gauges, smoke detectors, medical sources, hospital waste including clothing, paper, glassware	100
Defence	Electron tubes, radium painted watches, compasses, sealed sources	60
Other Commonwealth agencies	Used sources	10
Total	—	**3 200**

Source: DISR 2000.

Long-lived intermediate waste

Australia has accumulated approximately 500 cubic metres of long-lived intermediate waste, which includes wastes from the production of radiopharmaceuticals, wastes from mineral sands processing, and from used medical, research and industrial equipment (table 5.11). Accumulation of these wastes is predicted to continue into the future and will be supplemented by additional wastes from the research reactor of the Australian Nuclear Science and Technology Organisation (ANSTO). These wastes are not suitable for disposal in a near-surface repository, but can be safely stored in an above-ground, purpose-built facility.

5.11 INVENTORY OF LONG-LIVED INTERMEDIATE RADIOACTIVE WASTE — 2001

Typical long-lived intermediate waste	Estimated volume m^3
Target cans, alumina columns, used control arms, aluminium end pieces, solidified liquid waste	205
Thorium and uranium residues from mineral sands processing	165
Used sources from medical, industrial and research equipment	100
Used sources from medical and research equipment	35
Total	**505**

Source: DISR 2000.

The disposal and storage of Australia's radioactive waste

Two programs exist to deal with Australia's radioactive waste: the National Radioactive Waste Repository, for low-level and short-lived intermediate waste; and the National Store Project, for long-lived intermediate waste (DISR 2002).

The National Radioactive Waste Repository project began in 1992 to establish a single, centralised repository for low-level radioactive waste. At present radioactive waste is stored at more than 50 temporary locations around Australia, within major cities and in many country towns. Under current arrangements, those who produce this waste are responsible for looking after it.

The waste will be treated and conditioned to help immobilise it (including making it less soluble, as water is generally considered to be the most important transport mechanism for radioactive substances), packaged in steel or concrete drums, placed in a series of trenches 15–20 metres beneath the ground, covered with soil and capped with a layer of mounded clay to direct water flow away from the trenches and reduce water infiltration. The repository will be designed to make use of the natural meteorological, geological and hydrological characteristics of the site, in order to isolate the waste and prevent it from escaping and causing harm.

The operational lifetime of the repository is expected to be up to 50 years. During the 200-year control period following closure the site will be monitored for any changes in groundwater quality, levels of external radiation, and concentrations of radioactive atoms in the surrounding air. In January 2001 a preferred and two alternative sites near Woomera in South Australia were identified. After an environmental assessment process the final site will be chosen.

In February 2001 it was announced that a purpose-built National Store would be established on Commonwealth land to safely manage intermediate radioactive waste produced by Commonwealth agencies and departments including, among others, ANSTO, the Department of Defence, and CSIRO. In early 2003, the site selection process was being undertaken. It is expected that further assessments of short-listed sites will be carried out during 2003 to identify a preferred site.

The National Store will be located separately from the National Radioactive Waste Repository, and its function, like the repository, is to provide storage for radioactive waste so that people and the environment are protected from radiological hazards for a period of at least 50 years. The process of finding a suitable site for the store is similar to that undertaken for the National Radioactive Waste Repository, but the criteria used to determine the suitability of potential sites are somewhat different. For example, geology and groundwater are important factors in siting the repository, where low-level and short-lived radioactive waste will be disposed of in sub-surface trenches. These criteria are not as relevant to siting the National Store where long-lived intermediate-level radioactive waste will be stored in an above-ground structure.

WASTE MANAGEMENT AND WASTE MINIMISATION

Improving the ecological sustainability of Australian settlements implies reducing resource inputs and waste outputs while improving livability (SoE 1996). The guiding principles for current waste management strategies are represented by the waste-minimisation hierarchy. This strategy is aimed at providing options to avoid generating waste in the first place and extracting the maximum practical benefits from the existing waste stream. The hierarchy begins with waste avoidance in the first place, followed by minimisation, recycling, reuse, and finally treatment and disposal as a last option (table 5.12). Examples here include: converting methane gas at landfill and wastewater treatment plants to produce energy or use as a fuel; recycling of paper, rubber, glass, aluminium and steel; and reuse of wastewater and stormwater as a resource. This strategy embraces a life cycle approach whereby recycled, recovered and reusable waste outputs may be used as an alternative to traditional resource inputs. Hence, this strategy not only reduces waste outputs, but also alleviates some of the pressure on natural resources.

Aspects of waste management and minimisation are discussed in detail later in the chapter, with particular emphasis on household waste management and the costs of waste management in Australia.

5.12 COMPONENTS OF THE WASTE MINIMISATION HIERARCHY

Component	*Description*
Avoidance	This means preventing waste generation in the first place. It is cost effective; no waste means no disposal costs. Industry can modify or change a production process, adopt new technology or substitute other materials to produce manufactured goods. Householders can avoid generating waste by bulk buying, using refillable containers, composting food scraps, choosing products with minimal packaging, buying products that are built to last, and refusing disposable carry bags.
Reduction	This involves using durable, long-lasting goods instead of disposable ones, redesigning packaging to use less materials, eliminating unnecessary packaging, using materials more efficiently, and employing new technologies and processes, in order to reduce the input of virgin materials by consuming less.
Reuse	This involves using something more than once, either in its original form, or for a different purpose. Examples of original use include using refillable containers, donating old clothes to other family members or charities, and buying second hand or antique furniture. Reuse for a different purpose includes using paper, cardboard and packaging for children's art and craft activities, and reusing glass and plastic containers.
Recycling	This infers processing products or materials into similar products or using them as secondary raw materials for producing new products. Usually less energy is consumed, less virgin material is used (avoiding further environmental damage), and landfill space is saved.
Recovery	This generally refers to incinerating waste to recover the heat energy it contains, or extracting methane from landfills, to generate electricity.
Treatment and disposal	Despite using the options above, some waste still occurs, as some residual material is almost always left over. It has to be treated and disposed of effectively to acceptable environmental, pest, health and safety standards.

Source: Environment Protection Agency 2001, South Australia Fact Sheet.

Waste avoidance

By avoiding generating waste in the first place, many of the problems of waste disposal, as well as the financial costs of disposal and containment, can be minimised. Within households, waste avoidance may be achieved through bulk buying, composting, using refillable containers and bags, and choosing products with minimal packaging. With regard to the latter strategy, 87% of households reported that they would be prepared to accept less packaging in the products they bought, primarily because it meant less garbage and it was safer for the environment (ABS 2000). This indicates that Australian households are aware of the advantages of waste avoidance and are prepared to implement waste-avoidance strategies.

Waste avoidance *continued*

Environmentally friendly products (EFP) are important to waste avoidance within households as they are products created from recycled materials (e.g. paper, glass); use less or contain minimal or no levels of toxic or dangerous chemicals/substances when produced (e.g. unbleached paper, organic foodstuffs); are refillable/reusable (e.g. glass containers); are designed for extended life (e.g. durable, repairable, can be modified rather than replaced); and are made from minimal amounts of material. In Australia the principal EFP used by households are refillable containers. In 2001, 51% of households used these containers, 48% of households bought recycled paper and 33% purchased unbleached paper (table 5.13). However, more than half of all Australian households claimed that they never ate organically grown fruit and vegetables (56%), and nearly one in two households did not use unbleached paper (45%) or phosphate-free cleaning products (43%).

5.13 HOUSEHOLD USE OF ENVIRONMENTALLY FRIENDLY PRODUCTS — MARCH 2001

	Proportion (%) of households								
Product	*NSW*	*Vic.*	*Qld*	*SA*	*WA*	*Tas.*	*NT*	*ACT*	*Aust.*
Unbleached paper									
Yes	34.1	33.4	32.0	31.8	32.1	36.4	39.0	39.1	33.3
Sometimes/depends	17.8	18.4	18.8	18.4	17.1	16.2	15.2	17.7	18.0
No	44.2	44.3	46.5	46.4	47.2	45.1	43.1	41.5	45.1
Don't know	4.0	3.9	2.8	3.4	3.7	*2.3	*2.8	*1.6	3.6
Recycled paper									
Yes	47.7	47.0	46.0	48.4	48.5	47.7	53.1	56.8	47.5
Sometimes/depends	21.4	22.4	23.6	23.1	22.7	21.8	20.5	20.9	22.3
No	28.1	27.5	28.5	25.8	27.1	28.4	25.7	21.4	27.6
Don't know	2.9	3.1	1.9	2.8	1.7	*2.1	*0.6	*1.0	2.5
Phosphate-free cleaning products									
Yes	28.7	27.0	28.2	27.7	28.1	30.1	26.7	26.9	28.1
Sometimes/depends	11.4	11.6	12.2	12.5	9.4	10.9	*4.6	9.4	11.4
No	42.8	42.2	41.8	40.8	47.6	44.6	49.0	51.5	43.0
Don't know	17.0	19.1	17.7	19.0	14.8	14.4	19.6	12.2	17.5
Refillable containers									
Yes	51.0	47.6	53.7	48.4	54.4	50.6	58.3	61.1	51.0
Sometimes/depends	13.7	14.5	14.6	11.8	10.2	16.0	13.3	9.8	13.5
No	33.8	35.8	31.1	38.4	34.3	31.6	27.1	28.6	34.0
Don't know	1.5	2.1	*0.7	1.4	*1.1	*1.8	*1.3	*0.5	1.4
Organically grown fruit and vegetables									
Yes	18.2	20.1	19.1	17.7	18.4	26.5	18.0	19.9	19.1
Sometimes/depends	21.8	25.1	23.6	20.6	20.5	21.7	23.1	21.8	22.7
No	57.4	52.1	55.6	58.2	58.9	50.4	57.5	57.5	55.8
Don't know	2.6	2.7	1.7	3.6	2.2	*1.4	*1.4	*0.9	2.4

Source: Environment Issues: People's Views and Practices, 2001 (cat. no. 4602.0).

Of those households which did not choose to buy EFPs, cost is the single most important factor preventing their use. In 2001, over a third of households (37%) not using EFPs believed that these products were more expensive to buy, while 19% believed that these products were not readily available (table 5.14). Another 4% of households were not convinced about the environmental claims of EFPs.

5.14 REASONS(a) ENVIRONMENTALLY FRIENDLY PRODUCTS ARE NOT USED — MARCH 2001

	Proportion (%) of households								
Reason	NSW	Vic.	Qld	SA	WA	Tas.	NT	ACT	Aust.
More expensive	34.4	38.2	43.1	33.3	34.1	33.4	33.4	44.7	37.0
Always buys the same brand	16.1	16.3	14.4	14.2	14.7	16.1	*11.8	12.9	15.5
Inferior quality	15.3	17.1	17.1	16.2	16.7	16.1	*11.2	18.7	16.4
Not convinced about environment claims	5.0	4.6	3.8	2.6	3.0	*3.1	*5.5	6.7	4.3
Not interested/too much effort	16.2	16.1	12.6	11.8	13.0	11.2	16.6	14.9	14.6
Grows own fruit/vegetables	3.9	5.9	3.5	6.1	3.7	10.3	*2.1	5.9	4.6
Not readily available	20.0	16.0	15.3	23.6	23.1	11.1	31.1	14.6	18.5
Other	11.9	14.7	11.3	12.8	15.2	11.6	*7.8	14.4	12.9
No reason	12.6	13.1	13.5	14.5	14.6	19.0	*8.1	11.8	13.4

(a) Column totals do not equal 100% because more than one reason may be given.

Source: Environmental Issues: People's Views and Practices, 2001 (cat. no. 4602.0).

Recycling and reuse

Just over one and a half million tonnes of recyclable material were owned and sold by waste management businesses or organisations in 1996–97 (table 5.15). This equates to a recycling rate of 82.5 kg per person for this period. The majority of these recyclables (1.0 million tonnes) were managed by the private and public trading sector. In terms of total tonnage, paper and cardboard were the major items recycled (0.4 million tonnes).

5.15 QUANTITIES OF RECYCLABLES, BY TYPE — 1996–97

	Private and public trading sector		General government sector		Total	
	Recycling tonnage(a)	Contribution to total	Recycling tonnage(a)	Contribution to total	Recycling tonnage(a)	Contribution to total
Items	'000	%	'000	%	'000	%
Paper and cardboard	320.5	32.3	101.7	19.0	422.3	27.6
Glass	164.2	16.5	66.8	12.5	231.0	15.1
Mulch and compost	29.8	3.0	140.3	26.2	170.2	11.1
Oils	*2.0	0.2	140.3	26.2	142.4	9.3
Concrete	**330.0	33.2	22.9	4.3	**352.9	23.1
Plastic	18.8	1.9	6.4	1.2	25.2	1.6
Aluminium	4.9	0.5	2.3	0.4	7.2	0.5
Ferrous metals	46.0	4.6	42.3	7.9	88.3	5.8
Other metals	16.3	1.6	7.1	1.3	23.4	1.5
Other recyclables	*60.5	6.1	4.7	0.9	*65.2	4.3
Total	**993.1**	**100.0**	**535.0**	**100.0**	**1 528.0**	**100.0**

(a) Recycling tonnage is the quantity of recyclables owned and sold by each particular business or organisation.

Source: Waste Management Industry, Australia, 1996–97 (cat. no. 8698.0).

Households are often the final consumers of goods produced through the processing and manufacturing of raw materials. Households generate a large variety and volume of wastes and are integral to waste minimisation strategies. Recycling and reusing items such as old clothing, paper, glass, and kitchen and garden waste, conserves resources, reduces environmental pollution and reduces the volume of waste transported to landfills. These activities may be carried out either within the household or through public or private collection schemes.

Recycling and reuse *continued*

Households recycle paper more than any other material (85% of households in 2000), followed by old clothing and rags and plastic bags (both around 83% of households), glass (82%), plastic bottles (81%) and cans (75%) (table 5.16). The Australian Capital Territory has the highest rate of recycling among the states and territories in recycling, for all items. Overall, recycling activity by Australian households has increased since 1992. For example, recycling of paper has increased from 55% of households in 1992 to 85% in 2000. The two main recycling methods used by Australian households were a collection service from the dwelling and reuse within the household (both around 83%) (ABS 2000).

5.16 HOUSEHOLDS INVOLVED IN RECYCLING, ITEMS RECYCLED(a) — MARCH 2000

	Proportion (%) of households								
	NSW	*Vic.*	*Qld*	*SA*	*WA*	*Tas.*	*NT(b)*	*ACT*	*Aust.*
Paper	87.5	89.1	82.7	78.1	74.5	79.7	69.8	98.1	84.7
Glass	82.2	90.4	81.9	79.4	66.5	76.4	57.3	97.1	82.3
Cans	69.5	84.8	76.8	78.2	60.6	66.9	50.1	89.4	74.6
Plastic bottles	80.1	89.5	82.7	82.9	63.7	72.7	59.8	96.9	81.4
Plastic bags	79.6	84.8	85.6	82.2	81.5	82.7	74.7	91.2	82.6
Motor oil	12.5	10.4	14.8	9.9	10.3	12.2	12.5	20.8	12.1
Kitchen or food waste	45.4	56.3	50.2	52.3	44.3	60.1	45.8	60.4	50.1
Garden waste	57.4	64.4	62.4	61.1	54.8	63.4	51.3	70.6	60.4
Old clothing or rags	81.1	85.3	85.7	82.3	81.9	86.6	80.2	87.5	83.4
No recycling	4.1	1.4	2.3	3.2	5.6	4.7	8.8	*0.5	3.2
All items recycled	6.7	6.6	7.4	6.0	4.3	7.2	6.4	12.2	6.6

(a) Column totals do not equal 100% as more than one item may be specified.

(b) Northern Territory data refer mainly to urban areas.

Source: Environmental Issues: People's Views and Practices, 2000 (cat. no. 4602.0).

The proportion of households not participating in recycling has declined markedly over time (15% in 1992, 9% in 1996, and 3% in 2000). The primary reason given for households not recycling more is a lack of recyclable materials (73%) (table 5.17). The proportion of households giving this reason has increased over time (20% in 1992, 51% in 1996 and 73% in 2000). Other reasons given are that there are no services or facilities available (16%), and a lack of interest (13%). The Northern Territory has the most households citing that no services or facilities are available (46%). Western Australian households are highest for a 'no interest or too much effort' (18%), while New South Wales households rate highest for specifying no storage area in their dwelling or yard (8%). Inadequate services or facilities are the least important reason (4%).

5.17 HOUSEHOLDS NOT RECYCLING MATERIALS, REASONS FOR NOT RECYCLING(a) — MARCH 2000

	Proportion (%) of households								
Reason	*NSW*	*Vic.*	*Qld*	*SA*	*WA*	*Tas.*	*NT(b)*	*ACT*	*Aust.*
Not enough recyclable materials	71.8	79.4	73.8	75.8	57.6	68.5	55.6	77.4	72.8
No services or facilities provided	20.5	8.2	18	8.2	21.9	20.8	46.3	5.4	16.1
Not interested or too much effort	13	12.5	12.4	14.3	17.7	14.5	13	12.9	13.4
No storage area in dwelling or yard	8.1	6.5	4.9	6.8	5.5	5.5	6.7	5.0	6.6
Uncertain of services or facilities provided	4.4	7.0	4.7	4.9	6.1	3.7	*2.6	*3.2	5.3
Inadequate services or facilities	4.5	1.9	2.3	3.1	7.2	2.7	5.7	*1.8	3.5
Other	6.1	5.9	7.7	6.4	9.7	6.6	11.2	9.1	6.9
No reason	4.6	3.6	4.7	4.2	4.7	3.0	*0.3	3.7	4.3

(a) Column totals do not equal 100% as more than one reason may be specified.

(b) Northern Territory data refer mainly to urban areas.

Source: Environmental Issues: People's Views and Practices, 2000 (cat. no. 4602.0).

Box 1. Recycling of steel cans

Recyclable steel cans include food, drink and pet food cans, coffee cans, empty dried paint tins, and aerosol cans. Many council kerb-side programs now collect all types of steel cans in their wheelie bins and recycling crates.

In 1991 two councils in Australia collected steel cans from the kerb-side, with a national recycling rate of 0.01%. By the end of 2000 there were 375 councils participating, with a current national average recycling rate of 40% of the 1.7 billion cans bought by Australians each year. This represented an increase from 29% in May 1997, and 33% in May 1999. The national target was 45% by June 2000. In November 2000 Queensland had exceeded this target with 46%. While the Northern Territory had the lowest steel can recycling rate with 13%. Between June 1999 and November 2000 all the states and territories had increased their recycling rates, with South Australia showing the greatest increase of 15%.

Another goal is to ensure that 80% of the Australian population has access to steel can recycling, whether by kerb-side programs or at neighbourhood recycling drop-off centres. In November 2000 all states and territories except Western Australia and the Northern Territory had exceeded this target (table 5.18), the national population coverage being 89%.

5.18 PROPORTION OF POPULATION WITH ACCESS TO STEEL CAN RECYCLING — NOVEMBER 2000

	%
New South Wales(a)	84
Victoria	99
Queensland	93
South Australia	91
Western Australia	73
Tasmania	95
Northern Territory	53
Australia	**89**

(a) Includes Australian Capital Territory.

Source: Steel Can Recycling Council 2001.

Recovery: turning waste into energy

Concern over the volume and cost of waste disposal has led to the development of technologies which convert waste into energy or useful by-products. The energy in organic waste material can be recovered and used as a source of renewable energy. Waste suitable for energy extraction consists largely of solid and liquid organic material, or biomass, and usually arises from domestic household refuse (ACRE 2001). In addition to reducing the quantity of disposed waste, turning waste into energy has other advantages such as reducing emissions of methane (a greenhouse gas) from landfilling, and decomposition of wastes and reducing fossil fuel use by substituting energy recovery from waste combustion.

Organic waste-to-energy technologies can be broadly classified as either bio-chemical (BC) or thermo-chemical (TC) processes, and are outlined below.

- *Landfill gas* (BC) — when rubbish is dumped at landfills, the organic component is naturally converted by bacteria to methane, which can be recovered and used as landfill gas. The latter is captured and extracted by inserting pipes into the landfill, and is subsequently used to produce electricity or heat. The burning of methane to produce carbon dioxide and water also reduces the greenhouse impact of landfill, as carbon dioxide is a less potent greenhouse gas than methane (see the section Greenhouse gas emissions from waste).
- *Biogas* (BC) — anaerobic (i.e. without oxygen) digestion of wastes stored in large airtight tanks (or 'digesters') using bacteria to convert organic wastes to a mixed gas output of methane and carbon dioxide, usually termed 'biogas'. The biogas produced can be combusted and used either to produce electricity or heat, thereby acting as a substitute for fossil fuels. This technique has been used in sewage and wastewater treatment plants for many decades, usually to produce electricity for use on-site.
- *Thermo-chemical conversion* (TC) — thermal processing of organic waste materials can produce heat or a number of liquid or gaseous fuels. This includes mass combustion or direct incineration of solid waste to produce heat for cooking, space heating or industrial processes, or for electricity generation. Some solid wastes may be processed to produce refined fuels (i.e. pellets) for later combustion in incinerators.

It is estimated that landfill and wastewater material of approximately 100 petajoules (PJ) of energy content are discarded every year (ACRE 2001). Using existing international projects as a guide, approximately 80% of Australia's municipal solid waste is available for the production of energy. This represents a source of approximately 50 gigajoules (GJ) annually, excluding the total potential from existing landfill sites.

Recovery: turning waste into energy *continued*

Despite this potential, Australia is one of the few developed nations that does not have a well established waste-to-energy industry, unlike the United States of America, Japan, United Kingdom, much of continental Europe, Canada and Singapore. Constrained by the number of suitable sites and the need to try to minimise waste production in the future, only 15 landfill gas projects were operating in Australia in 1997 (AGO 1998). The use of sewage gas for electricity production is increasing in Australia and represented a 59% recovery of methane from wastewater treatment plants in 1997. Wide-scale adoption of waste-to-energy technologies is also limited by concerns raised by local communities and environmental groups that these schemes discourage the philosophy of 'reduce, reuse and recycle', and produce unsafe ash and smoke emissions (ACRE 2001).

Costs of waste management

Expenditure on environment protection by Australian governments, businesses and households is a key response to many of the environmental problems facing Australia. In 1996–97 the total national current expenditure (i.e. wages and salaries, payments to contractors, materials and fuels etc.) and capital expenditure (i.e. fixed assets such as land, machinery and equipment) for environment protection was estimated at $8.6b (ABS 1998b). The majority of national expenditure to protect the environment was on activities related to wastewater management and water protection ($3.0b) and solid waste management ($2.5b) (table 5.19). Together they represented around 63% of environment protection expenditure. The protection of ambient air and climate from air pollution and greenhouse gases accounted for a further $440m, or about 7% of national expenditure.

Expenditure on solid waste management and the protection of air and climate is dominated by the corporate and industry sectors, followed by the consumption of these services and activities by the household sector, with smaller amounts spent by general government. Households spent the most on wastewater management and water protection services. A substantial proportion of expenditure by the corporate sector was also for these purposes, with expenditure on these activities by general government being relatively small (ABS 1998b).

5.19 NATIONAL ENVIRONMENT PROTECTION EXPENDITURE FOR WASTE MANAGEMENT, BY SELECTED ENVIRONMENTAL DOMAIN(a) — 1996–97

	Solid waste management	*Wastewater management and water protection*	*Air and climate*
	$m	*$m*	*$m*
CURRENT EXPENDITURE			
General government	269.4	208.1	45.6
Households	617.4	1 749.9	100.0
Industry	1 194.7	431.5	61.5
Total(b)	*2 082.1*	*2 397.6*	*207.1*
CAPITAL EXPENDITURE			
General government	113.2	na	3.1
Corporate (public and private)	272.0	na	229.6
Total(b)	*385.1*	*620.7*	*232.7*
NATIONAL EXPENDITURE FOR ENVIRONMENT PROTECTION			
Total(b)	**2 467.2**	**3 018.3**	**439.9**

(a) Domains not included in table are 'biodiversity and landscape' 'soil and groundwater' and 'other'.

(b) Includes subsidies.

Source: Environment Protection Expenditure, Australia, 1995–96 and 1996–97 (cat. no 4603.0).

Local government is a significant player in managing Australia's environment and natural resources. Environment protection services carried out by local government include activities that prevent, reduce or eliminate pressures on the environment arising from social and economic activities. They also cover activities aimed at repairing or restoring damage to the environment after it has occurred. In 1999–2000, local governments spent $2.5b on environmental protection (table 5.20). Current expenditure was primarily for solid waste ($1.0b) and wastewater management ($0.6b). Solid waste management and wastewater management activities amounted to 89% of total current expenditure on environment protection in 1999–2000 (ABS 2001b). Nearly 65% of capital expenditure was for wastewater management activities. Across the states, Queensland and New South Wales had the highest expenditure (73% of total waste and wastewater expenditure), with variation reflecting the varying responsibilities of councils between states.

5.20 LOCAL GOVERNMENT ENVIRONMENTAL PROTECTION EXPENDITURE — 1999–2000

	Solid waste		*Wastewater*		*Total expenditure for all categories(a)*	
	Current	*Capital*	*Current*	*Capital*	*Current*	*Capital*
	$m	*$m*	*$m*	*$m*	*$m*	*$m*
New South Wales	395.2	36.7	234.2	140.4	699.7	193.6
Victoria	216.2	17.7	40.0	19.2	292.4	49.9
Queensland	254.8	22.4	311.6	189.6	635.2	291.2
South Australia	64.2	*6.2	17.5	13.7	92.1	22.9
Western Australia	85.1	11.0	10.6	4.3	106.7	20.0
Tasmania	23.1	1.5	32.8	26.2	60.9	28.8
Northern Territory	9.0	**0.2	2.2	*0.4	11.8	*0.6
Australia	**1 047.6**	**95.7**	**648.8**	**393.9**	**1 898.6**	**607.1**

(a) Includes local government environmental protection expenditure on wastewater, solid waste, biodiversity and conservation, soil resources, cultural heritage and other categories.

Source: Environment Expenditure, Local Government, Australia, 1999–2000 (cat. no. 4611.0).

SUMMARY

Australia is among the top 10 solid waste generators in the OECD. In 1996–97, landfills in Australia received 21.2 million tonnes of solid waste, equating to a disposal rate of around 1.146 tonnes per person, or 3.14 kg per person per day. Australia produces more waste today than at any time in its history. Increasing outputs of wastes are related to the nation's growing population and increasingly high standard of living. Without changes to consumption patterns these trends will continue.

Expenditure on environment protection by Australian governments, businesses and households has been a key response to many of the environmental problems facing Australia. In 1996–97, the majority of environment protection expenditure was on activities related to water management and prevention. Wastewater management, water protection and solid waste management accounted for around 63% of all environment protection expenditure. Measures aimed at reducing air pollution and greenhouse gases accounted for 7% of national expenditure.

Greenhouse gases have been a major focus of national and international attention in recent years. This is because increasing atmospheric concentrations of greenhouse gases have been linked to global climate change and human production of these gases has increased dramatically in the last century. Australia emits more greenhouse gases per person than any other nation, although the total volume emitted in Australia is a small percentage of worldwide emissions. Achieving international agreement on how to address the issue of greenhouse gases has proved difficult and it is likely that the issue will remain contentious.

The guiding principles for current waste management strategies are represented by the waste minimisation hierarchy. This strategy provides options to avoid generating waste in the first place and to extract the maximum practical benefits from the existing waste stream. The hierarchy begins with waste avoidance followed by minimisation, recycling, reuse, and finally treatment and disposal as a last option.

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APPENDIX ACCOUNTING FOR THE ENVIRONMENT IN THE NATIONAL ACCOUNTS

INTRODUCTION

The economy has a complex relationship with the environment. The environment provides the raw materials and energy for the production of goods and services that support our lifestyles, but it also sustains damage through the activities of households and businesses. The national accounts are sometimes criticised for including the value of goods and services produced and the income generated through the use of environmental assets, but not reflecting the economic cost of depleting those assets or the damage that arises from economic activity. This anomaly is well recognised by national accountants, as are a number of other deficiencies relating to the use of national accounts as a comprehensive measure of the 'wellbeing' of society (e.g. the value of unpaid housework is excluded from gross domestic product).

This appendix discusses how the environment is currently treated in the national accounts, and gives a broad overview of the work being done by the ABS to extend the core national accounts in what could be called a satellite account for the environment.

INTERNATIONAL STANDARDS

The national accounts are a macroeconomic data set revolving around the central economic concepts of production, income, expenditure and wealth. They also comprise a monetary system, and therefore rely substantially on being able to measure the monetary transactions taking place between the various economic agents in a market economy. The Australian System of National Accounts (ASNA) is based on the latest international standard, *System of National Accounts 1993* (SNA93).

While the environment clearly provides services to the economy, these are often provided at no cost or are implicit in the value of goods and services rather than in explicit transactions. Environmental assets are often not controlled by economic agents because of their physical nature, or in some cases are so plentiful that they have a zero price. For this reason, the valuation of environmental flows and stocks is fraught with conceptual and practical difficulties. Nevertheless, international research has been proceeding over a number of years and substantial progress has been made in developing the issues and concepts, although there is still limited experience in practical measurement.

INTERNATIONAL STANDARDS *continued*

The United Nations Statistical Division published an interim handbook *Integrated Environmental and Economic Accounting* in 1993. Over the last few years it has been redeveloped and extended by an international expert working group consisting of national accountants and environmental accountants. The revised handbook, titled the *System of Environmental and Economic Accounting* (SEEA), is currently in final draft stage and has recently been endorsed by the United Nations Statistical Commission for publication. It will provide a detailed conceptual and classification framework for environmental accounting and should provide an impetus for the advancement of environmental accounting internationally. Some of the material in the handbook relates to a clarification of the measurement of environmental assets in the traditional system of national accounts, but much of it concerns material that could be developed in a satellite account separate to the traditional accounts. Satellite accounts provide the freedom to develop alternative concepts, classifications and measurement techniques which are different, but at the same time retain a connection back to the national accounts based on SNA93.

The environmental accounting work being done by the ABS is consistent with the recommendations in SEEA.

NATURAL RESOURCES IN THE ASNA

Stocks

The national and sector balance sheets record the value of environmental assets that are defined as being within the scope of the system of national accounts — known as the asset boundary. For an asset to be included within the asset boundary of the national accounts it must have an identifiable owner, and the owner must be able to derive an economic benefit from the use of the asset. Assets included are those termed economic environmental assets such as subsoil assets, land, forests, water, and fish stocks in open seas that are under the control of an economic agent (often the government). Examples of assets excluded are land and timber in national parks that are not available for production.

Environmental assets such as atmospheric and terrestrial ecosystems are outside the scope of economic assets as they do not have an identifiable owner who can derive an economic benefit from their use. This is not to suggest that these assets are of no value. On the contrary, many of them are essential to life itself. However, even if they fell within the definition of an economic asset, the valuation techniques available to measure such assets tend to be arbitrary and controversial.

Stocks *continued*

The environmental assets on the Australian national and sector balance sheets are land, subsoil assets and native standing timber. Land valuations are available through administrative sources, and net present value (NPV) techniques (which take into account current production rates, prices, costs, and discount rates) are used to value both subsoil and native forest assets. Plantation standing timber could also be considered an environmental asset, and plantations are included in the balance sheet as inventories because timber growth is controlled. Water and fish stocks have not been included on the Australian national balance sheet due to a lack of available data.

The Australian national balance sheet recorded $3,459b worth of assets as at 30 June 2001, of which $1,160b (33%) were economic environmental assets (table A1.1).

A1.1 AUSTRALIA'S TOTAL ASSETS, CURRENT PRICES — AS AT 30 JUNE

	1993	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*
	$b	*$b*	*$b*	*$b*	*$b*	*$b*	*$b*	*$b*	*$b*
Financial	145	169	185	193	230	300	316	396	440
Buildings and structures	934	973	1 024	1 067	1 107	1 159	1 236	1 318	1 399
Machinery and equipment	251	257	265	268	274	291	301	312	317
Other produced(a)	96	101	107	104	106	111	118	129	138
Other non-produced(b)	—	—	—	—	—	—	—	3	6
Environmental	631	676	721	736	816	882	966	1 062	1 160
Total assets	**2 057**	**2 176**	**2 301**	**2 368**	**2 533**	**2 742**	**2 937**	**3 221**	**3 459**

(a) Includes livestock, computer software, entertainment, literary or artistic originals and inventories.

(b) Includes spectrum and spectrum licenses.

Source: Australian National Accounts: National Income, Expenditure and Product, June 2002 (cat. no. 5206.0).

While land accounts for 84% of the value of Australia's economic environmental assets, the value of rural land accounts for only 12% of the total value of land. Subsoil assets account for 15% and timber (native and plantation) account for 1% of Australia's economic environmental assets (based on table A1.2). No values are included for water or fish stocks, or other environmental assets outside the SNA asset boundary.

A1.2 AUSTRALIA'S ENVIRONMENTAL ASSETS, CURRENT PRICES — AS AT 30 JUNE

	1993	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*
	$b	*$b*	*$b*	*$b*	*$b*	*$b*	*$b*	*$b*	*$b*
Rural land	60	65	68	86	91	101	105	110	115
Other land	498	532	557	557	619	669	730	797	861
Oil and gas	38	43	49	49	51	48	51	61	76
Other subsoil	28	28	38	35	46	55	69	83	97
Native standing timber	2	2	2	2	2	2	2	3	3
Plantation standing timber	5	6	6	6	7	8	8	8	8
Total assets	**631**	**676**	**721**	**736**	**816**	**882**	**966**	**1 062**	**1 160**

Source: Australian National Accounts: National Income, Expenditure and Product, June 2002 (cat. no. 5206.0).

Stocks *continued*

The value of environmental assets in current prices grew strongly during the 1990s, increasing by 84% between 30 June 1993 and 30 June 2001. Much of this growth was due to rising prices. Environmental assets grew in volume terms by 18% during the same period (based on table A1.3).

A1.3 AUSTRALIA'S ENVIRONMENTAL ASSETS, CHAIN VOLUME MEASURES(a) — AS AT 30 JUNE

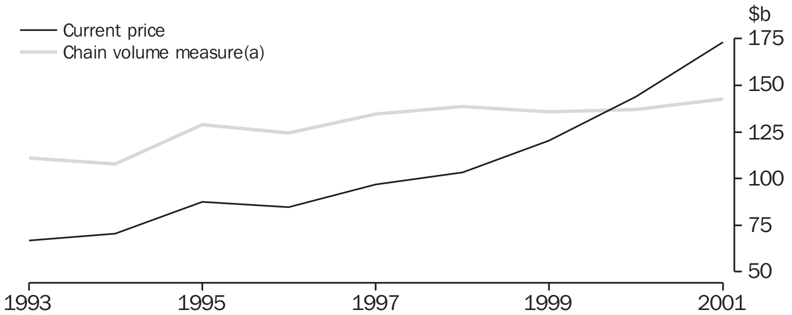
	1993	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*
	$b	*$b*	*$b*	*$b*	*$b*	*$b*	*$b*	*$b*	*$b*
Land	781	805	824	805	824	839	860	886	908
Subsoil assets	110	108	129	124	135	139	136	137	143
Native standing timber	3	3	3	3	3	3	2	2	2
Plantation standing timber	6	7	7	7	7	8	8	8	8
Total assets	**900**	**922**	**963**	**939**	**969**	**988**	**1 006**	**1 034**	**1 061**

(a) Reference year for chain volume measures is 1999–2000.

Source: Australian National Accounts: National Income, Expenditure and Product, June 2002 (cat. no. 5206.0).

Chain volume estimates of subsoil assets increased by 29% between 30 June 1993 and 30 June 2001, compared with growth of over 200% in current prices (graph A1.4). The strong volume growth has been due to new discoveries exceeding extractions during this period. The current price growth has been driven by increasing prices in significant minerals such as iron ore, magnesite, crude oil, condensate, and LPG, and falling real discount rates. Minerals deposits cannot be extracted all at once, but are extracted over a long time period, and a discount rate is needed to calculate the net present value of future extractions.

A1.4 SUBSOIL ASSETS — AS AT 30 JUNE

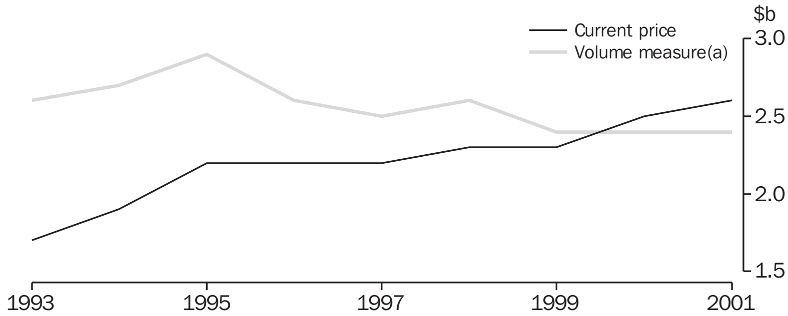


(a) Reference year for chain volume measures is 1999–2000.

Source: Australian National Accounts, National Income, Expenditure and Product, June 2002 (cat. no. 5206.0).

The volume estimates of native standing timber fell by 8% over the same period, while the current price estimates were increasing (graph A1.5). Volume estimates have fallen due to logging of native forests and the protection of some forests, resulting in their removal from the economic production boundary of the national accounts.

A1.5 NATIVE FOREST ASSETS — AS AT 30 JUNE



(a) Reference year for volume measure is 1999–2000.

Source: Australian National Accounts, National Income, Expenditure and Product, Australian National Accounts (cat. no. 5206.0).

While the area of land is unlikely to change very much during the normal course of events, volume change also includes changes in quality due to natural processes, soil conservation and other land improvement measures, land degradation due to human activity, and the rezoning of land so that it is available for higher value uses. The practical task of splitting value changes into their price and volume components is a difficult one. As an interim approach, the ABS has calculated the growth in volume of urban land at half the rate of growth in the volume of overlying construction. Zero volume growth is assumed for rural land. This assumes that land degradation, reclassification and land improvement net to zero for rural land.

Transactions — the national income, expenditure and production accounts

The transaction accounts of the ASNA measure production, incomes, consumption, capital and financial flows during the accounting period. GDP is the most readily identifiable statistic from the national accounts. Of most interest in the context of environmental accounting is the way environmental assets are used in the production process to produce goods and services for consumption, capital investment or export. However, the services provided by the environment are often either implicit in the values for other items or they are excluded as they are costed at zero price.

Where there are explicit rents for the use of natural assets, they are shown in the item 'rent on natural assets' in the sector income accounts. The general government sector received $2.6b in resource rents in 2000–01 (mainly from petroleum, mining and forestry royalties). Many environmental assets (e.g. land) are used by their owners and there is no money transaction.

In terms of GDP, the value of the services provided by the environment are implicit in the value of the output of the products produced and the incomes derived from their sale. In 2000–01, the industry gross value added of the agriculture, forestry and fishing industry accounted for 3.5% of total gross value added, while the mining industry accounted for 5.2%. The value added also reflects the input of labour and produced capital, as well as natural capital.

Transactions — the national income, expenditure and production accounts *continued*

The value of new additions to environmental assets such as discoveries of subsoil assets or natural growth in native standing timber are not included as income or GDP. However, the cost of mineral exploration is regarded as fixed capital formation, and is reflected in GDP as the creation of an asset.

As mentioned, no deduction is made from income for the depletion or degradation of the natural environment. Thus,

> ...a country could exhaust its mineral resources, cut down its forests, erode its soil, pollute its aquifers, and hunt its wildlife to extinction, but measured income would not be affected as these assets disappeared (Repetto et al. 1989).

A satellite account for the environment

The national accounts have a wide range of potential uses for policy making and economic and social research, and thus it is unlikely that the core accounts will be able to meet all possible objectives. In recognition of this, satellite accounts allow for a more flexible approach by providing frameworks that are linked to the national accounts, but focusing on a certain aspect of social or economic life. Satellite accounts also allow for standard concepts to be varied to suit particular studies within the context of the national accounts.

An environmental satellite account could take a number of forms and have a number of layers of detail. The ABS work program has focused on compiling asset accounts and accounts which decompose the changes in the value of assets during a period. The latter accounts can be used for adjusting the national accounts for the depletion of and additions to specific environmental assets in a satellite account framework.

Measuring depletion

Depletion is defined in the SNA93 as the

> ...reduction in the value of deposits of subsoil assets as a result of the physical removal and using up of the assets, ... the depletion of water resources, and the depletion of natural forests, fish stocks in the open seas and other non-cultivated biological resources as a result of harvesting, forest clearance, or other use (SNA93, 12.29 and 12.30).

Depletion in an economic sense results because the value of the resource stock has been lowered through its use in a productive activity, and the use has reduced the asset's ability to produce an income stream in the future. In this sense depletion is analogous to depreciation of produced assets whereby the current value of the stock of fixed assets declines from normal use.

Physical depletion may not necessarily equate to economic depletion in cases where asset values are low or the resource life is long. While the physical dimension of depletion can be fairly readily observed in practice, its value cannot. This is because the mineral or other natural resource product is not what is being valued — rather it is the decline in the value of the mineral asset below the ground or of the standing timber in the forest. Generally, one has to resort to capital theory to undertake this valuation. In capital theory the value of depletion is a derivative of the amount of the resource extracted and the resource rent.

Measuring depletion *continued*

The resource rent is the value of the flow of capital services provided by a natural asset. It is calculated as the value of the output of the natural resource production (e.g. coal, oil) after the intermediate expenses, returns to labour (wages), returns to produced capital (profits accruing from the use of produced capital), and return to government (taxes) have been removed.

Where the total stocks of an asset are unknown, discoveries of new stocks of subsoil assets or growth in biological assets may increase the stock of a resource so that the level of currently exploitable reserves from which the economic valuation is derived is rising rather than falling. How to account for additions is a vexed issue. In the national accounts, the value of mineral exploration is included as a separate produced asset and is therefore in income and GDP. It could be argued that this should be replaced with the actual value of discoveries.

The following sections focus on subsoil, land and forest assets respectively.

Subsoil assets

Subsoil assets are considered to be economic when they have a high geological assurance, extraction is expected to be profitable at the prevailing price and technology, and when they are owned by an economic entity (usually the government). In the Australian balance sheets economic demonstrated resources include both proven and probable reserves.

Although SNA93 recommends that assets should be valued at their current market price, for many natural assets it is not possible to observe the market price directly as there is little trading of undeveloped stocks in the marketplace. The next best method is to value assets as the NPV of the future expected earnings, which is theoretically equivalent to the market value. This is the approach adopted in the national balance sheet and in deriving estimates of the value of depletion and additions to subsoil assets presented in table A1.6.

Year-to-year changes in the value of subsoil assets for Australia can be decomposed into revaluations, depletion and discoveries. Revaluations capture the change in prices of the existing stock.

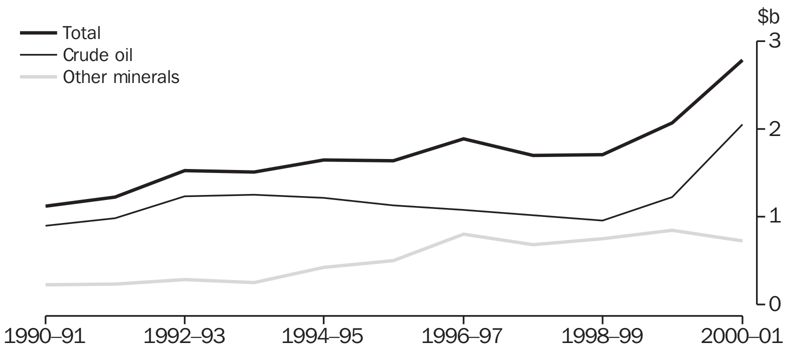
A1.6 RECONCILIATION OF OPENING AND CLOSING VALUES FOR SUBSOIL ASSETS, CURRENT PRICES

			Volume changes		
	Opening stock	*Revaluation*	*Depletion*	*Discoveries*	*Closing stock*
	$m	*$m*	*$m*	*$m*	*$m*
1990–91	52 020	4 653	–1 126	841	56 388
1991–92	56 388	–27	–1 228	634	55 768
1992–93	55 768	9 586	–1 531	2 737	66 559
1993–94	66 559	1 946	–1 509	3 470	70 466
1994–95	70 466	17 184	–1 650	1 542	87 543
1995–96	87 543	–2 846	–1 640	1 664	84 721
1996–97	84 721	13 332	–1 892	583	96 743
1997–98	96 743	6 558	–1 703	1 762	103 361
1998–99	103 361	15 716	–1 710	3 050	120 416
1999–2000	120 416	23 203	–2 073	2 383	143 929
2000–01	143 929	28 944	–2 785	2 785	172 873

Source: Australian National Accounts: National Income, Expenditure and Product (cat. no. 5206.0).

The depletion in any one year is the change in the value of the asset between the beginning and end of the year arising purely from the extraction of minerals. As can be seen from graph A1.7, the depletion of crude oil accounts for a high proportion of the total depletion estimate. This is a reflection of crude oil's relative scarcity and high value.

A1.7 SUBSOIL DEPLETION



Source: Australian National Accounts: National Income, Expenditure and Product, (cat. no. 5206.0).

A discovery occurs when previously unknown stocks of minerals are found and delineated. It is valued using the same NPV techniques described earlier. In the national accounts the value of a new discovery in itself is not considered as production or income because it is a gift of nature. However, the cost of mineral exploration is considered as production and included in income and GDP.

Subsoil assets *continued*

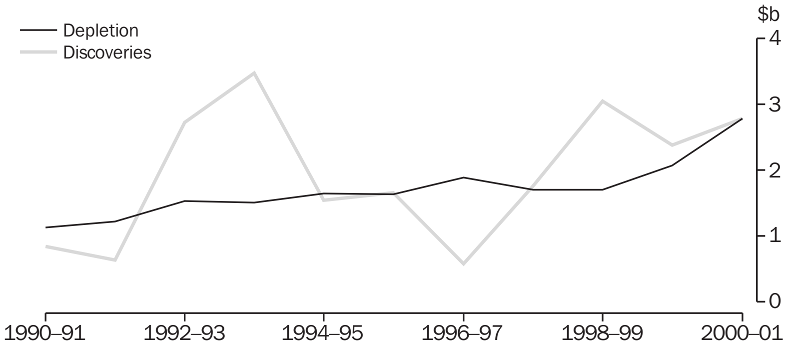
One approach that could be considered in a satellite account is to include the value of a discovery as production and income and to treat the exploration cost as intermediate input to the production of discoveries. As shown in graph A1.8, the value of discoveries shows an erratic pattern which, under such an approach, would flow through to income. A possible variation on the concept could be to record the value of discoveries as an accrual over the average period of exploration in order to smooth the income flow.

A1.8 SUBSOIL DISCOVERIES

Source: Australian National Accounts: National Income, Expenditure and Product, (cat. no. 5206.0).

As long as the value of discoveries continues to outpace or equal the value of depletion the activity can be seen to be sustainable. This is illustrated in graph A1.9.

A1.9 SUBSOIL DEPLETION AND DISCOVERIES



Source: Australian National Accounts: National Income, Expenditure and Product, (cat. no. 5206.0).

Land/soil assets

Where land is used sustainably, it has an infinite life and therefore no adjustment for depletion is required — the whole value of the resource rent would rightly be considered as income. However, where land is being degraded due to economic activity, an adjustment to income for land degradation is applicable. As for subsoil assets discussed above, any economic costs should be offset against the benefits (income) derived from agricultural land use.

Land/soil assets *continued*

In the context of economic depletion used here, land degradation represents the year-to-year decline in the capital value of land resulting from economic activity (after deducting price rises due to inflation). Looked at another way it is equivalent to the year-to-year change in the net present value of the lost resource rent resulting from the declining productive capacity of the land. As such, it stops well short of a full measure of the cost of land degradation such as the cost to environmental systems and public infrastructure. The latter would, however, be captured in the national accounts estimates for consumption of fixed capital.

Changes in the value of agricultural land can be ascertained from data on market values or land rates data. However, data for land values are affected by a host of factors other than changes in productive capacity from the impact of land degradation, including inflation, technological advances and changes in land use due to rezoning, subdivision and lifestyle considerations (Roberts 1997).

Two recent national studies used different approaches to measuring economic losses due to land degradation:

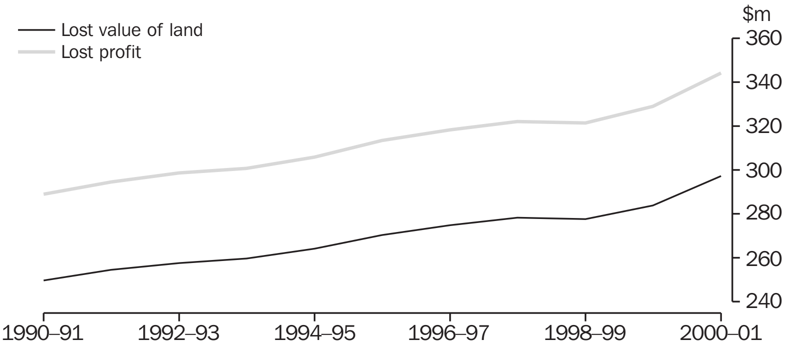
- Kemp and Connell (2001) used a farm survey to ascertain the extent of land degradation on farms. Combining data from the survey with land value data, regression techniques were used to estimate that the difference in the capital value of farms with and without degradation was approximately $14.2b in 1999. This represents the accumulated value of losses in land value due to degradation.
- The National Land and Water Resources Audit (2002) used models to estimate the 'yield gap'; that is, the difference between profits with and without soil degradation. Lost profit at full equity due to salinity, sodicity and acidity was estimated as $2.6b in 1996–97.

To compare the results, either the former estimate has to be converted to a lost profit stream or the latter has to be capitalised. Profit at full equity is a measure of the net returns to land and water resources used for agriculture, and the managerial skill of land managers. Adjusting this concept to resource rent by removing the returns to the manager's labour and produced capital, and using a real discount rate of 5.8%, the capitalised value of the lost resource rent due to all past degradation is $16.4b in 1996–97. The results using this method are sensitive to the discount rate. The real discount rate has been derived as the long-term government bond rate adjusted by the consumer price index in 1996–97.

Land/soil assets *continued*

While the estimates mentioned above represent the accumulated value of losses in land value due to all past degradation since European settlement, it is the year-to-year increment in the value of degradation that should be deducted from farm income in each period (consistent with the treatment of depreciation of produced assets). There are a number of issues to consider, including whether to deduct degradation from income in the periods when the effect becomes evident, or in the periods in which it was caused (sometimes decades or even a century earlier). The latter would seem appropriate in economic accounting. For the purpose of the indicative estimates contained in this article, it has been assumed that degradation accumulated evenly over a period of 50 years. Using the $14.2b figure for lost land value, the annual increment (in 1999 dollar terms) is $284m per year. Using the alternative estimate of $16.4b, degradation is $329m per year (in 1997 dollar terms). The annual losses are adjusted using the chain price index for GDP to arrive at degradation in current prices. The higher value has been taken into the summary estimates provided in a later table. For estimates post–1999 it has been assumed that degradation will accrue at the same rate. No adjustments have been made to account for land improvements that might reduce the future loss of resource rent. The resulting series are shown in graph A1.10.

A1.10 LAND DEGRADATION



Source: Australian National Accounts: National Income, Expenditure and Product, (cat. no. 5206.0).

Forest assets

Forests are renewable biological resources. There are two types of forest: old growth native forests (95% of the area of all Australian forests) and plantations. Broadleaved and coniferous plantation standing timber are treated as produced assets in the national accounts, as the growth is under the direct control, responsibility and management of the owner. They are classified as inventories. Native forests are treated as non-produced assets as, although they may be owned and available for use, their growth is not the result of an economic process. As for other non-produced assets, the depletion of native forest assets due to harvesting is not charged against income in the national accounts.

Forest assets *continued*

The valuation of the depletion of renewable assets presents a different set of issues to non-renewable assets as it may be possible to replace (over time) the part of the asset that is used in the current period. Where a forest is harvested sustainably, no depletion adjustment is required. SEEA suggests that either depletion and additions can be calculated separately, or that just the net depletion could be calculated. Where old growth will not be replaced, only a depletion adjustment will apply. In some areas however, old growth forest will become second growth forest. Where extractions (i.e. timber harvesting) still exceed growth, depletion should exceed additions. Once the transition period from old growth forest to second growth forest is complete, growth may exceed harvest. In this case yield can be considered economically sustainable.

In principle, the best approach would be to calculate both depletion and addition adjustments as this allows for the two impacts to be explicitly identified. Depletion is calculated as the change in the NPV of the forest arising from the harvesting of timber (similar to subsoil assets). The value of additions is the NPV of the growth in any one year. The compilation of this series requires data on the annual increase in forest cover.

It is also possible that forests will come into or out of scope of the balance sheet due to land use management decisions or catastrophic events (e.g. bushfires) that affect the volumes of standing timber. Such changes should not be recorded as depletion because they are not regular economic events. Rather, they should be included as either positive or negative additions to assets in the balance sheet and recorded in the 'other change in assets account'.

Estimates are not yet available for depletion of native forests. However, given that the value of native forests on the national balance sheet is $2.6b compared with $172.9b for subsoil assets, it is expected that depletion of the former will be relatively insignificant. This of course is taking an economic view only, and does not account for damage to intrinsic non-monetary values such as ecosystem services, biodiversity and aesthetic/recreational values.

Adjusting the national accounts

It was stated earlier in this article that there is an asymmetry in the national accounts between the treatment of produced assets such as buildings, and plant and natural (non-produced) assets. Depreciation of produced assets (termed consumption of fixed capital in the national accounts) is deducted to derive the various 'net' income measures in the national accounts such as net domestic product (NDP), net operating surplus (NOS), net national income and net saving. No such deduction is made for natural assets when they are used up or degraded as a result of economic activity. The net measures thus fall short of being sustainable concepts of income, although they are superior to the various 'gross' measures in the national accounts in this respect.

Adjusting the national accounts *continued*

The experimental estimates derived for the value of depletions and discoveries of subsoil assets and the degradation of agricultural land are indicative of adjustments that could be made to the national accounts in the context of a satellite account and are illustrated in table A1.11. Depletion adjustments unambiguously lower the net values. If the value of discoveries is included in income in place of the value of mineral exploration, the net effect of that adjustment can be positive or negative.

A1.11 PRODUCTION AND CAPITAL INCOMES ADJUSTED FOR DEPLETION AND ADDITIONS, Current prices

	1993–94	*1994–95*	*1995–96*	*1996–97*	*1997–98*	*1998–99*	*1999–2000*	*2000–01*
	$m	*$m*	*$m*	*$m*	*$m*	*$m*	*$m*	*$m*
plus								
Subsoil depletion	1 509	1 650	1 640	1 892	1 703	1 710	2 073	2 785
Land degradation	301	306	313	318	322	322	329	344
less								
Subsoil additions	3 470	1 542	1 664	583	1 762	3 050	2 383	2 785
plus								
Cost of mineral exploration	1 471	1 791	1 905	2 257	2 300	1 916	1 562	1 563
less								
COFC(a) on mineral exploration	1 109	1 147	1 199	1 248	1 316	1 364	1 448	1 517
equals								
Net depletion adjustment	**–1 298**	**1 058**	**995**	**2 636**	**1 247**	**–466**	**133**	**390**
GDP(b)	446 480	471 348	502 828	529 886	561 229	591 592	629 212	670 029
less								
Consumption of fixed capital	73 773	76 264	78 617	80 376	86 160	91 316	97 663	104 292
equals								
NDP(c)	*372 707*	*395 084*	*424 211*	*449 510*	*475 069*	*500 276*	*531 549*	*565 737*
less								
Net depletion adjustment	–1 298	1 058	995	2 636	1 247	–466	133	390
equals								
Depletion adjusted NDP(c)	**374 005**	**394 026**	**423 216**	**446 874**	**473 822**	**500 742**	**531 416**	**565 347**
GOS and GMI(d)	185 849	192 149	202 687	210 158	227 762	234 776	253 803	264 641
less								
Consumption of fixed capital	73 773	76 264	78 617	80 376	86 160	91 316	97 663	104 292
equals								
NOS(e)	*112 076*	*115 885*	*124 070*	*129 782*	*141 602*	*143 460*	*156 140*	*160 349*
less								
Net depletion adjustment	–1 298	1 058	995	2 636	1 247	–466	133	390
equals								
Depletion adjusted NOS(e)	**113 374**	**114 827**	**123 075**	**127 146**	**140 355**	**143 926**	**156 007**	**159 959**
Net saving	9 238	6 038	10 717	19 600	20 567	18 173	19 672	18 508
less								
Net depletion adjustment	–1 298	1 058	995	2 636	1 247	–466	133	390
Depletion adjusted saving	**10 536**	**4 980**	**9 722**	**16 964**	**19 320**	**18 639**	**19 539**	**18 118**

(a) Consumption of fixed capital.
(b) Gross domestic product.
(c) Net domestic product.
(d) Gross operating surplus and gross mixed income.
(e) Net operating surplus.

Source: Australian National Accounts: National Income, Expenditure and Product, June 2002 (cat. no. 5206.0).

The net saving levels are changed by the same amount as for NOS, but the nation's net lending position is left unchanged.

Adjusting the national accounts for depletion and additions of subsoil assets also affects growth rates, which may increase or decrease. As table A1.12 shows, the adjustments have the biggest impact on both NDP and NOS in 1994–95, due to the low value of subsoil asset additions in that year compared to the previous one.

A1.12 PRODUCTION AND CAPITAL INCOMES ADJUSTED FOR DEPLETION AND ADDITIONS, Percentage changes

	1993–94	1994–95	1995–96	1996–97	1997–98	1998–99	1999–2000	2000–01
	%	%	%	%	%	%	%	%
GDP(a)	4.9	5.6	6.7	5.4	5.9	5.4	6.4	6.5
NDP(b)	4.7	6.0	7.4	6.0	5.7	5.3	6.3	6.4
Depletion adjusted NDP(b)	4.9	5.4	7.4	5.6	6.0	5.7	6.1	6.4
Net change in NDP(b) growth	**0.2**	**–0.7**	**—**	**–0.4**	**0.3**	**0.4**	**–0.1**	**—**
GOS and GMI(c)	4.7	3.4	5.5	3.7	8.4	3.1	8.1	4.3
NOS(d)	4.0	3.4	7.1	4.6	9.1	1.3	8.8	2.7
Depletion adjusted NOS(d)	4.7	1.3	7.2	3.3	10.4	2.5	8.4	2.5
Net change in NOS(d) growth	**0.6**	**–2.1**	**0.1**	**–1.3**	**1.3**	**1.2**	**–0.4**	**–0.2**

(a) Gross domestic product.

(b) Net domestic product.

(c) Gross operating surplus and gross mixed income.

(d) Net operating surplus.

Source: Australian National Accounts: National Income, Expenditure and Produce, June 2002 (cat. no. 5206.0).

Energy and greenhouse gas emissions

A satellite account for energy and greenhouse gas emissions using the input-output framework was published by the ABS in *Energy and Greenhouse Gas Emissions Accounts, Australia* (cat. no. 4604.0) in 2001. It presented information on the supply, use and stock of primary energy resources, supply and use of secondary energy products, and greenhouse gas emissions associated with the use of these energy resources. Energy use and emissions of greenhouse gases were linked with economic data and tracked through the economy so that emissions were allocated to final end users of products, rather than the producers of products.

Of the total net energy supply (13,397 PJ), 66% was exported, 7% was consumed by households and 18% consumed by industry. Together household electricity use and motor vehicle use by households accounted for over 30% of Australia’s energy related greenhouse gas emissions.

FUTURE WORK AND FURTHER INFORMATION

The work program on environmental satellite accounting is continuing. The ABS hopes to extend the depletion adjustment to include native forests. Other areas of work will be to highlight environmental protection expenditures and to look at extending the economic asset boundary to include the value of water and possibly fish. Work on the valuation of environmental damage (externalities associated with human and economic activity) is an undeveloped field of research and it is unlikely that the ABS will have the capacity to make advances in this area in the foreseeable future.

The ABS welcomes comments on environmental satellite accounts and measuring the depletion of Australia’s natural resources. These can be directed to Tony Johnson on Canberra 02 6252 7297 or email <tony.johnson@abs.gov.au>.

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ABBREVIATIONS, SYMBOLS AND OTHER USAGES

ABBREVIATIONS

ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
ACF	Australian Conservation Foundation
ACMER	Australian Centre for Mining Environmental Research
ACRE	Australian Cooperative Research Centre for Renewable Energy
AFFA	Department of Agriculture, Fisheries, Forestry Australia
AGO	Australian Greenhouse Office
AHC	Australian Heritage Commission
AMD	Acid Mine Drainage
Ameef	Australian Minerals and Energy Environment Foundation
ANSTO	Australian Nuclear Science and Technology Organisation
ANZECC	Australian and New Zealand Environment and Conservation Council
ANZSIC	Australia and New Zealand Standard Industry Classification
APHIS	Animal and Plant Health Inspection Service
ASIC	Australian Standard Industry Classification
ASNA	Australian system of national accounts
AUSLIG	Australian Surveying and Land Information Group
AUSTMINE	Australian Mining Equipment Technology and Services
AWRC	Australian Water Resources Council
BC	Bio-chemical
BHP	Broken Hill Proprietary Company Ltd
BRS	Bureau of Rural Sciences
CAR	comprehensive, adequate and representative
CEC	Commission of the European Communities
CO_2-e	Carbon dioxide equivalent
COFC	Consumption of fixed capital
CRA	Comprehensive Regional Assessment
CRC	Cooperative Research Centre
CRCSLM	Cooperative Research Centre for Soil and Land Management
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSRC	Contaminated Site Remediation Conference
DEST	Department of Environment, Sport and Territories
DFA	Deferred Forest Agreements
DFI	Direct foreign investment
DISR	Department of Industry Science and Resources
DME	Department of Minerals and Energy, Queensland
EA	Environment Australia
EDR	Economic Demonstrated Resources
EFP	environmentally friendly product
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EPA	Environment Protection Agency
EPBC	Environment Protection and Biodiversity Conservation
EPE	environmental protection expenditure

ABBREVIATIONS *continued*

ESD	Ecologically Sustainable Development
ESDWG	Ecologically Sustainable Development Working Groups
EVAO	Estimated value of agricultural operations
GA	Geoscience Australia
GDP	Gross domestic product
GM	Genetically modified
GMO	genetically modified organism
GPI	Genuine Progress Indicator
GWE	Gross Roundwood Equivalent
HDI	Human Development Index
HIFAR	High Flux Australian Reactor
IBRA	Interim Biogeographic Regions of Australia
ICOMOS	International Council of Monuments and Sites
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
ISL	in situ leaching
JANIS	Joint ANZECC/MCFFA National Forest Policy Statement Implementation Sub-committee
LNG	Liquefied Natural Gas
MAPW	Medical Association for Prevention of War
MCA	Minerals Council of Australia
MCFFA	Ministerial Council on Forestry, Fisheries and Aquaculture
MDBC	Murray–Darling Basin Commission
MUF	Multiple-use Forests
NCR	Nature conservation reserves
NDP	net domestic product
NFI	National Forest Inventory
NGGI	National Greenhouse Gas Inventory Committee
NLWRA	National Land and Water Resources Audit
NOS	net operating surplus
NPI	National Pollutant Inventory; *also* National Plantation Inventory
NPP	Net Primary Productivity
NPV	net present value
NRE	Department of Natural Resources and Environment, Victoria
NT	Northern Territory
OECD	Organisation for Economic Co-operation and Development
OGTR	Office of the Gene Technology Regulator
OT	Ordinary time
OUP	Oxford University Press
PER	public environment report
RAC	Resource Assessment Commission
RAOU	Royal Australasian Ornithologists Union

ABBREVIATIONS *continued*

RFA	Regional Forest Agreement
RIRDC	Rural Industries Research and Development Corporation
RMU	removal unit
RNE	Register of the National Estate
SACME	South Australian Chamber of Mines and Energy
SDR	Sub-economic Demonstrated Resource
SEEA	System of Integrated Environmental and Economic Accounting
SF NSW	State Forests of New South Wales
SNA	System of National Accounts
SNA93	*System of National Accounts 1993*
SoE	State of the Environment; *also* State of the Environment Reporting Council
TC	Thermo-chemical
UN	United Nations
UNEP	United Nations Environment Program
UNFAO	United Nations Food and Agriculture Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNSW	University of New South Wales
WCED	World Commission on Environment and Development
WWF	World Wide Fund for Nature

SYMBOLS AND OTHER USAGES

b	billion
b m^3	billion cubic metre
CH_4	methane
cm	centimetre
CO_2	carbon dioxide
CO_2-e	carbon dioxide equivalent
Gg	gigagram
GJ	gigajoule
GL	gigalitre
Gt	gigatonne
ha	hectare
kg	kilogram
kL	kilolitre
km	kilometre
km^2	square kilometre
kt	kilotonne
kW	kilowatt
L	litre
m^3	cubic metre
Mc	megacarat
mg	milligram
mL or ml	millilitre
ML	megalitre
Mt	megatonne
MW	megawatt
N_2O	Nitrous oxide
na	not available
n.c.	not collected
ne	not estimated
n.e.c.	not elsewhere classified
n.e.i.	not elsewhere included
n.e.s.	not elsewhere specified
no.	number
np	not available for publication but included in totals where applicable
nya	not yet available
PJ	petajoule
pphm	parts per hundred million
t	tonne
Tcf	trillion cubic feet
TJ	terajoule
TWh	teraWatt hour
*	subject to high standard errors and should be used with caution (i.e. relative standard error between 25% and 50%)
**	subject to sampling variability too high for practical purposes (i.e. relative standard error greater than 50%)
$b	billion (one thousand million) dollars
$m	million dollars
—	nil or rounded to zero (including null cells)
. .	not applicable
%	per cent

SYMBOLS AND OTHER USAGES *continued*

'000	thousand
$'000	thousand dollars
kilo	10^3
mega	10^6
giga	10^9
tera	10^{12}
peta	10^{15}
milli	10^{-3}

GLOSSARY

Abatement To decrease or reduce in amount.

Acid mine drainage Acid mine drainage is produced through the reaction of sulphide with air and water to form sulphuric acid.

Afforestation The planting of new forests on land which historically has not been covered by forest (as defined by the IPCC).

Algal blooms A sudden proliferation of microscopic algae in water bodies, stimulated by the input of nutrients such as phosphates.

Anthropogenic Of human origin or human induced; can be used in the context of emissions that are produced as a result of human activities.

Asset (economic) An entity functioning as a store of value:

i) over which ownership rights are enforced by institutional units, individually or collectively; and

ii) from which economic benefits may be derived by its owner by holding it, or using it, over a period of time.

The economic benefits consist of primary incomes derived from the use of the asset and the value, including possible holding gains/losses, that could be realised by disposing of the asset or terminating it.

Assimilate (waste) Absorption and storage of waste products.

Basel Convention An international convention set up to control the movements of hazardous wastes between countries.

Beneficiation Crushing and separating ore into valuable substances or waste by any of a variety of techniques.

Biodiversity Biological diversity; variability among living organisms — including genetic diversity, diversity within and between species and diversity within ecosystems (see also Ecosystem).

Biogeographic region An extensive region distinguished from adjacent regions by its broad physical and biological characteristics.

Biomass The total weight of living organisms in a given area. Total biomass consists of both above-ground (stem, tree crown) and below-ground (roots) biomass.

Biosphere The realm where living organisms are found on earth.

Biotechnology A range of technologies that make use of natural processes or products of living things. Gene technology is the modern extension of this.

Capital expenditure (environmental protection in the mining industry) Refers to expenditure on any element of production processes specifically concerned with protecting the environment and elimination of pollutants and wastes. It could be remedial (end-of-line) or by preventative (change-in-production) measures.

Carbon Dioxide Equivalent (CO_2-e) Relates to greenhouse gases. Non-CO_2 gases are converted into CO_2-e terms by multiplying the amount of gas by the appropriate global warming potential (GWP).

Chain volume measures For certain types of economic analysis it is useful to examine estimates of the principal flows of goods and services in the economy revalued in such a way as to remove the direct effects of changes in their prices over the period under review. Chain volume measures for Gross Domestic Product and other aggregates are obtained by linking together (compounding) movements in volumes, calculated using the average prices of the previous financial year and applying the compounded movement to the current price estimates of the reference year.

Coastal The region extending seaward and inland from the shoreline that is influenced by, and exerts an influence on, the seas and their resources and biota.

Commercial and industrial waste Inert waste arising from institutional, commercial, and industrial activities. Consists of non-hazardous materials.

Construction and demolition waste Materials arising from demolition and building activities (e.g. demolition rubble and building off-cuts).

Current expenditure (environmental protection in mining industry) Expenditure to operate and maintain a plant and equipment to abate pollution; payments made to contractors to remove and dispose of water; costs associated with wind and water erosion; on-going site rehabilitation; regular sampling tests; and related research and development expenditure.

Deforestation Conversion of land from forests or grasslands to pasture, crop land or other managed uses (as defined by the IPCC).

Discount rate An interest rate used to discount (i.e. reduce the value of income or expenditure in the future) due in part to a preference for consumption now rather than later. It is often expressed in 'real' terms, (i.e. adjusted to exclude the effects of inflation).

Diversion Volume of water diverted from a stream or aquifer on a sustained basis to supply water for rural, urban and industrial usage. Includes diversions undertaken by a water authority, a private company or a group of individuals authorised to act as a water supply industry.

Domain The environmental media or type of pollution-nuisance-degradation used to classify environment protection expenditures. The six domains used in this publication are: waste management; waste water and water protection; ambient air and climate protection; protection of biodiversity and landscape; protection of soil and groundwater; and other environment protection activities.

Domestic and municipal waste Comprises waste from domestic premises (e.g. household refuse, garden waste etc.) and council activities largely associated with servicing residential areas (e.g. street sweepings, street tree lopping, parks and gardens and litter bins).

Eco-efficiency The efficiency with which ecological resources are used to meet human needs. Eco-efficiency measures may aim to: reduce the material and energy intensity of goods and services; minimise toxic waste and pollution; enhance the capacity of materials to be recycled; maximise the use of renewable resources, and; extend the durability of products.

Ecological footprint An estimate of the area of land a population uses to produce the natural resources it consumes and to assimilate the waste it generates.

Ecologically Sustainable Development (ESD) Development which meets the needs of the present without compromising the ability of future generations to meet their own needs.

Economic Demonstrated Resources (EDR) Resources judged to be economically extractable and for which the quality and quantity are computed partly from specific measurements, and partly from extrapolation.

Ecosystem A dynamic complex of plant, animal and microorganism communities which, together with the non-living components, interact to maintain a functional unit.

Ecosystem services The role played by ecosystems in creating a healthy environment for human beings, from production of oxygen to soil formation and maintenance of water quality.

Endangered (species/ecological community) Species which are in danger of extinction and whose survival is unlikely if the causal factors continue; included are species whose numbers have been reduced to a critical level or whose habitats have been so drastically reduced that the species are deemed to be in danger of extinction (see also Vulnerable species/ecological community).

Endemic/Endemism Species that are confined to a particular region; for example, a species endemic to Australia is only found in Australia.

Enterprise Group Unit covering all operations in Australia of one or more legal entities under common ownership and control. Legal entities may be bound by trusts and partnerships as well as companies which operate under the terms of current Corporation Law.

Environmental Impact Assessment The process of identifying, predicting, evaluating, and mitigating the biophysical, social, and other relevant effects of proposed projects and physical activities prior to major decisions and commitments being made.

Environmental indicator Physical, chemical, biological or socioeconomic measures that can be used to assess natural resources and environmental quality.

Environment protection expenditure Expenditure on actions and activities that are aimed at the prevention, reduction and elimination of pollution as well as any other degradation of the environment (including conservation of biodiversity and landscape, and protection of cultural heritage).

Eutrophication Process by which waters become enriched with nutrients, primarily nitrogen and phosphorus, which stimulate the growth of aquatic flora and/or fauna.

Exotic organisms An animal or plant that has been introduced to a region (compared with native species).

Extinct (species/ecological community) A species or community is categorised as extinct when there is no reasonable doubt that the last individual/member of a species/community has been eliminated.

Fauna The entire animal life of a region.

Flora The entire plant life of a region.

Fossil fuels Any natural fuel derived from decomposed or partly decomposed organic matter. Common fossil fuels include coal, oil and natural gas.

Genetically Modified Organism Organisms (plant, animal, fungi, bacteria or viruses) that have been modified in such a manner that they cannot be derived through 'traditional' breeding methods. Activities of this nature are broadly termed gene technology.

Greenhouse Gases Those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and re-emit infra red radiation. Includes (water vapour) carbon dioxide (CO_2); methane (CH_4); nitrous oxide (N_2O); hydroflurocarbons (HFCs); perflurocarbons (PFCs): and sulphur hexaflouride (SF_6).

Global Warming Potential (GWP) An estimate of how much a given mass of greenhouse gas contributes to global warming. It is a relative scale comparing gases to carbon dioxide which has a GWP of one.

Greenhouse Effect (or Enhanced Greenhouse Effect) The warming of the earth's atmosphere caused by a build-up of carbon dioxide and other gases. Many scientists believe that this effect is being significantly enhanced through various human activities.

Gross Domestic Product (GDP) The total market value of goods and services produced in Australia after deducting the cost of goods and services used up in the process of production (intermediate consumption), but before deducting allowances for the consumption of fixed capital (depreciation).

Gross National Income (GNI) A monetary measure of the production of goods and services derived by subtracting net income paid overseas from Gross Domestic Product. It is the aggregate value of gross primary incomes for all the nation's institutional sectors, including net primary income received from non-residents.

Hardwood Timber produced from broadleaved species such as eucalypts, predominantly found in native forests. An increasing area of hardwood plantations is being established.

Hierarchy A series of successive terms of different rank.

Indicator A physical, chemical, biological or socioeconomic measure that provides useful, quantifiable information about a system or phenomenon. An example is the concentration of ozone depleting substances in the atmosphere: an increase is harmful to the stratospheric ozone layer, while a decrease shows that efforts to protect the ozone layer are succeeding.

Industry Gross Value added Represents the value added by an industry to the intermediate inputs used by the industry.

Input-output A compilation method which provides a description of the inter-industry flows of goods and services within the economy, and the structure and inter-relationship of industries.

Joule Unit of energy.

Landfill A naturally formed or excavated hole in the ground used to dispose of waste. There can be both dry and wet landfills.

Life expectancy The average number of additional years a person of a given age and sex might expect to live if the age-specific death rates of the given period continued throughout their lifetime.

National balance sheet A comprehensive statement of produced assets (e.g. houses, cars and machinery) and non-produced assets (e.g. land, minerals and timber), financial assets and liabilities (e.g. money, shares, bonds) and net worth.

Natural assets (tangible non-produced assets) Natural resources (eg. land, subsoil assets, non-cultivated biological resources and water) over which ownership may be established and transferred. Environmental assets over which ownership rights have not, or cannot, be established, such as open seas or air, are excluded.

Net present value The value now of a stream of income over future years, calculated by discounting future income. Usually applied where no market prices are available in the case of assets for which the returns are spread over a lengthy period.

Net Primary Productivity (NPP) The net rate at which plants absorb and store carbon; equal to the difference between carbon gained (positive) by plant photosynthesis and the carbon lost (negative) by plant respiration.

Net water consumption Net water consumption is equal to mains water use plus self-extracted water use minus mains water supply. (see *Water Account for Australia, 1993–94 to 1996–97* (cat. no. 4610.0) for more details.)

Non-renewable resources Resources which are not self-regenerating (e.g. coal, oil and minerals).

Nutrients Elements or compounds essential as raw materials for organic growth and development such as carbon, oxygen, nitrogen and phosphorus.

Ordinary time earnings Comprises base pay plus payment by measured result. Excluded are non-cash components of salary packages, salary sacrificed, overtime payments, retrospective pay, pay in advance, leave loadings, severance pay, and termination and redundancy payments.

Parts Per Million (greenhouse gases) The ratio of the number of greenhouse gas molecules to the total number of molecules of dry air. For example, 300 ppm means 300 molecules of a greenhouse gas per million molecules of dry air.

Photosynthesis The conversion by plants of atmospheric carbon dioxide to organic carbon compounds and oxygen, with the addition of energy.

Pollution 1. Presence of substances and heat in environmental media (air, water, land) whose nature, location or quantity produces undesirable environmental effects.

2. Activity that generates pollutants.

Primary energy The forms of energy obtained directly from nature. They include non-renewable fuels such as black coal, crude oil and natural gas as well as renewable fuels such as wood and hydro-electricity.

Recycling The separation of a given material from the waste stream and its processing so that it may be used again as a material for products which may or may not be similar to the original.

Reforestation The planting of forests on land which historically has contained forest but which has been used for another purpose since last being covered by forest (as defined by the IPCC).

Renewable energy Renewable energy sources are those that can be theoretically used at a rate that can be sustained indefinitely. The main forms are hydro-electricity, wood, solar heaters or photovoltaic cells, wind generators, geothermal plants, ocean or tidal generators and biomass generators.

Roundwood Wood in its natural state as removed from forests.

Run-off The amount of rainfall which actually reaches a stream or storage.

Sawlogs Logs that can be sawn to produce sawn timber, sleepers, poles etc.

Secondary energy An energy source derived from the conversion of a primary energy fuel. For example, the production of electricity by burning coal.

Sequestration A process whereby carbon is removed from the atmosphere and stored for a period of time.

Sewage Organic waste and waste water produced by residential and commercial establishments.

Silviculture The care and cultivation of forest trees.

Sinks Natural or anthropogenic processes which result in the removal of CO_2 from the atmosphere and its storage in a pool or reservoir.

Softwood Timber produced from conifers, predominantly grown in plantations. The most common species grown is the introduced Pinus radiata. There are also a number of Gondwanan conifer genera that still survive in native forests.

Species Group of animals or plants having common characteristics and able to breed together to produce fertile (capable of reproducing) offspring, so that they maintain their 'separateness' from other groups.

Stormwater Sudden, excessive run-off following a storm.

Sub-economic Demonstrated Resource (SDR) Similar to Economic Demonstrated Resources in terms of certainty of occurrence. Although considered to be potentially economic in the foreseeable future, these resources are judged to be sub-economic at present.

Subsoil asset Proven reserves of mineral deposits located on or below the earth's surface that are economically exploitable given current technology and relative prices. Mine shafts, wells and other extraction sites are included with structures rather than with the subsoil asset.

Surface water resources (assets) Volume of water that could be diverted from a basin each year on a sustained basis.

Taxon A term used to denote any taxonomic category; i.e. species, genus or family is called a taxon (plural: taxa).

Tailings The material rejected from a treatment plant after the extraction of recoverable valuable materials. Disposal methods include:

Land Disposal — in topographical depressions or in constructed impoundments;

Riverine and estuarine disposal — direct discharge into the waterways; and
Marine disposal — direct discharge to the sea.

Transgenic (crops) Plants with genes derived from a different species (e.g. fish gene for anti-freeze).

Vulnerable (species/ecological community) Species which may soon move into the 'endangered' category if causal factors affecting their numbers continue. Included are species of which all, or most, populations are decreasing because of overexploitation, extensive destruction of habitat; species which are seriously depleted; under threat from severe adverse factors throughout their range; and species with low or localised populations and dependent upon a limited habitat which would be vulnerable to further threats (see also Endangered species/ecological community).

Waste management Includes the collection, transportation and disposal of unwanted by-products. It also includes the payments to contractors and/or fees and levies paid to local government or other agencies to remove and dispose of waste.

Wastewater Water discharges from domestic effluent, industrial (e.g. trade waste) and other sectors.

Wetlands Shallow bodies of water which can be freshwater, saline or brackish and periodically or permanently inundated.

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