Environmental Indicators

for National State of the Environment Reporting

human settlements

Australia: State of the Environment
Environmental Indicator Report

Peter Newton [1, 2]
Joe Flood [2]
Mike Berry [2]
Kuldeep Bhatia [3]
Steve Brown [1]
André Cabelli [4]
Jeanette Gomboso [5]
John Higgins [6]
Tony Richardson [7]
Veronica Ritchie [5]

1	CSIRO Building, Construction and Engineering	Graham Road, Highett VIC 3190
2	Australian Housing and Urban Research Institute	Level 7, 20 Queen Street Melbourne VIC 3000
3	Australian Institute of Health and Welfare	6A Traeger Court, Fernhill Park, Bruce ACT 2617
4	André Cabelli and Associates	5 Kilsyth Avenue Toorak VIC 3142
5	CSIRO Land and Water	Floreat Park Laboratories, Underwood Avenue Floreat Park WA 6014
6	Environment Australia	GPO Box 787, Canberra ACT 2601
7	Transport Research Centre	Level 2, 20 Queen Street Melbourne VIC 3000

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Preface

The Commonwealth State of the Environment Reporting system supports the *National Strategy for Ecologically Sustainable Development* and helps Australia meet its international obligations, such as those under *Agenda 21* and the OECD environmental performance reviews. The first independent and comprehensive assessment of Australia's environment, *Australia: State of the Environment 1996* was released by the Commonwealth Environment Minister in September of that year.

The next step in the evolution of the reporting system is to develop a set of environmental indicators that, properly monitored, will help us track the condition of Australia's environment and the human activities that affect it. To help develop these indicators, Environment Australia has commissioned reports recommending indicators for each of the seven major themes around which Commonwealth state of the environment reporting is based. The themes are:

- human settlements
- biodiversity
- the atmosphere
- the land
- inland waters
- estuaries and the sea
- natural and cultural heritage.

An eighth report deals with the use of the recommended indicators by local or regional environmental managers and with the role of the community in indicator work. It is the result of a pilot study carried out by the Australian Local Government Association and Environment Australia.

Clearly, none of these themes is independent of the others. The consultants worked together to promote consistent treatment of common issues. In many places issues relevant to more than one theme receive detailed treatment in one report, with cross-referencing to the other reports.

Report authors were asked to recommend a comprehensive set of indicators, and were not to be constrained by current environmental monitoring. One consequence of this approach is that many recommendations will not be practical to implement in the short term. They are, however, a scientific basis for longer term planning of environmental monitoring and related activities.

These reports are advice to Environment Australia and have been peer reviewed to ensure scientific and technical credibility. They are not necessarily the views of the Commonwealth of Australia.

The advice embodied in these reports is being used to advance state of the environment reporting in Australia, and as an input to other initiatives, such as the National Land and Water Resources Audit and the Australian Local Government Association's Regional Environmental Strategies.

Summary

A key set of 104 environmental indicators for human settlements is recommended for Australian state of the environment reporting at the national scale. Of these, 48 relate to the condition of human settlements in relation to their three constituent elements: the physical environment (e.g. air quality), the built environment (e.g. housing affordability), and the human environment (e.g.Environmentally related human health such as (waterborne) diarrhoeal outbreaks); 44 relate to pressures on the physical environment by activities associated with human settlements. Monitoring strategies and approaches to interpreting and analysing each of the indicators are discussed, and possible sources of data are noted. Recommendations are also made for further development of environmental indicators for human settlements.

Aims of the study

- present a key set of indicators for human settlements for national state of the environment reporting;
- ensure that the list of indicators adequately covers all major environmental themes and issues;
- examine each indicator in detail to ensure that it is rigorously defined and measurable and in an interpretive framework;
- identify suitable monitoring strategies for each indicator – including measurement techniques, appropriate temporal and spatial scales for measurement and reporting, data storage and presentation techniques, and appropriate geographical extent of monitoring;
- identify relevant data sources for each indicator, if these are available;
- define the baseline information that is needed to properly interpret the behaviour of the indicators.

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Executive Summary

There are two contexts in which human settlements may be considered for the purposes of SoE reporting: through their direct and indirect impacts on the physical environment, and through the fact that human settlements constitute a significant 'environment' in their own right. Monitoring of human settlements must consider both the internal environment of the settlement itself and its success in delivering desirable outcomes to its inhabitants while minimising problems and undesirable effects, as well as the effect that the settlement has on the wider physical environment through resource use and waste outputs.

Australia is one of the most highly urbanised countries in the world, with 86 percent of the population living in urban areas, and over 50 percent living in the five largest cities. The process of urbanisation has an ongoing impact on the natural environment, through the resources used by urban areas, and through pollutants and waste which are produced through the activities of large concentrations of people. Human settlements, however, are the places where most people choose to live, and the activities carried out in cities provide the population with goods, services and quality of life. Given that urban communities are the environments in which most Australians have chosen to live, a key challenge for the 21st century is one where judicious urban policy and planning actually *reduces* the impact of population concentration on the physical environment while *enhancing* livability—see von Weizsacker *et al*. (1997). Cities could then expect to be regarded as the optimal arrangement for carrying a given population.

In previous SoE reporting (State of the Environment Advisory Council, 1996), the difficulty of obtaining adequate data presented in a formally developed framework was recognised as a significant limitation. A series of reports on broad environmental themes has been subsequently commissioned in an attempt to remedy this deficit by providing suggestions for indicators developed in a rigorous way and with sufficient direction to allow their collection as input to future SoE processes (p 182). This report covers the theme of *human settlements*. Its purpose is to suggest indicators which might be used both to measure the impact of urban systems on the environment, and to measure their success in providing an adequate environment for their inhabitants. This has been addressed by developing indicators for each of ten *domain areas of human settlement* in Australia. These domain areas are: energy, water, urban design, transport and accessibility, population, housing, indoor air, environmental health, noise and waste.

Several commonly used models and frameworks for developing urban indicators have been examined and drawn upon in this report. For physical systems in particular, the *Pressure-State-Response* framework of the OECD[1] is useful in distinguishing environmental pressures, system conditions, and responses to problems; to which this report has added supra-national exogenous pressures. For urban systems, however, the *Sustainability Model* is often used, which considers not solely the physical environment sphere, but also the economic, social and institutional environments, which interact to produce desirable and sustainable outcomes for the population. *Goal-based frameworks* such as those of the United Nations/World Bank have been used to consider the different perspectives of the urban actors and to tie indicators into the policy development process.

The model that has been used often in the present report is the *Extended Urban Metabolism Model* developed for the 1996 SoE Report, which considers the throughput of materials in human settlements from raw inputs to waste outputs, and the transformation of these through the dynamics of urban settlement processes into desirable livability outputs. This model is also normative, having explicit goals of reducing resource inputs, reducing waste outputs and improving livability for future generations. As such, this report extends into areas which may be considered beyond the physical environment for domains where social and economic factors can be seen to exert an environmental effect. Such linkages are most evident in the urban environments of developing countries (Devas and Rakodi, 1993), but remain operative in advanced industrial economies (www.whitehouse.gov, 1997). Issues of economic and social sustainability *per se* remain beyond the scope of this report, however.

The indicators in this report have been developed in the context of these models by an expert panel, with the assistance of a larger group of stakeholders. Indicators assembled from a wide range of published sources and studies have been supplemented with new suggestions, and the resultant set of 'proto-indicators' have been refined through application of a set of

[1] This report classifies indicators into the derivative Condition—Pressure—Respose framework.

formal criteria and through peer review, within the context of a model for each domain. The selected key indicators have then been elaborated in terms of rationale; analysis, including possible difficulties in interpretation; data sources; monitoring design for those indicators not already published; reporting scale; possible outputs suitable for the SoE report; targets or system limits where appropriate; and links with other indicators.

Where new indicators have been identified, suggestions for further development of these indicators through research have been made. As well as research directly related to particular indicators, it is suggested that a hyperlink-style 'document' could be produced which is suitable for internet application. More formal models of human settlements also could be constructed which make use of settlement and system dynamics concepts which would involve greater attention being given to the *interaction* between the indicators developed here to investigate sustainable urban futures.

This work represents the planning stage in the development of a system of human settlements indicators for future SoE reporting. The implementation of this plan will require further development of some indicators, examination of data sources and setting up of processes for collection or analysis in some cases, and the synthesis of data into a well-tempered and presented picture of the state of the human settlements environment in Australia.

Key Environmental Indicators for Human Settlements (1)

		C-P-R(2)
Macro-Level / Exogenous		
0.1.	International Migration to Australia	P
0.2.	Gross Domestic Product (GDP)	C
0.3.	Globalisation—Economic Dependency	P
0.4.	Information Economy	C
Energy		
1.1.	Total Energy Use	C
1.2.	Energy Use in Industry	C
1.3.	Energy Use in Transport	C
1.4.	Domestic Energy Use	C
1.5.	Commercial Energy Use	C
1.6.	Expenditure on Energy Programs	R
1.7	Renewable Energy	R
1.8	Cost of Energy	C
Water		
2.1	Proportion of Settlements Served by Treated Water	C/R
2.2	Municipal Household Water Consumption Patterns	P/C
2.3	Total Annual Water Usage by Sector	P/C
2.4	Sewage Disposed to Water Bodies and Re-used	P/C
2.5	Wastewater Discharged	P/C
2.6	Population Serviced by Treated Wastewater	C/R
2.7	Stormwater Discharged to Receiving Waters	P/C
2.8	Contaminants in Stormwater Discharges	P/C
2.9	Stormwater Recycled	R
2.10	Wastewater Re-used by Type of Application	C/R
2.11	Residential Water Consumption Under Alternative Water Pricing	R
2.12	Investment in Wastewater and Stormwater Technology / Conservation	R
2.13	Community Drinking Water Violations	P/C

Urban Design		
3.1	Stock of Heritage and Cultural Assets	C/R
3.2	Land Converted from Non-Urban to Urban Uses	P
3.3	Public Urban Green Space per Capita	C/R
3.4	Residential Density	P
3.5	Percentage of Medium and High Density Residential Construction	C/R
3.6	Index of Industrial Concentration	C
3.7	Mixed Land Use Ratio	C/R
3.8	Home-based Workers	C
3.9	Physical Assaults in Public Places	C/P
3.10	House Burglaries	C/P
3.11	Indices of Urban Socio-Economic Inequality	P
3.12	Indices of Socio-Spatial Segregation	P
Transport and Accessibility		
4.1	Access to Public Transport Stops	C
4.2	Car Ownership	P
4.3	Perceived Residential Density	P/C
4.4	Driving Licence Holders by Age and Sex	P
4.5	CBD Parking Supply and Charges	P/R
4.6	Fuel Pricing and Taxing	P/R
4.7	Average Speed by Mode and Distance	C
4.8	Mode Choice by Trip Purpose by Area	C
4.9	Total Time and Distance Travelled	C
4.10	Perceived Daytime Density	P/C
4.11	Economic Costs of Road Accidents	C
4.12	Fuel Consumption per Transport Output	C
4.13	Costs of Congestion	P/C
Population		
5.1	Population and Household Growth Rate	P
5.2	Households in Poverty	C
5.3	Unemployment Rates	C
5.4	Visitor Numbers	P
Housing		
6.1	Floor Area per Person	C
6.2	House Price to Income Ratio	C
6.3	New Dwellings Completed	P/C
6.4	Dwellings Constructed on Greenfield Sites	P/C
6.5	Ranges of Lot Size	P/C/R
6.6	Homelessness	C
6.7	Building Materials Used in Housing/Embodied Energy	P/C/R
6.8	Operating Energy Efficiency	P/C/R
Indoor Air Quality		
7.1	Occupant Satisfaction with Commercial Indoor Air Quality	C
7.2	Mechanical Ventilation Rate of Commercial Buildings	C
7.3	Thermal Comfort in Commercial Buildings	C

7.4	Air Infiltration Rates of New Housing	C
7.5	Proportion of Population Sensitive to Pollutants	C
7.6	Proportion of Adult Smokers with Children	P
7.7	Proportion of Commercial and Recreational Buildings with Smoking Prohibition	R
7.8	Quantity of Asbestos Products Removed from Workplaces	P/R
7.9	Number of Unflued Gas Heaters in Residences and Schools	C
7.10	Number of People Housed in Mobile Buildings	P
7.11	Proportion of Residences with High House Dust Mite Allergen	P/C
7.12	Incidence of Legionnaires' Disease	C
7.13	Production of Low-VOC Emission Building Products	R
7.14	Exposure to Indoor Air	P/C
Environmental Health		
8.1	Bacterial Contamination of Food or Water	P
8.2	Incidence of Vector-borne Diseases	P
8.3	Exposure to Hazardous Chemicals and Wastes	P
8.4	Passive Smoking	P
8.5	Health Literacy and Coping Skills	C
8.6	Depression and Related Disorders	C
8.7	Melanoma of the Skin	C
8.8	Cause Specific Mortality Rates	C
8.9	Mortality Among Indigenous Australians	C
8.10	GP Consultations	C/R
8.11	Hospital Separations, All Causes	C/R
8.12	Health Services Expenditure	R
Noise		
9.1	Exposure to Traffic Noise	C
9.2	Exposure to Aircraft Noise	C
9.3	Exposure to Industrial Noise	C
9.4	Industrial Noise Injuries	C
9.5	Cost of Noise Control	R
9.6	Road Traffic Density	P
9.7	Air Traffic Density	P
Waste		
10.1	Domestic Solid Waste Generated	P
10.2	Domestic Solid Waste Disposed to Landfill	P
10.3	Waste Recovered—Recycled	R
10.4	Commercial and Industrial Waste Generated	P
10.5	Energy Recovered from Waste	R
10.6	Proportion of Sludge and Biosolids Re-used	P/R
10.7	Hazardous Waste Generated	P
10.8	Domestic Hazardous Waste Collected	R
10.9	Contaminated Land	P

Note:

1. The Key Indicators listed in this Table are those to have emerged as a result of this study. The process by which they were derived is outlined in the body of this document.
2. C-P-R (Condition-Pressure-Response).

Background

Commonwealth State of the Environment Reporting

In 1992 Australia's *National Strategy for Ecologically Sustainable Development* (Council of Australian Governments, 1992) was endorsed by the Commonwealth, all State and Territory Governments and Local Government. The objectives of this strategy are:

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

The strategy called for the introduction of regular state of the environment (SoE) reporting at the national level to enhance the quality, accessibility and relevance of data relating to ecologically sustainable development.

The broad objectives of state of the environment reporting for Australia are:

- to regularly provide the Australian public, managers and policy makers with accurate, timely and accessible information about the condition of, and prospects for, the Australian environment;
- to increase public understanding of the Australian environment, its conditions and prospects;
- to facilitate the development of, and review and report on, an agreed set of national environmental indicators;
- to provide an early warning of potential problems;
- to report on the effectiveness of policies and programs designed to respond to environmental change, including progress towards achieving environmental standards and targets;
- to contribute to the assessment of Australia's progress towards achieving ecological sustainability;
- to contribute to the assessment of Australia's progress in protecting ecosystems and maintaining ecological processes and systems;
- to create a mechanism for integrating environmental information with social and economic information, thus providing a basis for incorporating environmental considerations in the development of long-term, ecologically sustainable economic and social policies;
- to identify gaps in Australia's knowledge of environmental conditions and trends and recommend strategies for research and monitoring to fill these gaps;
- to help fulfil Australia's international environmental reporting obligations; and
- to help decision makers make informed judgments about the broad environmental consequences of social, economic and environmental policies and plans.

The first major product of this system was *Australia: State of the Environment 1996* (State of the Environment Advisory Council, 1996)—an independent, nation-wide assessment of the status of Australia's environment, presented in seven major themes: human settlements; biodiversity; the atmosphere; the land; inland waters; estuaries and the sea; and natural and cultural heritage.

In *Australia: State of the Environment, 1996*, each theme is presented in a chapter that follows the Organization for Economic Cooperation and Development (OECD), (1993); Pressure-State-Response model (P-S-R), (see also DEST, 1994). The OECD P-S-R model describes, respectively, the anthropogenic pressures on the environment, conditions or states of valued elements of the environment, and human responses to changes in environmental pressures and conditions.

Australia: State of the Environment 1996 is the first stage of an ongoing evaluation of how Australia is managing its environment and meeting its international commitments in relation to the environment. Subsequent state of the environment reports will assess how the environment, or elements of it, have changed over time, and the efficacy of the responses to the pressures on the environment. The next national SoE report is due in 2001, consistent with the regular reporting cycle of four to five years. In order to assess changes in the environment over time it is necessary to have indicators against which environmental performance may be reviewed. As pointed out in *Australia: State of the Environment, 1996:*

> *'In many important areas, Australia does not have the data, the analytical tools or the scientific understanding that would allow us to say whether current patterns of change to the natural environment are sustainable. We are effectively driving a car without an up-to-date map, so we cannot be sure where we are. Improving our view of the road ahead by enhancing the environmental data base is a very high priority. Our intended destination is a sustainable pattern of development, but it is not always clear which direction we need to take to get there.'*

The development of a nationally agreed set of indicators is the next stage of the state of the environment reporting system. This report recommends environmental indicators for human settlements. Indicators for inland waters (Fairweather and Napier, 1998), the land (Hamblin, 1998), biological diversity (Saunders *et al.*, 1998), estuaries and the sea (Ward *et al.*, 1998), atmosphere (Manton and Jasper, 1998) and natural and cultural heritage (Pearson *et al.*, 1998) have been developed in consultancies run in parallel with (or slightly ahead of) the development of indicators for human settlements.

Environmental indicators

Environmental indicators are physical, chemical, biological or socio-economic measures that best represent the key elements of a complex ecosystem or environmental issue. An indicator is embedded in a well-developed interpretive framework and has meaning beyond the measure it represents. The set of key indicators is defined as the minimum set that, if properly monitored, provides rigorous data describing the major trends in, and impacts on, Australia's human settlements environment.

The selection criteria for national environmental indicators are listed below (from DEST, 1994) and selected indicators of human settlements should satisfy as many of these as possible. Thus, indicators should:

1. serve as a robust indicator of environmental change;
2. reflect a fundamental or highly valued aspect of the environment;
3. be either national in scope or applicable to regional environmental issues of national significance;
4. provide an early warning of potential problems;
5. be capable of being monitored to provide statistically verifiable and reproducible data that show trends over time and, preferably, apply to a broad range of environmental regions;
6. be scientifically credible;
7. be easy to understand;
8. be monitored regularly with relative ease;
9. be cost-effective;
10. have relevance to policy and management needs;
11. contribute to monitoring of progress towards implementing commitments in nationally significant environmental policies;
12. where possible and appropriate, facilitate community involvement;
13. contribute to the fulfilment of reporting obligations under international agreements;
14. where possible and appropriate, use existing commercial and managerial indicators; and
15. where possible and appropriate, be consistent and comparable with other countries' and State and Territory indicators.

For the purpose of this report, we have simplified these criteria by assembling them into five categories, which may be simply designated as:

- important (2, 3, 12);
- feasible (8, 9, 13, 15);
- credible (5, 6, 14);
- understandable (7, 10); and
- useful (1, 4, 11);

where correspondences with the criteria are in brackets. It was against these criteria that key indicators relevant to the domain areas for human settlements were evaluated (see Appendix 2).

Scope of human settlements

Human settlements encompass all the places where people live, including remote communities, rural centres, and cities (see Newman *et al.*, 1996).

Human settlements are considered from two perspectives in state of the environment reporting. First, they are environments in their own right, the *human habitat*. Human settlements are a critically important environment, given that most Australians spend the greater part of their time in such settlements.

Second, human settlements are a source of pressure on the rest of the environment. Settlements draw upon resources (such as energy, land, and materials), and expel wastes into the air, land and water.

This *dual nature* of human settlements can complicate reporting on the state of the environment which exists within them.

This dual characteristic of human settlements is reflected in the set of environmental indicators being developed as part of the present phase of the SoE Reporting process. In the 1996 Report, Australia's urban, rural and remote settlements were each examined separately in the context of their own characteristic 'environmental' pressures, states and responses. In the present phase of SoE reporting, a set of key indicators of human settlements are being sought that can describe and monitor the state of the environment at appropriate scales across Australia's urban hierarchy.

Human settlements indicators

Indicator development directed at cities and human settlements rather than at the national level has also intensified over the past twenty years. The OECD (1978) began a process of developing indicators specifically directed at cities and urban areas, but this was never implemented. However, a 'competitive' approach to measuring the quality of life in different cities arose independently (Stuart, 1972; Flax, 1972, 1978). The growth and development of cities was compared by Hughes (1974) using indicators as the measure of progress or decline. This has continued with extensive comparisons such as the World Resources Institute (1992, 1993) and Zero Population Growth (1990, 1991) which compare American cities, and the Population Crisis Committee (1990) which compiled an index and a comparison of the quality of life in the world's 100 largest metropolitan areas.

Regarding indicators projects which aim to cover most aspects of the urban condition, a number of initiatives have been undertaken. The most significant of these are the Healthy City Project of the World Health Organisation/United Nations Environment Programme (WHO/UNEP) which has used indicators to determine the condition of cities (Hancock and Duhl, 1988; City of Toronto, 1991), the City Data Program (1994) of the United Nations Centre for Human Settlements (UNCHS) (Habitat) and the Network on Urban Research European Communities (NUREC), which have collected data for about 800 large cities, and the UNCHS (Habitat)/World Bank Urban and Housing Indicators Programme (Flood, 1997), which collected and analysed data for 220 cities as part of the development of National Action Plans for the Habitat II conference in Istanbul in June 1996, and which have been subsequently incorporated in a Global Urban Observatory. Other activities currently under way include the European Urban Observatory Project, and projects within the Commission of European Communities, the Economic Commission for Europe (ECE), NUR in the ECE, the OECD and Eurostat.

As well, a number of cities have undertaken local indicators development work under the broad sustainable development mandate of Agenda 21. City level conceptual frameworks in North America which provide important guides for action include those constructed generally by the Global Cities Project (1992), and specifically by the Center for Neighbourhood Technology (1993) in Chicago, City of Toronto (1991) in Toronto, the National Civic League (1990) in Denver, the Jacksonville Community Council (1992) in Jacksonville Florida, the Sustainable Seattle Indicators Project (1993) in Seattle and Dominski *et al.* (1992) in Santa Barbara. Other activities include an extensive city-based programme in the United Kingdom, and several initiatives in Australia such as the recent work in the City of Melbourne and in local governments in New South Wales. While there has been a considerable diversity of approaches, a consensus has been reached that different countries and communities need to develop their own indicators to reflect their particular circumstances, endowments, cultures and policy environments (see, for example, The President's Council on Sustainable Development, 1996).

Guiding models for indicator development

The *extended urban metabolism model* of human settlements developed by Newman *et al.* (1996) for *State of the Environment Australia 1996* is a valuable conceptual model for guiding urban environmental indicator development (Figure 1.1).

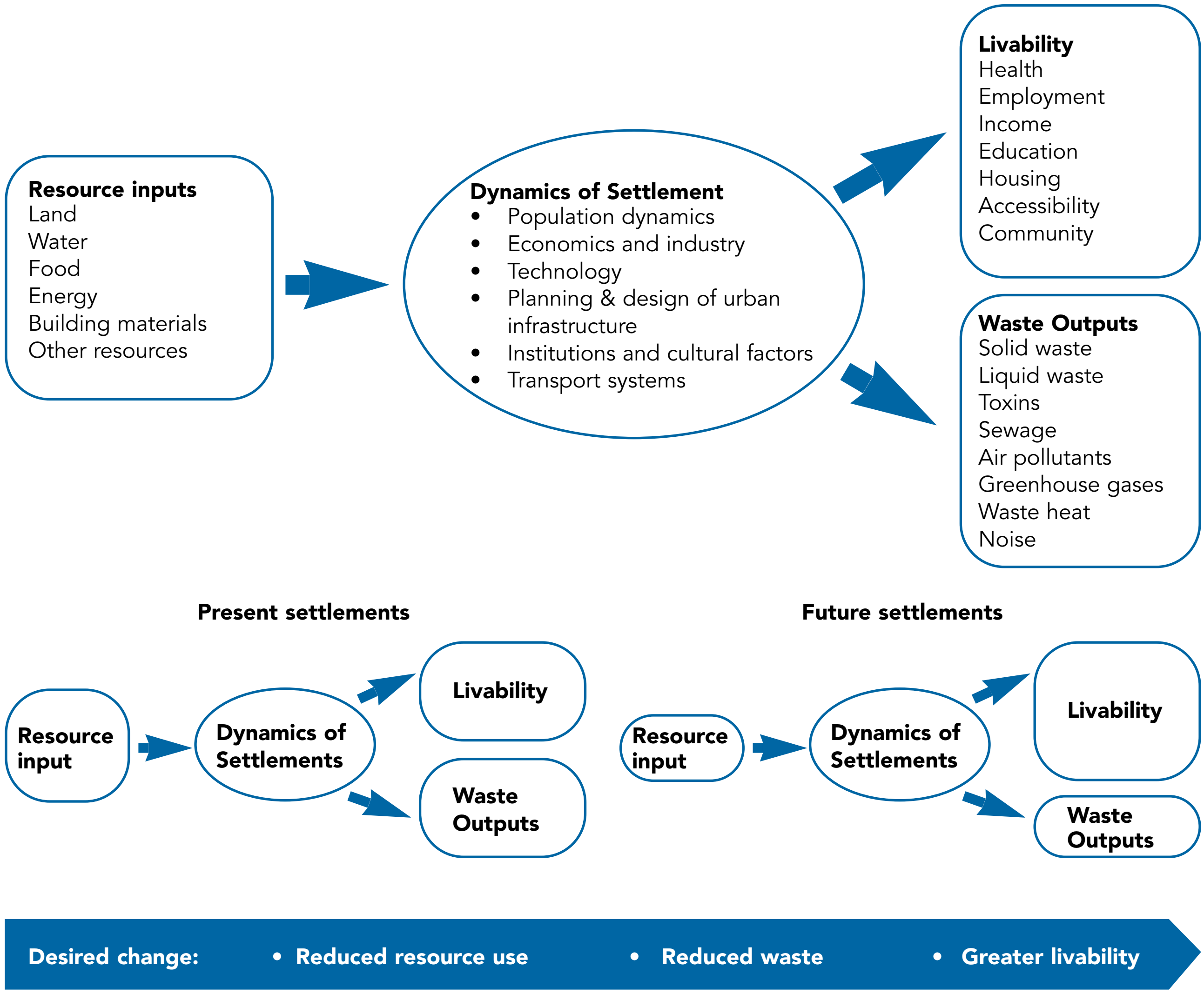


Figure 1.1: Extended metabolism model of human settlements.

Source: Newman et al. (1996).

In traditional state of the environment (SoE) reporting (eg. OECD, 1994) social and economic conditions are discussed to the extent that they impact the biophysical environment. Quality of life (QOL) studies seek to examine contemporary social, economic and environmental conditions and the linkages among them with little regard for inter-generational issues (Maclaren, 1996). By contrast, the extended metabolism model of human settlements is more closely aligned conceptually with the *sustainable development paradigm*. Here the primary emphasis is upon such issues as: future orientation, sustainability goals and targets and linkages among economic, social and environmental factors.

The extended metabolism model also has merit in highlighting the following *key domains* for urban environmental indicator development: urban planning and design, population, transport, energy, water, waste, noise, indoor air quality, environmental health, housing and urban access. The extended metabolism model, discussed here, considers the throughput of resources in human settlements from raw inputs to waste outputs, and the transformation of these through the dynamics of settlement processes into desirable livability outputs. These components are discussed below.

Dynamics of settlement Cities represent the *engines* of 21st century economies, where 90 percent of gross national product (GNP) will be produced as a result of the utilisation of resource inputs (Brotchie *et al.*, 1995). In this context, the key transformative and mediating processes of cities, such as *urban planning and design* (that is, how infrastructure, population and economic activity are accommodated across a metropolitan area) assumes considerable significance in the context of recent studies which clearly link urban form with environmental performance (Newton, 1997). Where to locate such factors as *population* in an urban metabolism model are liable to be the source of some debate, however. In a society and an economy which is becoming increasingly information-based it is appropriate that population be located within the *dynamics of settlement* (rather than Resource Inputs), given that the key human inputs to production are increasingly knowledge-based (machines having replaced human muscle in the course of the earlier transition to an industrial society). Indeed, it is primarily through the implementation of rapidly growing scientific and technological knowledge that von Weizsacker *et al.* (1997) can claim that the prospect of halving resource use while doubling wealth is a realistic prospect for 21st century societies. 'Population' dynamics and distribution are major determinants of urban activity, resource usage and environmental impact, while population is the major matrix and beneficiary of sustainability in human settlements. *Transport and accessibility* represents another key domain area. It has been largely through the evolution of transport (and, more recently, communication) technologies that human settlements have evolved from constellations of towns spatially delineated by horse-based travel to global megacities linked by high speed rail, road, air and telematic networks.

Resource inputs The inputs to urban systems are many and varied. For the most part they are inanimate (land, water, food, energy) and are subject to the laws of nature as well as to human operation[2]. *Energy and water* represent key resource inputs to human settlement. Food, materials for building and industry, and especially land, are other major resource inputs to human settlements.

Waste outputs The catalogue of waste outputs from human settlements are now relatively well studied and over time have been subject to a variety of attempts at minimisation if not removal, ranging from end-of-pipe technologies to systematic redesign. Indicators related to waste outputs represent fundamental vital signs for urban communities. Key domain areas for human settlements indicator development include: *noise, water* and *waste.*

Livability As places which accommodate an increasing proportion of the world's population, cities and their livability are increasingly important factors for resident quality of life as well as key factors in global competition for investment capital and human capital. A wide array of indicators may be assembled to measure livability which can be defined as the degree to which an urban centre provides a safe, inclusive and environmentally benign basis for the social and economic life of all its citizens.

Debate exists as to which domain areas should be included in SoE reporting under Livability. A minimalist position would include only those with a clear or dominant link with a *physical built environment,* such as *housing or indoor air quality.* Housing, however, as but one example, involves many issues in addition to the purely physical (eg. condition) such as affordability, access and homelessness—which are social and economic issues. *Environmental health,* also, while generally being regarded as linked to the physical environment, also involves many socio-economic considerations. In this report, key domain areas for livability indicator development include: *environmental health, housing* and *indoor air quality;* that is, those pertaining to the human and built environment components of settlements (as distinct from the natural environment components).

Other sustainability or SoE reporting frameworks have adopted a more comprehensive approach, and give (for example) quality of life concerns such as neighbourhood crime, social cohesion, citizen participation, and local government financial stability an equal weighting to the natural environment. Irrespective of whether one adopts a minimalist or comprehensive approach to indicator development, however, the extended metabolism model appears well suited to accommodating both at a conceptual level.

Guiding frameworks

In a recent review of urban indicators reporting, Maclaren (1996) identified several general frameworks capable of being employed in environmental indicator development. These are sustainability, issue and goal-based, causal, sectoral and domain-based and are described below.

[2] Ann Hamblin (1998) makes this important distinction when discussing indicators of land resources, separating pressures into two principal classes, termed 'geomorphic process' and 'human interventions'.

Sustainability frameworks

Sustainability frameworks typically highlight the interconnected troika of economic, social and environmental systems as represented in Figure 1.2, where a variety of economic-environment paradigms exist, reflecting competing societal ethos in relation to development. The spectrum is one which extends from a strongly anthropocentric frontier economics paradigm, through environmental protection, resource management and eco-development to deep ecology paradigms that are strongly bio-centric (Naess, 1992).

These frameworks consider separate spheres—ecology or the physical environment, society or the social environment, and economy or the economic and institutional environment, in relationship to each other. The strength of this approach lies in its universal acceptance as defining the key dimensions of sustainability, which require joint attention; its weakness is due to the fact that it lacks the specificity necessary for practical implementation. They can be used in conjunction with other more detailed sectoral frameworks, as has been done in several places in this report.

Progress towards the development of sustainable development indicators (SDI) is under way in the United States where an Inter-agency Working Group on Sustainable Development Indicators (IWGSDI) have developed a framework to identify, organise and integrate national SDIs. The framework is proposed to cover all aspects of the earth system: society, economy and environment, and is based on the concept of endowments, outputs and the processes that act on both (see Figure 1.3). To date, IWGSDI have assembled a candidate list of some 450 indicators, drawn from a wide variety of sources, which are considered relevant to sustainable development issues. From this set, the SDI Group (IWGSDI) have selected 32 indicators considered necessary for measuring progress towards sustainable development. The indicators will collectively monitor the capacity of the United States to meet present and future needs.

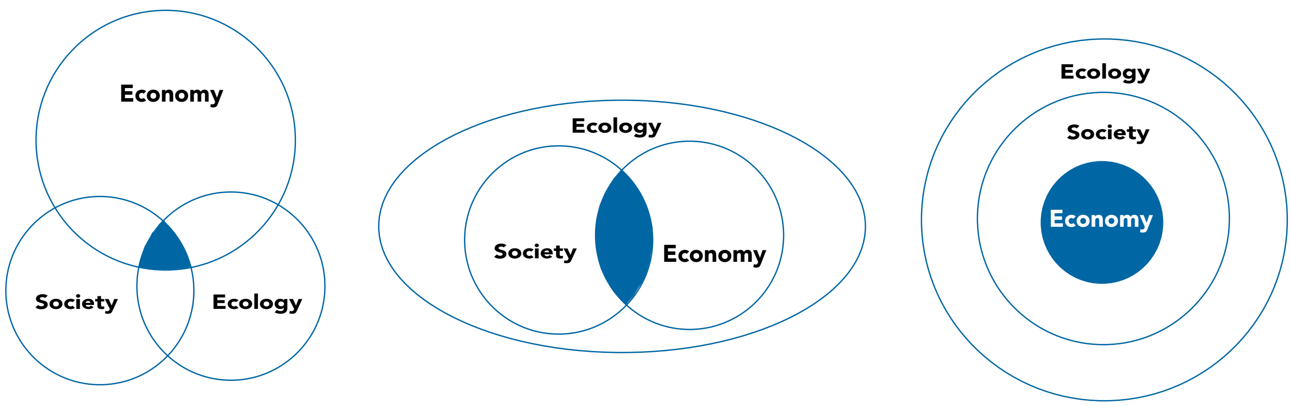


Figure 1.2: Models of sustainable development: changing paradigms.
Source: SoEAC (1996).

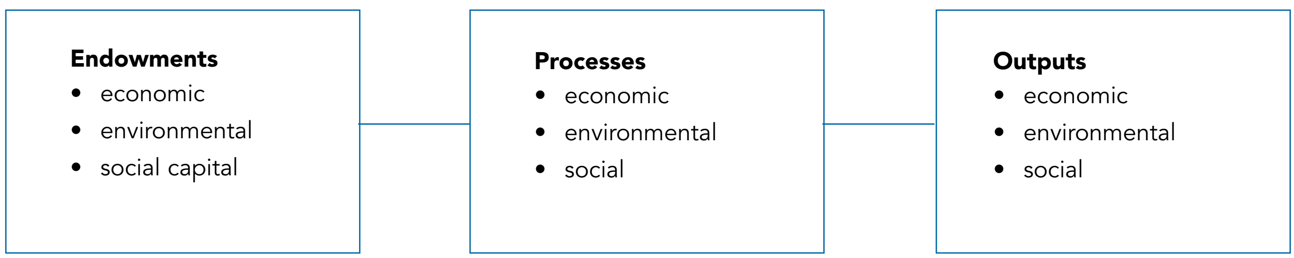


Figure 1.3: Sustainable development indicator framework.
Source: http://venus.hq.nasa.gov/iwgsdi/sdi_ol_framework.htm

A similar process could be followed at the conclusion of this round of SoE indicator development, whereby the total output from the seven theme reports constitute potential input within the *framework* of one or more guiding models—such as the US SDI model outlined above. Here, for example, *endowments* would be populated by a selection of state variables drawn from estuaries and the sea, inland waters, land resources, biodiversity, atmosphere, culture and heritage and human settlements (viz. human health, literacy, housing, mobility, industrial structure, etc.) which establish baseline conditions. *Processes* would include a range of activities—either natural or anthropogenic in origin (see Hamblin, 1998, p.16)—which operate on the matrix of endowments in a manner which is more or less beneficial to society. *Outputs* are necessary for the mapping of sustainability trajectories (see Figure 2.2) and the articulation of policies and action programs to direct private and public sector behaviour (see Figure 1.6).

Issue and goal-based frameworks

Issue and goal-based indicators emerge as a consequence of community concern in a particular area. Common examples of issue-based indicators include crime and safety, unemployment, urban sprawl, air quality, etc. Possibly the oldest approach to developing indicators is directly policy linked, and uses policy development concepts rather than system concepts. The original social indicators work of Bauer (1966) and other authors focussed on developing a comprehensive series of norms or objectives for social well being , and on finding indicators which would best measure progress towards meeting these objectives. These indicators were arranged following a sectoral approach, or sometimes an issue based approach.

This methodology was carried further in 1991-1996 by the United Nations Centre for Human Settlements/ World Bank Urban and Housing Indicators Programmes (Flood, 1997). The modified approach asks the question 'What is a well-functioning city?'. It seeks to represent all the major concerns or 'norms' in human settlements from the point of view of each major group of stakeholders or actors in the arena, and to develop indicators which will measure progress toward achieving each policy 'norm'. This approach has the advantage of taking a community-based, holistic approach to indicators which explicitly recognise the distinct views of different actors. The methodology is also very explicit about including only indicators for which some policy action may be taken; the philosophy is 'no policies without indicators, and no indicators without policies'. (UNCHS /World Bank 1994-6). A typical table of goals, indicators and policy responses from part of the UNCHS urban indicators system, showing key and other indicators for a range of policy goals, is shown in Table 1.1.

The model is driven largely by the policy process, by the need to incorporate the often conflicting views of different players in the policy arena, and in utilising indicators during policy and strategy development, during monitoring of outcomes, and during strategy reformulation and redirection. The advantages of the model are the highlighting of possible alternative viewpoints, the association of particular indicators with particular strategies and outcomes, and the incorporation of indicators as part of general policy development.

A disadvantage of the model is that it pays no attention to environmental causality except as already accepted within the policy process. While generally attractive to policy makers and other stakeholders in that each indicator is associated with explicit goals, issue-based approaches have been less appealing to modellers and physical scientists who prefer to use more explicit, objective and causal frameworks which may assist in establishing more complete and consistent indicator sets (Maclaren, 1996).

The Natural Step is a framework developed in 1989 by Karl-Henrik Robert for sustainability based on resource theory. Ashworth (1998) summarises National Step's four 'system conditions' as:

- nature cannot withstand a systematic build up of dispersed matter mined from the earth's crust;
- nature cannot withstand a systematic build up of persistent compounds made by human beings;
- nature cannot withstand a systematic deterioration of its capacity for renewal; and
- therefore, if we want life to continue, we must be more efficient in our use of resources and promote their fair distribution.

This normative model of sustainability is one which is relevant to all stakeholders of our urban systems, be they individual residents, private companies or governments. It was originally developed in Sweden as a tool for businesses to determine their priority actions for achieving sustainable economic practices (and, as such, could be viewed as a type of goal-based model).

Urban metaphors have also emerged in recent years as a source of powerful city-based goals, and are frequently featured in city promotional literature. Metaphors are often abstract representations of complex phenomena (such as cities) conceived in a way designed to deliver a message with maximum impact upon a particular audience (Siber, 1995). Spatial metaphors have been used to powerful effect in the market, in public policy and in academic polemics. Examples include: 'Information Superhighway', 'Better Cities', 'Livable City', etc. Their heritage is well established in the field of urban analysis, where well chosen metaphors represent important guides for thinking about the present and likely future working of cities. They frequently attract considerable debate and the rich content of the associated literature can be explored in a manner which may provide new insights into the way in which a city functions. A representative sample of urban metaphors identified from published literature are featured in Table 1.2.

Table 1.1

Urban environmental management: policy goals, indicators, and policy instruments

POLICY GOALS/SUB-GOALS	INDICATORS	POLICY INSTRUMENTS
Improve urban air quality • Achieve target for environmental quality standards • Limit emissions • Reduce respiratory disease • Minimise indoor and outdoor air pollution	Indicator: Air pollution concentrations Indicator: Emissions per capita Indicator: Acute respiratory deaths	• Standards/regulations/enforcement • 'Polluter pays' strategy • Infrastructure investment • Quality monitoring frequency • Public information and health measures
Improve urban water quality • Improve extent and effectiveness of wastewater treatment • Reduce costs and promote efficiency • Improve recycling of 'grey' water • Improve sustainability of water supply system	**Key Indicator: Percentage of wastewater treated** Indicator: Percent of Biological Oxygen Demand (BOD) removed Indicator: Cost of wastewater treatment Indicator: Lowering of groundwater table Indicator: Waste water recycled Indicator: Level of treatment	• Water resource planning • Investment in improved water treatment technology • Investment in improving and repairing the reticulation network • Use of recycling technologies
Improve provision of solid waste collection and disposal service • Improve access to solid waste collection and disposal • Improve affordability of solid waste collection and disposal • Improve convenience and reliability of solid waste collection and disposal • Improve recycling of waste • Ensure sustainability of solid waste collection service	**Key Indicator: Solid waste generated** **Key Indicator: Disposal methods for solid waste** **Key Indicator: Regular solid-waste collection** Indicator: Biodegradable waste Indicator: Recycling rate Indicator: Average cost of waste disposal Indicator: Cost recovery Indicator: Industrial waste generation	• Investment in solid waste disposal systems and collection services • Planning for future waste collection • Encouraging provision of recycling facilities • Full cost recovery pricing • Regulation of industrial waste disposal
Ensure sustainability of resource usage • Manage usage of natural resources on a sustainable basis • Reduce usage of non-renewable resources and emissions of carbon dioxide • Encourage food consumption at sustainable levels which preserve good health	Indicator: Energy usage per person Indicator: Fuelwood usage Indicator: Renewable energy usage Indicator: Food consumption	• Encouraging reduced energy usage through consumer information • Full cost energy pricing • Husbanding of forest resources • Improved health education and diet advice
Reduce effects of natural and man-made disasters • Ensure housing is safely located • Reduce deaths and property damage from natural disasters • Improve industrial safety	**Key Indicator: Housing destroyed** Indicator: Disaster mortality Indicator: Housing on fragile land Indicator: Fatal industrial accidents	• Releasing safe land for affordable housing • Regulation of dwelling standards • Provision of emergency services • Disaster planning • Enforcement of safety regulation in industry
Improve urban natural and built environment • Provide adequate green space for recreation, amenity and environmental enhancement • Minimise destruction of historic buildings	Indicator: Green space Indicator: Monument list	• Land use planning • Protection of heritage sites

Source: UNCHS (1993), Table A4.

Table 1.2

City metaphors as sources for human settlements indicators

City Metaphor	**Key Concept(s)**	**Exemplar Indicators**
Livable City	For some writers (eg. Pressman, 1981), livability relates to the scale and design of city spaces that maximise walking and minimise car use. For others it is a broader concept which includes a spectrum of quality of life factors that together deliver a city attractive to working and living (www.worldbank.org)	• Proportion of trips undertaken on foot or by bicycle • Broad range of indicators related to social and physical well-being
Ecological City	Ecological cities are distinguished by the degree to which environmental considerations are incorporated into decision making in both private and public sectors. An ecological city strives to become better at finding and implementing solutions to environmental problems (OECD, 1995).	• Use of ISO 14000 Standards • Existence of coordinated transport and landuse planning • Frequency of environmental incidents
Sustainable City	A sustainable city is an aspired to objective by an increasing number of government bodies at federal, state and local levels (Newman *et al.*, 1998). According to the United Nations' sponsored Program on Sustainable Cities (www.undp.org/un/habitat), 'a sustainable city is a city where achievements in social, economic and physical development are made to last'.	• Refer to set of Indicators in *Sustainable America* (The President's Council on Sustainable Development, 1996)
Multicultural City	The large contemporary city in the 1990s comprises myriad communities differentiated according to ethnic, socio-economic, political and gender processes—representing an unprecedented challenge to urban planners in developing strategies for efficient and equitable city building (Sandercock, 1998).	• Levels of social segregation based on race, political affiliation, social status, family status, gender and sexuality • Nature of political representation at municipal metropolitan and state levels • Appeal mechanisms and rate of overturned decisions
Healthy City	Concept associated with a World Health initiated program designed to place health on the agenda of the decision-makers in cities as well as build a strong lobby for health at the local level. The objective is to enhance the physical, mental, social and environmental well-being of the people who live and work in cities (www.who.dk).	• Indicators of physical, mental, social and environmental well-being
Safe City	Parts of cities in most countries are not encouraging of public (street) life as a result of fear of crime and general apprehension regarding safety. A range of strategies relating to urban design, surveillance and rule-making can contribute to emergence of safer cities and the associated economic, recreational and cultural benefits (Oc and Tiesdell, 1997).	• Crime statistics • Resident perceptions of neighbourhood safety • Police per 1000 population

Human Innovation City	A prosperous and satisfying urban future requires that we move towards a much more highly educated workforce and population and towards structures and organisations that create the necessary conditions for encouraging and rewarding creativity. Termed by some an innovative milieu (Maillat, 1991).	• Industrial innovations • Quality and qualifications of local labour markets • Number of small high growth firms
Information City	Cities are centres of information exchange and management (Meier, 1961; Hepworth, 1987; Castells, 1991; Newton, 1993)—face-to-face as well as electronic. Revolutionary advances in information and communication technologies will intensify the role of the city as an information hub and transform its structure and industry base. Related concepts are the Intelligent City (Droege, 1995) and the New Technology City (Blakely, 1991).	• Information industries • Information workers • Information infrastructure (networks and capacities) • Access to information technologies and services
Virtual City	Relates to the emergence of a new type of 'city' represented by a system of virtual spaces connected by telecommunication networks which convey data, voice and media (Mitchell, 1995; Philips, 1997). Related concepts include Digital City (composed of 'electronic spaces' designated as 'homes', 'theatres', 'bike paths', etc., where people with common interests can digitally interact (www.dds.nl).Related concepts are Wired City, Cybercity (Boyer, 1995).	• Penetration of telematic devices into homes and workplaces (eg. computers, fax, email, Internet, etc.) • Percentage of networks permitting digital communication • Amount of time spent in Cyber -space
Entrepreneurial City	Embraces the array of city-level local economic development initiatives created within the so-called 'rust belt' North American and European cities of the early 1980s designed to attract capital investment, new industry, new jobs and overall urban revitalisation (Judd and Ready, 1986). A concept which has subsequently surfaced in developing countries (Gaye, 1996).	• New capital investment • Job creation
Competitive Cities	There is intense competition between cities on a global basis to attract investment, key industries, key workers, and major events because cities are the economic engines of nations in the 21st century, where 90% of GNP is likely to be produced. The most successful cities will be in a position where they can choose among incoming economic activities, while others have to be content with what they can get (Brotchie *et al.*, 1995). Related concept Productive Cities (Brotchie, 1992).	• City's share of jobs, industries, events, growth, investment, etc.
The Exploding City	A phenomenon associated with western cities in the decades immediately following World War II when a combination of baby boom, rural to urban migration and international migration combined to induce high rates of urban growth that some commentators expected to continue—requiring massive infrastructure investments (Wright and Stewart, 1972). In more recent times, this phenomenon has been characteristic of cities in the Asia-Pacific region (Devas and Rakodi, 1993), although not exclusively (Stein, 1993).	• Rates of natural increase • Rural-urban migration • International immigration to cities • Urbanisation • Levels of infrastructure provision and access (physical and social infrastructure)

Mega-City	The processes of population growth, urbanisation, industrialisation and globalisation are combining to produce a multiplication and growth of giant cities, increasingly in less-developed countries. By 2010 there are expected to be over 500 cities with populations of a million or more (Doga and Kasarda, 1988; Hall, 1998). Related concepts include Ecumenopolis (Doxiadis—refer to journal *Ekistics),* Megalopolis (Gottman, 1986), World Cities (Hall, 1971).	• Number of cities with more than one million population • Percentage of world's population in large cities
Global City	Global cities are those that play a significant role in shaping the economic fortunes of cities and regions beyond their immediate hinterland. In relation to economic, cultural, environmental and educational issues they are regularly the key nodes (agoras) for knowledge exchange and dissemination (Sassen, 1991). Related concepts include the International City.	• Headquarters of international companies and organisations • Telecommunications traffic • Air passenger traffic
Compact City	Refers to the re-urbanisation, densification, and urban consolidation occurring in many western cities in the 1990s as a result of key shifts in locational preferences of certain types of household and certain classes of industry (eg. producer services) which favour the inner city compared to the outer suburbs. It also is linked to urban policies which favour higher levels of residential density, public transport and higher levels of utilisation of existing infrastructure (Jenks *et al.*, 1996).	• Level of public transport usage • Residential density • Average travel times for key activities (work, shop, etc.) • Level of mixed landuse
Edge City	Edge city is the term coined by Garreau (1991) to describe the contemporary form of growing American cities. The key element of this urban form is the existence of multiple urban cores. Los Angeles is the archetype. These cores have materialised as a result of the third wave of urban development, viz. the movement of jobs to the middle and outer suburbs, a trend which has followed the earlier movement out from the centre of population and housing and retail services.	• Office space • Retail space • Day time working population
Winter City	Emphasises the importance of considering the significance of climatological conditions in the planning and design process for settlements in extreme climatic zones (Pressman, 1990). Similar arguments have been made in relation to hot, arid regions (Golany, 1983; Brealey *et al.*, 1988).	• Energy efficient design
Sunbelt City	Term used to collectively describe cities in the south of the USA and UK and the north and west of Australia where high rates of population growth began to be experienced in the 1970s and 1980s in contrast to the population losses from the so-called 'rust-belt' (manufacturing) cities in the more temperate parts of each country. Key drivers for such population shifts included the attraction of sunbelt cities from a lifestyle and retirement perspective as well as investment in post-industrial industries such as tourism and high tech as well as resource-based industries, especially energy (Butler and Chinitz, 1982; Birrell *et al.*, 1995).	• Economic base • Growth rate of population, industry and investment • Age profile of residents • Occupation profiles

Australian City	As well as the significant influence exerted by the set of global forces which operate on and within cities to generate forms and structures which are common across different societies (here technological, market and demographic forces exhibit particularly strong influences), there are a set of additional factors which operate to distinguish cities one from another. Such factors include the dominant political and organisational structures, social and cultural influences, climatic factors, etc. (see Stimson, 1982)	• Ethnicity • Religion • Political system • Economic System • Population size • Climate • Resident attitudes
Historical Cities	Cities evolve over time, and each socio-technical era leaves its distinctive imprint or heritage, the most valued parts of which become embroidered into the ongoing fabric of the city. As such, in contemporary cities we find the 'walking city', 'the transit city', the 'automobile city', and perhaps in the early 21st century the 'telematic city' (Mumford, 1961; Pirenne, 1956; Newton *et al.*, 1997).	• Significant urban artefacts
Designer Cities	From time to time new visions for a city will emerge. Few are implemented in their entirety, but some of the underlying concepts attain wider implementation (Corden, 1977). These include: the Garden City, the New City / New Town, the Technopolis (Technopoles).	• City structure and form (viz paths, edges, districts, nodes, landmarks, element inter-relations, quality—after Lynch, 1960)
Intentional Cities	Concept which proposes that governments at all levels (local to national) need to be more pro-active in articulating a direction for future urban development that optimises efficiency, equity and environment (Troy, 1996). Also, that architect-planners need to be restored to their uniquely creative and integrative role in developing cities. It is considered that without this ingredient there can be no real city, just a mere aggregation of parts, or simply chaos (Jensen, 1974).	• Level of balance of public / private involvement in the process of urban development
Whose City	The central concepts developed by Pahl (1975) revolve around issues of access to, and allocation of, urban resources (eg. housing, schools, health centres, public transport, recreation areas, etc.). Key questions include: who gets the scarce resources and facilities? who decides how to distribute or allocate these resources? who decides who decides? Related concepts are found in Harveys (1973) *Social Justice and the City* and Smith's (1977) *Social Geography: a Welfare Approach.*	• Accessibility and affordability indicators related to key urban services • Level of public participation in urban decision making

Causal frameworks

A majority of environmental indicator studies are characterised by a listing of diagnostic variables which are likely to be *clustered* or grouped in a particular manner to reflect the generative *framework* that has been used in directing the work (see, for example, Department of Home Affairs and Environment, 1983). A major shortcoming of such studies, as outlined in the sections above, has been the absence of an over-arching *'model'* of the respective *domain areas* and the set of *linkages* that interconnect the key *elements* (indicators).

The pressure-state-response (P-S-R)[3] framework represents an advance in environmental indicator development in that it introduces the idea of cause and effect relationships. The framework was developed by the OECD (OECD, 1995) to differentiate indicators which respectively relate to human pressures on the environment, actual states of the environment, and the responses which may be undertaken to alleviate environmental damage. The emphasis of P-S-R is on causality within a systems diagram such as Figure 1.4, with flows between inputs, states, and outputs. It is particularly useful in focussing attention on responses to environmental problems, which are often a neglected area in indicator studies. It is most completely applied in the human settlements context in relation to Indoor Air Quality (see Table 3.3).

The categories of P-S-R are:

Pressures—policies, programs or activities (generally human) which affect the environment. In the case of urban transport, for example, pressures may include: changing patterns of travel demand by mode; urban density patterns; the siting of new housing or commercial development; tax deductibility for commercial vehicles regardless of size and efficiency; the fuel efficiency and pollution control requirements for vehicles; spending on roads and public transport; and local requirements for provision of parking spaces as a condition of new development.

States (Condition) observable conditions of various aspects of the environment of a defined place. For transport these may include: the level of emissions of different pollutants including CO_2; the number of cases of asthma reported in urban areas; the number and size of vehicles on the road; the number of kilometres travelled by various types of vehicles; traffic noise; accidents; the amount of fossil fuel consumed, and the distance of housing from public transport.

NATURE AND USE OF URBAN ENVIRONMENTAL INDICATORS

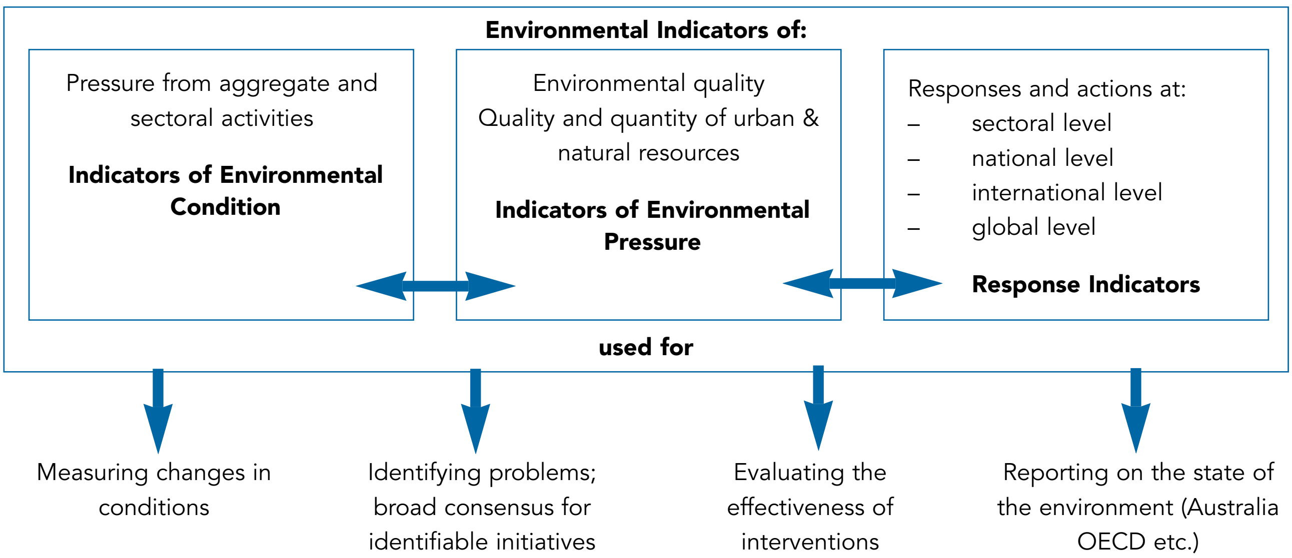


Figure 1.4: The pressure–state–response model in environmental reporting.
Source: Adapted from OECD (1994).

3 The P-S-R model is also termed by some as the condition-pressure-response (C-P-R) or condition-stress-response (C-S-R) model. In some studies (UN, 1996) the P-S-R framework has been modified to D-S-R (Driving forces-State-Response). Here the concept of pressure has been replaced by that of 'driving forces' in order to accommodate more accurately the additional social, economic and institutional indicators. In others, both 'Driving Force' and 'Pressure' have been *jointly* applied as affectors of State: Driving forces refer to socio-economic activities, while Pressures refer '...to the environmentally harmful products that may emerge from the socio-economic activities' (Kjellstrom and Corvalan, 1995, p.149).

Responses—are the actions taken to respond to impacts or impediments to sustainability. They may ameliorate or exacerbate the impacts. Where responses cause an increase in impact, they become further pressures. Responses to transport impacts could include: tighter air pollution requirements for new vehicles; reduction of the amount of lead in petrol; public transport pricing; traffic calming measures; construction of new roads and freeways to reduce congestion; encouragement of higher density housing development and locally based employment opportunities; increased sales tax on imported cars; tax deductibility and government employee reimbursement limited to levels for efficient vehicles; and programs to encourage companies to offer transport vouchers as alternatives to free parking.

Limitations of P-S-R

The model is a useful framework to apply to any environmental indicators set, with its focus on human causes and responses, but it has some acknowledged shortcomings. Firstly the implied cycle of cause and effect is simplistic; in particular the model only deals with human responses and not ecological (non-human) ones (see Hamblin, 1998); so that feedback from other parts of the physical environment to the phenomena under question is not usually part of the model.

Secondly, the distinctions between pressures, states and responses are not always clear-cut, because the focus of the viewer may change depending on the underlying objective, so that an indicator which is a pressure in one perspective may be a state in another and a response in a third. For example, an indicator such as 'Number of housing starts' can have different interpretations. If the perspective is the use of resources in housebuilding and the effect on environment and land use, then the indicator is a Pressure. If the focus is on the activity of the building industry, then it is a State. If the focus is on housing shortage and homelessness, then it is a Response. It is therefore necessary to specify the perspective or the policy objective before an accurate decomposition into P-S-R can be undertaken. Thirdly, it lacks the intergenerational dynamics inherent in sustainability approaches to future paths of development. Fourthly, there is a tension in applying it to human settlements, since human activities are generally considered to be pressures (see all other Indicator reports in this series). Yet human settlements are entirely the result of human activity. Therefore, the 'human environment' must be considered a pressure on itself. These shortcomings notwithstanding, the Australian SoE Report in 1996 adopted P-S-R as its guiding framework, as have the subsequent Indicators studies. In Australia the modified Condition-Pressure-Response model is increasingly being used.

There is a further element that needs to be built into a C-P-R model applied to human settlements that recognises the *macro* processes that exert pressures on urban centres in late 20th century society (Sassen, 1995). As such, we propose to add a set of *Macro (or Exogenous) Pressures* (ie., influences exerting their presence beyond national borders) to those Endogenous Pressures which are more closely aligned to a particular built environment domain (see Figure 1.5). The key macro-level pressures associated with Australia's human settlements are: international migration; economic growth; globalisation in the context of trade and economic dependency; and technological change in energy (renewable)[4] and information processing and communication.

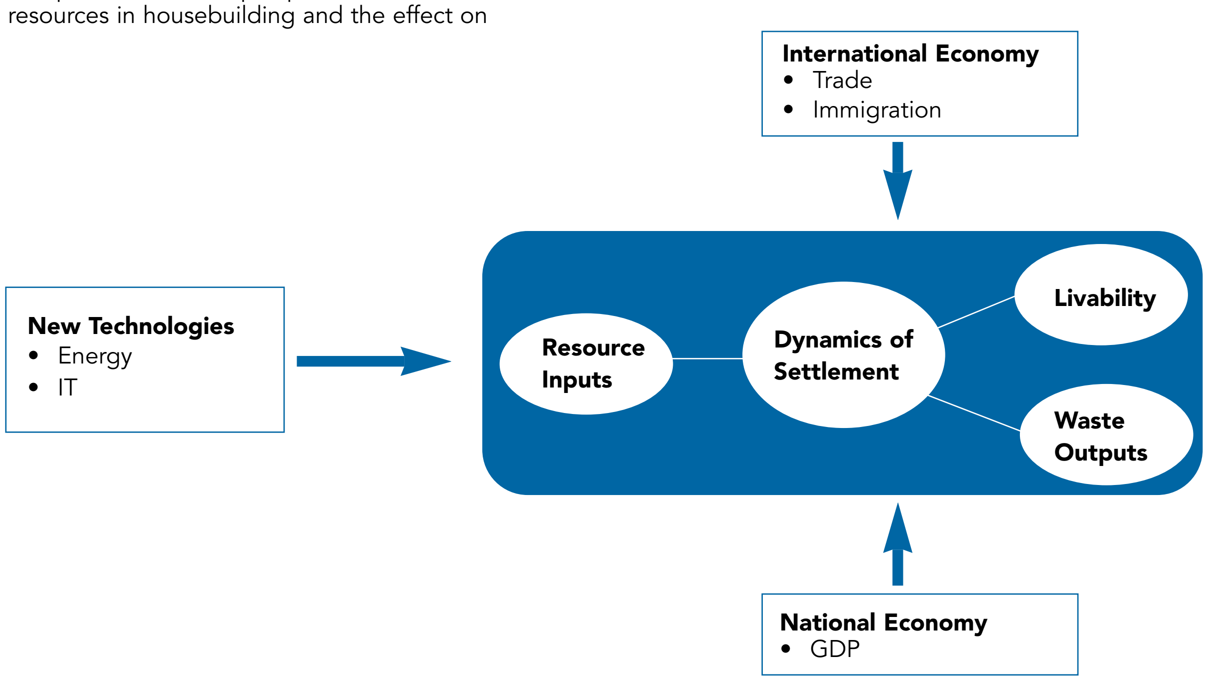


Figure 1.5: Macro-level context for human settlements indicator development.

[4] It could be argued that renewable energy is not a major pressure for Australia, given its status as an energy exporting nation. Renewables are, however, gaining greater significance within Australia in the light of international environmental fora (e.g. Kyoto, December 1997).

Sectoral and domain frameworks

Indicators developed on a sectoral basis respond primarily to the requirements of government departments at all levels (Local, State, Commonwealth); for example: transport, housing, employment, social welfare and environment. As such they can be narrowly focused (ie., restricted to those areas for which the Department is directly accountable) and may fail to capture the complexity inherent in major urban settlements (the strong linkages between housing, employment, transport and the environment are one example).

An alternative to using industry or societal sectors is to use *domains,* which are similar to sectors but reflect specific disciplinary areas or areas of expertise (as reflected in the cells in Figure 1.1). To some extent, it is necessary for any SoE report to make use of a domain framework for human settlements, simply because experts are necessary in each domain to develop credible indicators with a substantial scientific or disciplinary backing.

The brief for this report required the development of a scientifically credible set of environmental indicators that also have relevance to policy-makers and practitioners. This requirement has influenced the selection of the study team for this report and the approaches to (domain) model development and indicator specification utilised in this study (refer to Figure 1.6).

Basic research is necessary to derive the underlying principles and interactions which permit an understanding of *system processes* in the different domain areas. It is imperative that indicators reflect a thorough understanding of the systems they are to monitor. As such, conceptual models are developed in each domain area as context for the indicators which represent the key processes and issues within each domain area of human settlement.

An appreciation of the policy environment is also necessary in order to define *key issues and objectives*, while *targets* need to be informed by system parameters as well as social or policy imperatives. From the objectives, *action programs* must be set in place which enable targets to be met, and then indicator values are used as *monitoring and evaluation* tools for the success of the programs.

The approach subsequently used in this report has been to firstly construct models of system processes within each human settlement *domain area* in the context of which individual indicators and linkages are subsequently outlined; secondly, develop indicators separately for each domain and to revise these in collaboration with experts from other domains: urban design, population, housing, water, waste, transport and access, indoor air quality, health, energy and noise[5]. *Domain models* are developed for each of these areas to assist in obtaining as comprehensive a picture of causality as possible. These make use of, *inter alia*, extended metabolism, sustainability, and condition-pressure-response frameworks at each domain level, and are outlined in the third section. Before proceeding, however, we address several of the key methodological issues associated with developing environmental indicators for human settlements.

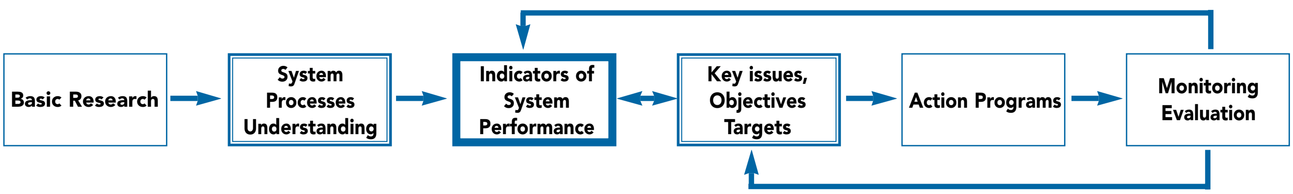


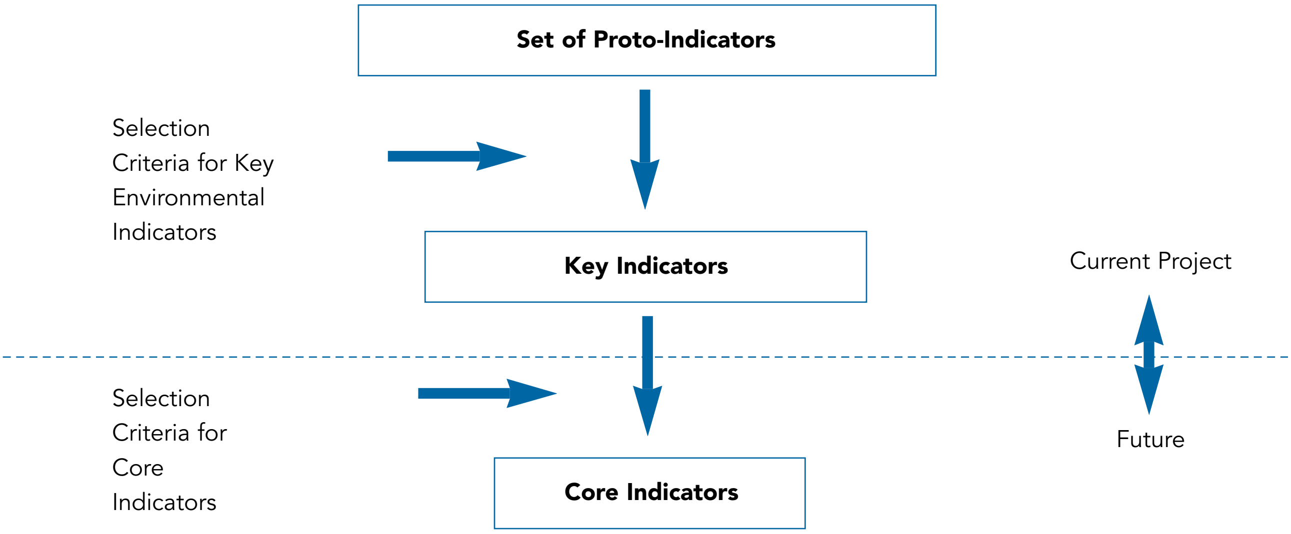
Figure 1.6: Integrated process for environmental indicator development

[5] Those domains and indicators included in this volume were selected through an interactive process of discussion within the team and with other experts in the relevant fields (including the workshop process, interactions with the ANZECC SOE Taskforce and Environment Australia. The set of domains and indicators are not exhaustive but constitute a balanced set, trading off the cost and data requirements against completeness. Two domain areas for Human Settlements which might have been expected in their own rights are materials and industry. The reality is, however, that relevant key indicators capable of being assembled against the above two areas exist within other domains in this report as well as the companion reports in this series (see list at the end of this publication). For example, against materials and industry we have the resources used in building and construction as well as the suite of energy resources, land resources (in Hamblin, 1998) and the increasingly important information industries and distributive industries.

Methodology

Selecting Indicators

The principal objective of this report is the identification of a set of key environmental indicators for human settlements in Australia. The process we have followed is outlined in Figure 2.1.



Proto-indicators are a collection of indicators derived from a comprehensive search of extant indicators studies undertaken in Australia and overseas.

Key environmental indicators are the minimum set of indicators which, when properly monitored, will provide rigorous data describing the major trends and impacts on the Australian environment.

Core environmental indicators are those that are useful for identifying environmental trends at all spatial scales, thus requiring a consistent reporting basis across jurisdictions.

Figure 2.1: Process for developing environmental indicators of human settlements.

The process used was to collect a wide range of indicators from many sources including suggestions from the study team, then to subject these 'proto-indicators' (see Appendix 1) to a ranking against the five criteria listed under Environmental Indicators (p 8). The results for the most significant of these, which have been chosen as the key indicators for human settlements, are discussed in detail in under Key Environmental Indicators and summarised in Appendix 2. As well, categorisations against the major model frameworks are shown—the urban metabolism model, Condition-Pressure-Response, and sustainability spheres (Economic/Institutional, Social, Natural Environment).

Reporting scale: defining human settlements for SoE indicator development

Defining what is urban is increasingly problematic in societies where broadband communication and networked computing have essentially delivered Webber's (1964) once-prophetic 'non-place urban realm' as a reality. Urban centres defined along traditional lines using *political-administrative* boundaries, however, continue to be by far the most common units for data collection and analysis (the most fundamental building block being the census collector's district, CCD). *Functional urban regions* represent a more realistic conceptualisation of an urban centre's economic reach, where boundaries are typically drawn on the basis of daily travel fields. As freeway and fast rail networks begin to link cities with their hinterlands and neighbouring cities, boundaries extend further. With modern communications, the prospect of *virtual cities* is an increasing prospect for certain areas and groups. With globalisation in trade, the *ecological footprint* has emerged as yet another concept for defining an urban centre, albeit primarily in an environmental impact context.

In 1996, 86 percent of Australia's population lived in 741 urban centres (see Table 2.1).

Table 2.1

Number of urban centres and localities, Australia, 1996

Size of Urban Centre	Population	Percent share	No of urban centres
1,000,000 and over	8,529,482	47.7	4
500,000 - 999,999	978,100	5.5	1
100,000 - 499,999	1,650,347	9.2	8
50,000 - 99,999	546,220	3.1	8
20,000 - 49,999	1,197,677	6.7	42
10,000 - 19,999	689,243	3.9	51
Less than 10,000	1,790,533	10.0	628
Total Urban	15,381,602	86.0	741
Localities 200-1,000	450,267	2.5	919
Rural balance	2,049,248	11.5	
Total	**17,881,117**	**100.0**	

Source: *ABS (1997), Demography Section, Special Tabulation.*

Note 1: *This table represents the entire 1996 Australian census count.*

Note 2: *ABS (Statistical Geography, Vol.3, 1995, pp.6-8, Cat. No. 2909.0) delimits urban centres via two methods. For centres with a population of 20,000 or more, definition relates to areas formed by aggregation of contiguous CDs (collector districts) which have a population density of 200 or more persons per square kilometre. For centres with a population less than 20,000, urban delimitation is undertaken subjectively by inspection of aerial photographs. Localities are population clusters of 200-1,000.*

Fifty-three percent of the nation's population live in the five largest cities (Sydney, Melbourne, Brisbane, Perth and Adelaide) which are also the capitals of the most populous states. A further 10 percent of the nation's population live in the remaining capital cities—an overall proportion (63 percent) which has remained relatively constant since 1971. Almost two-thirds of Australia's population live in cities above 100,000. Many of the remaining urban centres are provincial cities or towns in rural areas. Remote towns and indigenous settlement accommodate around 2 percent of Australia's population (Newman *et al.*, 1996).

In the context of identifying and scoping environmental indicators for human settlements the issue to be considered in each instance is whether a specific indicator is liable to demonstrate a *scale effect*. In other words, are there domain areas of human settlements where the size of settlement affects metabolic, economic or social processes? If so, statistical data for indicator development should be obtained across the full spectrum of the urban hierarchy (as outlined in Table 2.1). There are several areas where scale effects have been identified for human settlements. These include economic domains (viz. income differentials, housing costs) as well as environmental domains (viz. ambient air quality).

In other domain areas—especially those concerned with human health and access—in a continent the size of Australia, *remoteness* will also likely emerge as a factor affecting the behaviour of specific indicators. If this is expected to be the case, then statistical data for settlements should be sampled to reflect *metropolitan,* *rural* and *remote* milieux. This process has been followed in the recent study of health in urban, rural and remote areas of Australia (Titulaer *et al.*, 1997) using the DPIE & HSH (1994) classification.

There are many instances where level of aggregation involved in particular indicators requires careful consideration if the heterogeneity inherent in the larger settlement systems is not to be inappropriately submerged as a result of attempting to simplify comparison. For example, is there likely to be greater variability *within* an urban classification than *between* urban and rural or urban and remote classifications? At another level, aggregation internally across cities can mask important realities; for example, the variability across cities in relation to population density, incomes, air quality, etc.

There are other domain areas where scale and remoteness may have little, if any, impact. Rather, there are domain areas where indicator variability is likely to be experienced more significantly on a *sectoral basis* than a spatial basis. Energy is an example where sectoral effects are likely (viz. differential energy consumption between domestic and industrial sectors; between sectors of industry; between different types of housing, etc.). As well, there are indicators which reflect geographic *(climatological)* position in addition to those listed above. Obvious contenders here are indicators relating to domestic energy use and commercial energy use. And given Australia's distinctive settlement geography that favours development in coastal areas, a *coastal versus inland* classification and sampling frame can, on some occasions, be warranted.

Given these factors, the following *categories* are employed within the Report in designating an appropriate *Reporting Scale* for each indicator within a domain area as a guide to the nature of sampling of urban centres considered necessary to capture the full environmental character of Australia's human settlement system:

MU – sample only settlements with more than 100,000 population *(major urban).*

UH – sample settlements based on full national *urban hierarchy.*

URR – sample settlements that are representative of *urban, rural* and *remote* milieu.

LG – sample settlements at *municipal* (or statistical local area) level in order to pick up intra-metropolitan variability.

C/I – sample on the basis of *coastal* versus *inland* regions.

C – sample on the basis of *climatic* regions.

S – primarily *sectoral,* limited settlement effect; sample on basis of national industry profile, national housing profile, etc.

Units of measurement

Each indicator will have a nominated unit of measurement considered most appropriate to its representation (see Section 4). These may include:

- *intensity* indicators, eg. number, volume, mass, etc.;
- *exceedances* (related to some threshold or standard);
- *extremes* (percentiles, etc.).
- *normalised* indicators, eg. per capita, per m2 / km / hectare, etc.

Spatial statistics, perhaps more than any other class of statistic, possess the capacity to 'disguise' key features, trends or relationships. The ecological fallacy problem is well known in this regard (King, 1997) as are issues related to area homogeneity versus heterogeneity (Newton and Johnston, 1976). As Table 2.2 indicates, frequently more than one metric is required to adequately convey the 'performance' or 'behaviour' of a particular city or region. In the urban pollution illustration, *per capita* statistics reflect aspects of individual behaviour with respect to issues such as vehicle ownership and usage and mode choice; while *per hectare* statistics are more reflective of urban forms and landuse-transport configurations.

Table 2.2

Transport pollutant emissions in selected metropolitan areas, circa

Cities	Emissions of VOCs (per year)	
	Kg/capita	**Kg/ha**
Average Australian	23.0	294
San Francisco	21.7	347
Frankfurt	12.1	564
Tokyo	2.0	209
Hong Kong	2.4	721
Kuala Lumpur	22.8	1338
Bangkok	23.2	3464

Source: Kenworthy et al. (1997); Newton (1997).

Performance standards and thresholds

Environmental thresholds represent the point or level at which a particular pressure is of sufficient intensity or impact to begin to produce a change in the state of a particular system (human, physical or built environment) which if maintained would threaten the sustainability of that system (see Figure 2.2).

In a number of domain areas, such as ambient air quality, water quality, noise, and thermal performance, knowledge is accumulating to a point where it is becoming possible to advance *performance standards.* This has been done in some detail in the Netherlands environmental reports (Adriaanse, 1993)[5]. In other areas, such as access to services, indoor air quality, population, transport, etc., we are still some distance from achieving this level of understanding.

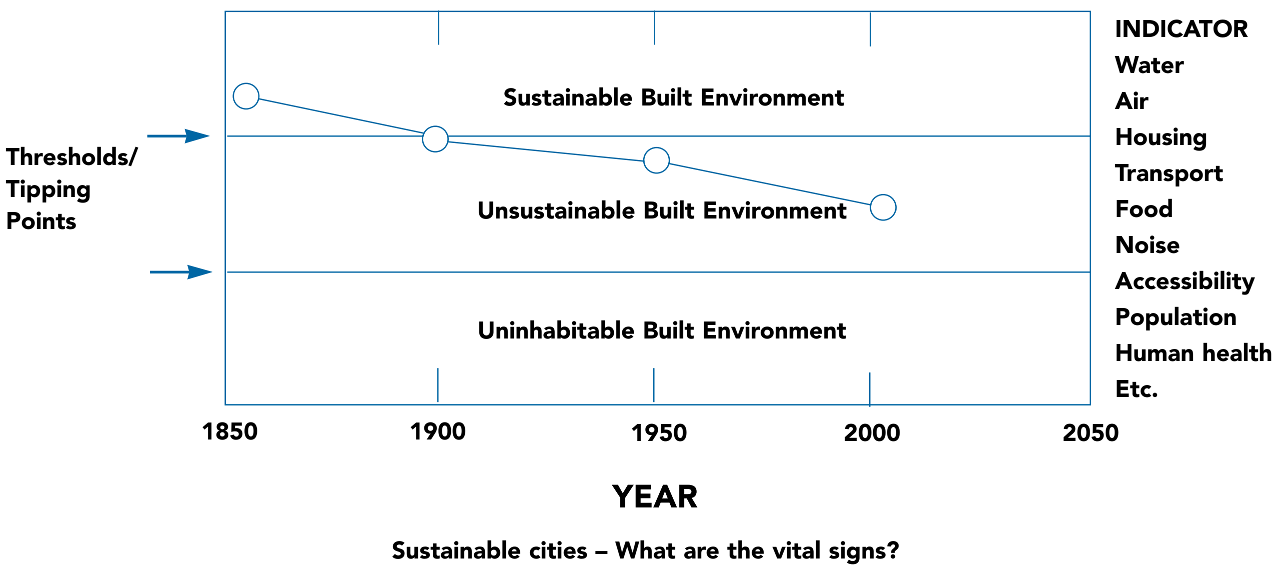


Figure 2.2: Significance of Thresholds in Mapping Sustainability Trajectories

[5] Some of the performance goals used by Adriaanse are rather ad-hoc and have not yet gained a firm scientific basis or policy agreement.

Human Settlement Domains

Indicators have to reflect a thorough understanding of the systems they are to monitor.

In developing environmental indicators for human settlements the extended metabolism model or its variants have much to offer. The extended metabolism model of human settlements (discussed in Chapter 1) identifies several *domain areas* in respect of *resource input, settlement dynamics, livability* and *waste output* that call for development of key indicators. Among Resource Inputs, for example, *energy* emerges as a key domain area, given its fundamental role in changing the shape and character of human settlement over the past two hundred years (Ryan, 1980) and its role in the current transition of society to one based on renewable resources.

Urban design is one of the key domain areas in Settlement Dynamics in that it embodies the processes by which settlements are shaped, how different land uses and populations (residential, commercial, industrial, transport, etc.) are distributed—in short, how the three sustainability principles of efficiency, equity and environment are implemented in particular geographic settings/political jurisdictions to deliver a distinctive urban form and system performance.

Air pollution[6], *greenhouse gas emissions, noise, solid and liquid wastes,* etc., represent key domain areas in Waste Outputs within the extended urban metabolism model. Activities of industries, transport and resident populations all contribute to pollutant emissions, albeit in different ways (by virtue of the source/type of emission), at different spatial scales and with different impacts (on human health, buildings and amenity).

In the sections that follow, a set of domain models have been developed for the following: energy, water (Resource Inputs), transport and accessibility, population, urban design (Settlement Dynamics), noise, water quality, waste generation (Waste Outputs), housing, indoor air quality and human health (Livability), providing the framework within which both key and (subsequent) core environmental indicators are developed.

Key resource inputs to human settlements

Energy

Energy is fundamental to the operation of modern urban environments; it is central to the provision of goods and services, to production in industry, to mobility, to comfort and livability in the domestic context. While these needs can be satisfied in many ways, some are more energy intensive than others, some cheaper or more convenient. At this time, the choice is seldom mandated by legislation in Australia. Earlier studies have indicated measures to reduce consumption or increase the efficiency of production and use of energy, but market failures often mitigated against this with the result that energy use is increasing at a rate which may be viewed as unsustainable in the long term. Governments have therefore initiated programmes to encourage implementation of efficiency measures to reduce energy consumption and environmental impacts. Some of the programmes involve fuel substitution, education, implementation of improved technologies, promotion of renewables and energy reform. Indicators will provide *inter alia*, a measure of the success of these programmes. Notwithstanding such programmes, there are continuing subsidies to energy use (eg. road freight) as well as policies likely to inhibit conservation (viz. recent reforms to the electricity industry, aiming to make power cheaper).

Energy is at the core of the extended metabolism model that was used to describe the operation of urban systems in the 1996 SoE Report. The domain model for energy applied in this report is shown in Figure 3.1. This conceptual model, which is equally valid for a multitude of other non-organic systems, reflects the need to input energy (and in a practical sense, materials) into the urban system. The system transforms these inputs through work processes into products and services for livability, and also wastes in all its forms, including energy. However efficient we may aspire to become, waste will remain inevitable since there must ultimately be a sink to all energy processes, and that sink will inevitably have a finite energy level. The main question that arises is how efficient is our urban system?

Energy is produced from a range of raw inputs. It is transported or transmitted, transformed or used. In each of these processes, there are inherent inefficiencies and some energy is rejected to waste as a mini-metabolism. Since the operation of our urban

[6] Ambient air quality is examined in Manton and Jasper (1998)

environment and the impact on the natural environment are critical to these inefficiencies, it is important to determine measures of the energy use, useful outputs and by implication, the efficiency of the urban system.

The urban environment cannot prosper without using energy and yet, generation and use of energy have some negative consequences for the environment. The sources of energy determine the magnitude and extent of these environmental impacts, which may in turn limit sustainable growth if kept unchecked. Typically, energy contributes over half the greenhouse gas emissions in Australia and the impacts viz-a-viz greenhouse are primarily concerned with emissions of CO_2 (67% of CO_2 emissions is energy related). Other issues contributing to the nexus between energy use and environmental impacts are emissions of particulates and noxious gases (which may or may not also contribute to the greenhouse effect), residues (which put a load on the system through disposal) and depletion of resources (which also impact on inter-generational equity).

Energy consumption in Australia is sourced mostly from fossil fuels: 40% from coal, 37% from oil and 17% from natural gas. Each fuel imposes a different load on the environment and emits different quantities of greenhouse gases (in CO_2 equivalent) per unit of energy consumed. Gas is the least emitting of these fuels and it is encouraging to see the trend for its increasing use relative to the other fuels. It is sometimes assumed that the use of energy from renewable sources (currently between 5 and 6%), will solve all environmental problems. Indeed, this may be the case when using solar, wind or wave energy, as the environmental impacts vis-a-vis greenhouse are irrelevant (although visual impact may not be). However, this may not be the case when using wood as a source of heat, even when the timber is grown sustainably. While CO_2 emission from biomass energy systems is balanced by CO_2 uptake when the biomass is grown, other emissions affecting air quality are reduced, but not eliminated.

Currently the cost of renewable energy technologies (except from traditional sources such as hydro-electric) is only competitive in niche markets where conventional energy costs are high. For example, Australia is at the forefront of photovoltaic electricity systems (which are particularly well suited to dispersed population centres). While the capital cost of these systems is high, successful penetration into the Asian markets may provide Australia with the economies of scale to improve their competitive position.

Energy production

Energy production in Australia is dominated by the production of black coal (49 percent) and uranium (22 percent). Other primary sources of energy are brown coal (5 percent), crude oil (10 percent), natural gas (11 percent), LPG (1 percent) and renewables (2 percent) such as hydro-electricity, wood, bagasse, solar and wind energy. However, not all production is for Australian consumption; indeed, the greater proportion (69 percent) is exported offshore. Three-quarters of black coal production, all uranium and one third of crude oil production are exported. Less than 10 percent of the total energy production is imported to supplement crude oil needs.

Secondary energy sources, such as electricity and petroleum products are derived from the above primary sources through conversion processes that are themselves limited in efficiency. Electricity generation has grown eightfold between 1960 and 1994. This expansion was driven by growth in large electricity consuming industries (eg aluminium) and increased electricity consumption in the commercial, residential and manufacturing sectors.

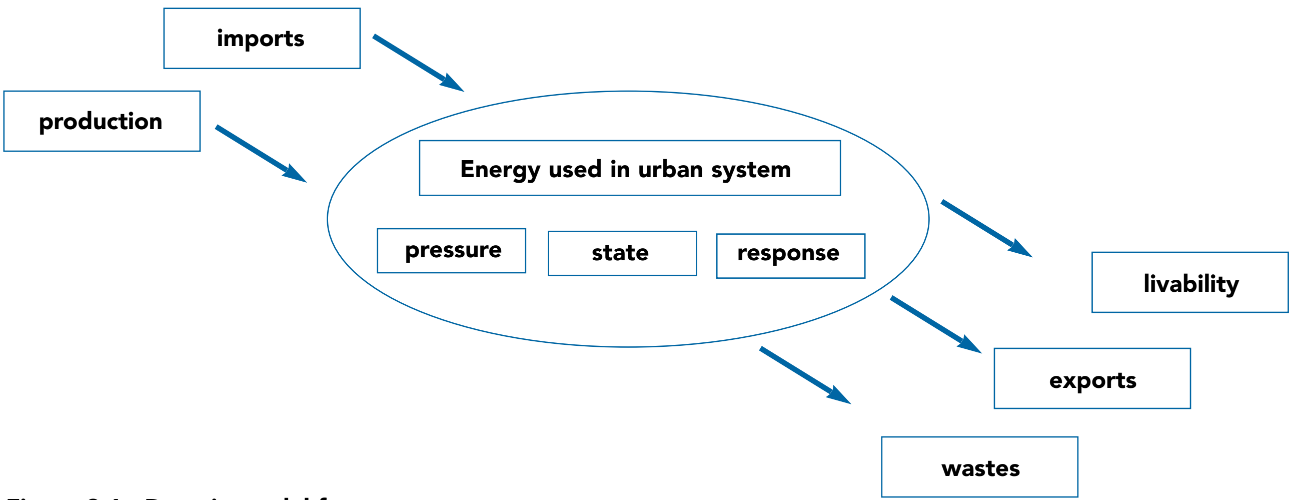


Figure 3.1: Domain model for energy.

Energy consumption

In the context of the urban environment, energy consumption is a measure of production effectiveness or profligacy. In the short to medium term, it provides the greatest opportunity to control and reduce greenhouse gas emissions. Energy consumption in Australia has increased steadily since the 1970s and in the last ten years the rate of growth has been just over 2 percent per annum which is faster than the OECD average of 1.1 percent. Some of this increase is associated with an economic growth of 3 percent experienced over the same period of time. However, the increase has not been uniform over the range of energy sources. Indeed, among the primary fuels, natural gas has shown the greatest increase, at the expense of crude oil whose decline reflects a shift to other fuels for stationary applications such as boilers, kilns etc for water, air and process heating. On the whole, energy intensity, which is defined as the energy use per unit of output has decreased (albeit not steadily) since the mid-seventies, reflecting an increase in 'efficiency'. This is therefore an appropriate measure of the energy effectiveness of industry and the relative energy intensity of different industries. For example, the most energy intensive sector of the economy is the electricity gas and water sector at 88PJ/$b[7] while manufacturing industry on average uses 19PJ/$b. Within the manufacturing sector, the range is very wide; it is high for metal production at 50PJ/$b and as low as 0.8PJ/$b for the commerce and services sector or 1.6PJ/$b for the construction sector. This wide variation in energy intensity presents a problem when comparing different economies or different sectors, as we shall explore in the following section.

Indicators of energy use

Indicators of energy use are usually expressed as intensive quantities of total energy use, production, or consumption, normalised to facilitate comparison. The normalising factor could be sectoral output or contribution to GDP, population or residential area. The ratio of energy use to the normalising factor however, conceals a number of effects, even when the energy data and the normalising factor are known. Consider for instance the energy use per $ contribution to GDP (at constant prices) for a particular sector of the economy. The fact that this indicator may be changing, say reducing over time, is an indication that energy use per unit output is dropping. However, this in itself does not guarantee a more efficient operation because the indicator says nothing of the structure of that sector and whether this has also changed. The indicator combines efficiency of energy use, the structure of the sector and fuel and technology efficiency. There is a hierarchy of indicators, from the most detailed to the most aggregate to describe the performance of a sector. Typically, one could report process efficiencies at the most detailed level, rate of utilisation or quality, sub-sectoral or sectoral intensities en route to sector totals. Each of these provides a different level of analysis.

ABARE (1997) uses energy intensity as an 'indicator of the change in energy use pattern .... the amount of energy consumed per unit of activity. Energy intensity is influenced by a number of factors, particularly the structural make up of the economy; that is, the relative size of energy intensive and less energy intensive sectors, output and the intensity of energy use within sectors'. One can use the same argument at the sector level, disaggregating sub sector components or end-uses. The technique to determine the impact of any one of these components, holding the others constant is called factorisation. ABARE provides the following diagram to explain the components.

The production effect is the change in energy use caused by a change in the level of activity while the structural effect is the change in energy caused by a change in the relative share of intensive and less intensive sectoral contributions.

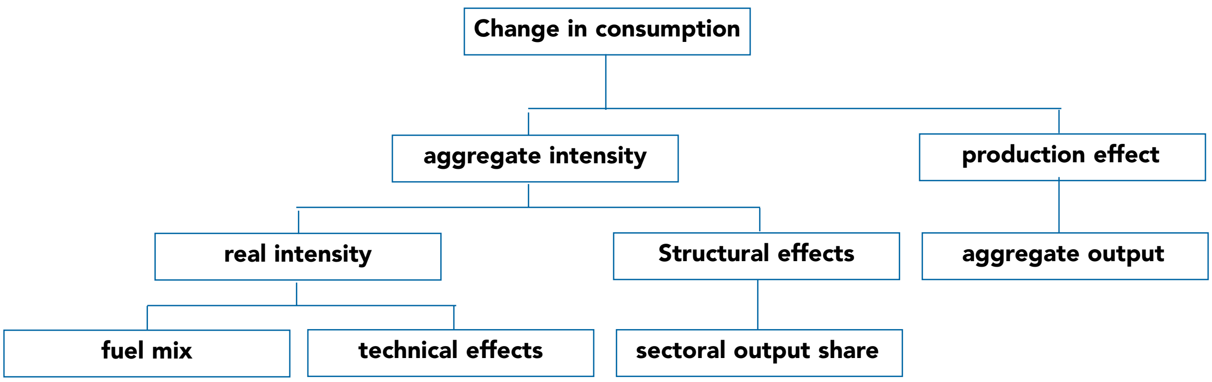


Figure 3.2: Factors leading to change in energy use.
Source: ABARE (1997).

[7] Energy is measued in Joules (or for large quantities Peta Joules: 1 PJ=10^{12} J, Giga Joules: 1 GJ=10^9 J, Mega Joules: 1 MJ=10^6 K) or kWh (1kWh=3.6×10^6 J). The reference for output is usually GDP.

The key indicators presented under Key Environmental Indicators (p. 58) will not provide the tools for a full analysis. Nor are they intended to. It is important, however, while recognising the overarching nature of these key indicators, to recognise also their limitations. It was pointed out in the previous section that total energy consumption has increased at a little over 2 percent pa. and that economic growth has been approximately 3 percent pa. The ABARE report also shows that the growth is caused exclusively by a combination of production and, albeit to a very small extent, structural effects. Technical and fuel effects contributed to reduce aggregate intensity by 15 percent between 1973 and 1994, while structural effects contributed a minimal increase of 0.6 percent. Production effects contributed an increase of 78 percent. In the absence of technology improvements, Australia would have therefore experienced an increase in energy utilisation of 78 percent. Instead, the increase was 52 percent. Australian industry as a whole is now more efficient in the production of goods and services, but it also produces much more than it did in 1973. The implication of imposing severe restrictions on Greenhouse gas emissions is obvious. However, this is no justification for complacency. Several studies suggest that within a no-regrets scenario, there are further opportunities for energy reduction, with consequent savings in Greenhouse gas emissions.

Government initiatives

A key factor driving the development of energy efficiency policies in Australia will be the 1998 National Greenhouse Strategy (NGS) and complementary government initiatives such as the Prime Minister's 'Safeguarding Our Future' Statement of November 1997. Action including the development of Energy Performance Codes and Standards for Housing and Commercial Buildings as well as Domestic Appliances and Industrial Equipment will be developed in conjunction with States and Territories. The Commonwealth Government is working with the Motor Vehicle industry to develop an Environmental Strategy for that industry and voluntary programs to involve industry and local government in greenhouse gas emissions reduction will include the Greenhouse Challenge Program, Bush for Greenhouse Program and Cities for Climate Protection Program. The Statement denotes an important shift by the Government beyond the no-regrets framework for greenhouse response action.

An initial set of primary performance indicators for Australia's greenhouse response, including energy, was endorsed by CoAG in mid 1996. A comprehensive set of both primary and secondary indicators will be developed following finalisation of the National Greenhouse Strategy (NGS) which will consider the current set of indicators and look at their appropriateness given the new NGS. These indicators are discussed more fully in the report on environmental indicators for the atmosphere (Manton and Jasper 1998).

Table 3.1 illustrates a framework for specifying indicators of energy relevant to urban settlements. An asterisk identifies Key indicators. A full description of these key indicators follows later.

Water

Water is one of Australia's most precious natural resources. It supports human, plant and animal life, and the natural environment; promotes economic opportunities; and provides beauty and enjoyment to many (US EPA, 1996). It is of particular importance in Australia. Despite being the driest inhabited continent, Australia has one of the highest total water consumption levels per head by international standards (OECD, 1995; DEST, 1996), and in the context of Australia's future growth and development, water resources will come increasingly under pressure.

Water supply

Water is diverted from a number of sources: surface waters (including rivers, streams, lakes, reservoirs and wetlands) and groundwater. Most of Australia's rivers are short and coastal, or ephemeral (only running in the wet season). There are 245 river basins in Australia's 12 Drainage Divisions. In 1987, the amount of divertible surface water resources in these drainage divisions totalled over 100,000 gigalitres, and in 1993 total storage capacity was estimated to be 81,000 Gl in 1993 (ABS, 1996). Storage is mainly in the form of dams and reservoirs, which provide water for urban use, hydro-electric power generation, flood mitigation and multi-purpose development (ABS, 1992). Groundwater underlies about 60 percent of Australia (or 5.2 million km2). About 80 percent of Australia (by area, as distinct from population) is dependent on groundwater supplies, and of that, 20 percent relies on groundwater as the dominant source (ABS 1992; ABS, 1996). About six hundred small communities in Australia depend mainly on groundwater for their domestic water supply (ABS, 1996).

Water demand

Water withdrawal (demand) is a major pressure on freshwater resources. It has a range of uses within agriculture, mining, manufacturing, urban and natural environments. Agriculture is the main user of water in Australia, with irrigation accounting for approximately 70 percent of all water used annually (10,240 Gl). 'Urban and industrial' mean annual water use, which comprises domestic, industrial and commercial accounts for 20 percent (3,061 Gl) in total. Non-irrigated rural activities accounts for 9 percent per annum (ABS, 1996).

Table 3.1

Energy Indicators

	PRODUCTION	IMPORTS	ENERGY USE*							EXPORTS
			Industry*	Domestic*	Commerce*	Transport*				
			1 2 3	1 2 3	1 2 3	Road	Rail	Air	Sea	
Natural gas										
Liquid Petroleum Gas										
Electricity										
Black Coal										
Brown coal										
Oil										
Renewables Total										
- hydro										
- solar										
- wind										
- wood										

	SECTOR								
	Government	Industry	Domestic	Commerce	Transport				
					Road		Rail	Air	Sea
					Publ.	Priv.			
Expenditure on energy Progs									
Unit cost of * Natural gas									
Liquid Petroleum Gas									
Electricity									
Black Coal									
Brown coal									
Oil									
Renewables									
Drivers* Population									
Gross Domestic Product									
# cars									
Travel/mode									
Car economy									
Average home area									
Service floor area									
Value added (industry)									
Greenhouse strategy									

Response to water supply/demand issues

A range of responses have been initiated to address our constrained water supply situation which is characteristic of this low rainfall, low runoff, high evaporation continent. One important human response has been to modify the environment, by storing water for urban and irrigation purposes, to suit human needs (Water Resources Commission, 1986). An example of water storage techniques which have gained increasing attention in the water arena, is the use of aquifer storage and recovery. Another major response has been to introduce water re-use or recycling technologies. Community awareness and education, and planning and policy are also used as tools to encourage more efficient water use.

Water as a waste output

The volumes of treated sewage and stormwater runoff form very large components of the urban water cycle. Wastewater refers to sewage or industrial effluents which have a specific origin. Stormwater contributions to urban effluent may comprise runoff from landfills, roads, commercial/industrial sites, building sites and domestic residences (SoEAC, 1996).

Results from a national effluent re-use survey, reported that an estimated 1200 GL of treated sewage was discharged from town sewage treatment plants to coastal waters in Australia in 1994 (Thomas *et al.*, 1997). Survey results also indicated that this volume is predicted to increase by over 400 GL by 2020 (see Figure 3.3). The current and expected shares of effluent discharged to inland/fresh water, land, or re-used are shown in Figure 3.3.

Urban stormwater is a major contributor to nutrient and sediment loads in Australian cities. In Melbourne, for example, stormwater accounts for more than 80 percent of effluent flow and contains most of the sediment, pathogens, toxicants and litter (Langford and Dorrat, 1995). Industrial and trade wastes are other major sources of water pollution. Discharges from these sectors include: cyanide, lead, arsenic, cadmium, phosphorus, ammonia, suspended solids, grease and oils. In terms of agriculture, the use of fertilisers and pesticides and the existence of feedlots, piggeries and poultry farms, for example, may all contribute to the increasing nitrogen and phosphorus levels in both surface waters and groundwaters. The clearing of native vegetation for agriculture in both dryland and irrigated areas, has also increased groundwater and surface water salinity levels in these areas.

Transferring waste outputs into resource inputs

Although not utilised to its full advantage at present in Australia, both stormwater and treated wastewater offer a large potential resource, economically and environmentally. The main motivations for re-use schemes are: to supplement limited primary water sources and help prevent excessive diversion of water from alternative uses (including the natural environment); as a method for managing in-situ water resources; to minimise water supply and distribution costs (including total treatment and discharge costs); to reduce or eliminate discharges of treated sewage to receiving waters; and to account for political and institutional constraints (Thomas *et al.*, 1997). Reclaimed water may be used for a number of purposes. These include: irrigation of woodlots, crops and pastures; irrigation of urban landscapes and recreation areas; non-potable residential uses, including both domestic level re-use and dual reticulation schemes; residential potable re-use; industrial and commercial uses (including re-use within treatment plants); groundwater management; and surface water management such as aquaculture and mariculture.

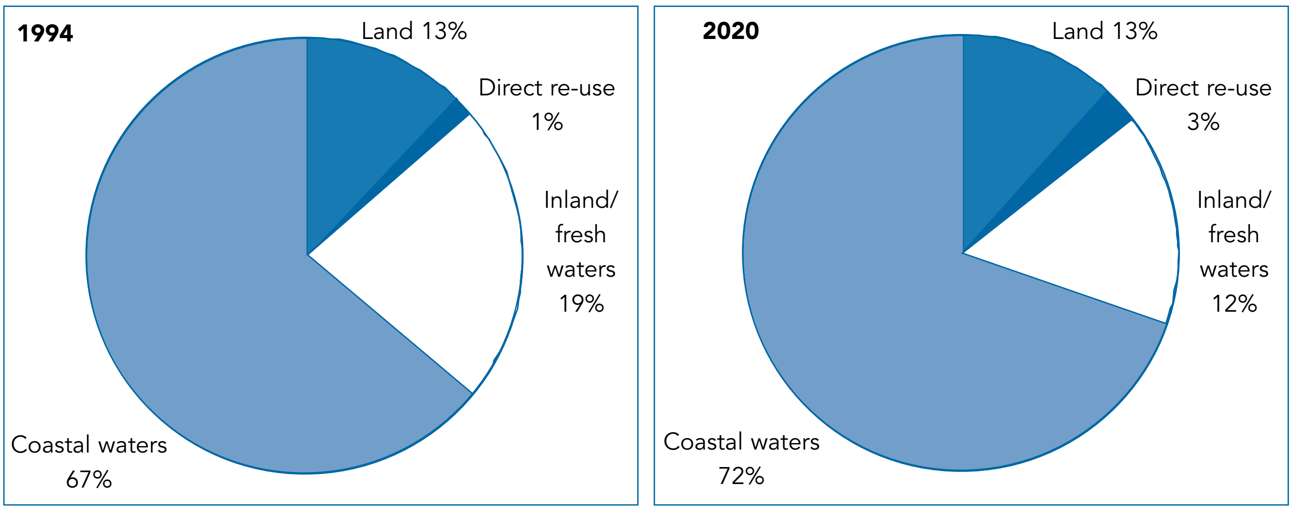


Figure 3.3: Percent of effluent discharged in Australia, by category (1994-2020).
Source: Thomas et al. (1997).

Barriers to the adoption of re-use practices in Australia are mainly the result of community (such as public health and public perceptions), economic and institutional constraints.

Importance of developing water indicators

The impacts of environmental damage from human activities, including stormwater runoff and wastewater disposal, are difficult and expensive to detect, and are often only noticed after considerable environmental damage has occurred. This is particularly the case in large aquatic systems, for example, which have lengthy time lags between the onset of pollution inputs and environmental response (Deeley, 1993). The regular monitoring and reporting of the state of our water bodies, through a series of published water quality indicators, can play an important role in helping to prevent the onset of environmental degradation, by identifying and reporting variations in the condition of environmental resources over time (such as wetlands, beaches, rivers and streams).

Existing water quality/quantity models

A range of models have been developed to describe water indicators for human settlements. The UK Department of the Environment (1997) and International Institute for Sustainable Development (IISD), for example, has developed a water domain model based on a modified pressure-state-response framework, to emphasise water quality/quantity issues. Here, various human activities or sectors within the economy generate wealth and welfare for households, enterprises, government and other actors. The quality of the environment, in turn, can impact on the welfare of households and individuals and other actors. The actors respond to changes in the state of the economy and of the environment, through behavioural and policy changes which either directly affect the environment, or alter the pressure on it from the economics sectors. Responses which constrain the activity of the economy in order to protect the environment may also be regarded in some senses as pressures, since they may reduce the ability of these sectors to generate wealth and welfare, and this in turn may inhibit the development of solutions to environmental problems.

Extended metabolism model for water

The indicator domain model for *water* developed in this report, represents a modification of the extended metabolism model, emphasising the importance of water as both an input and an output. Here, *output* may be in the form of both a positive *livability* output or a negative *waste* output. This is shown in Figure 3.4, and is described below.

Water is a key input for many activities within the economy, including agriculture, mining, households and industry. As discussed previously, groundwater, surface waters, lakes and reservoirs, wetlands, oceans, inland waters, and recycled waters are all components of that resource base. Using water as an input, the various human activities or sectors within the economy generate wealth and welfare for households, enterprises, government and other actors. The provision of water at drinking quality standard is a good example of welfare provision to all sections of the economy. Although the dynamics of settlement improve our overall standard of living, they also generate waste output, and impact on the availability and quality of future resources.

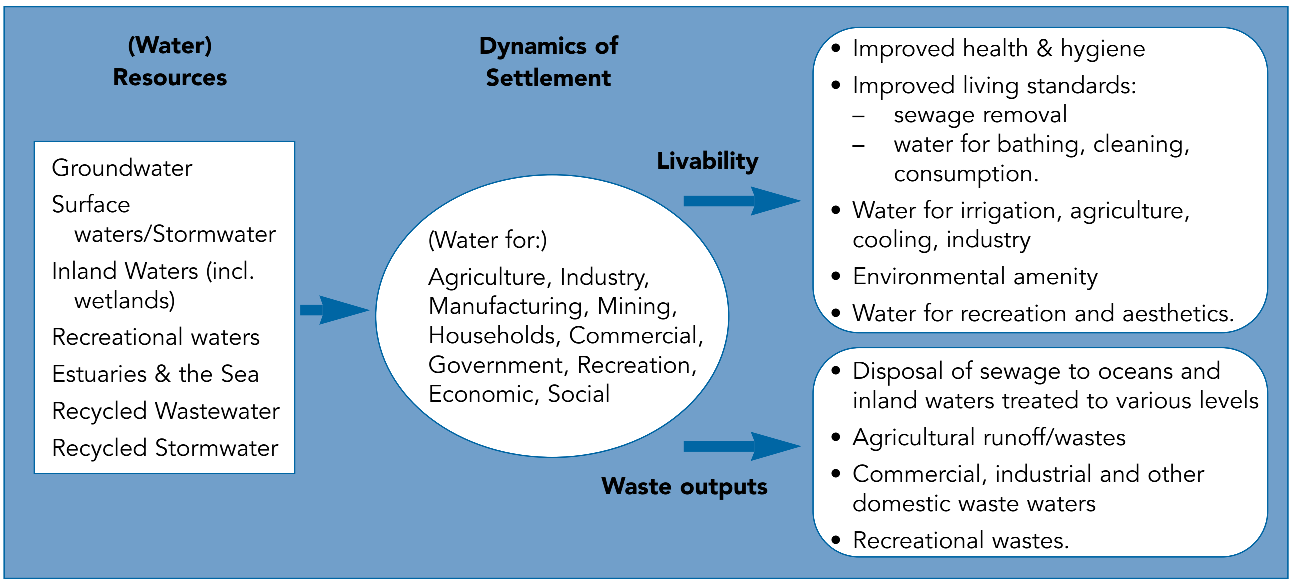


Figure 3.4: Domain model for water.

Improving livability through the effective use of water resources is widespread. Health is improved by providing good quality water for consumption, bathing and cleaning throughout most parts of Australia. This in turn improves overall hygiene thus reducing the spread of disease. The removal of wastewaters (such as sewage and industrial wastewaters), further reduces health and odour problems and improves livability. Water is also important for the maintenance of recreation areas, environmental habitats and wetlands. Wetland areas, for example, are a natural part of water systems, providing natural filtration to watercourses and specific habitats for plants and animals. However, the modification to drainage systems by humans and the clearing of land for development, has compromised the future survival of many wetlands in Australia (ABS, 1996). Within the Swan Coastal Plain in Western Australia, for example, 80 percent of wetlands have been lost since European settlement, due to the establishment of landfills, industrial waste disposal, stormwater sumps, road construction and urban development (Godfrey, 1989; Gomboso, 1997).

Thus, it is evident that human/economic activity creates pressure on the environment, through the consumption of (often limited) water resources and the discharge of pollutants (such as effluent and household wastewater). The quality of the environment (marine water quality near ocean outfall sewage outlets), in turn, can impact on the future livability and welfare of households and individuals (for example, by increasing the risks of infections and health problems at beaches located close to sewage outfall pipes or degrading the amenity of an area). Society responds to changes in the state of the environment and the economy, through behavioural and policy changes within the system dynamics (such as increased tertiary treatment at the wastewater treatment plant, extending ocean outfall pipes, encouraging re-use) or by directly encouraging alternative water sources within the resource base (such as reclaimed waste and storm waters).

Identification of water indicators for human settlement

A number of research institutions and organisations have developed indicators for water. These are presented in SoE (1996), USEPA (1996), UK Department of Environment (n.d.), Atkisson (1996), Maclaren (1996), OECD (1993), SoE Canada (1994), Environment Canada (1991), Fairweather and Napier (1998) Ward *et al.* (1998).

In developing water indicators it is important that, wherever possible, the environmental impact (such as waste output, or resource utilisation) is related to some measure of the economic output or benefit of that activity, to illustrate the reconciliation that needs to be made between the two objectives of maintaining economic growth and minimising environmental damage (UK Department of the Environment, n.d.). Examples of such indicators include water consumption by industry in relation to industrial output, and wastewater discharges per capita.

Quantified response indicators are particularly difficult to develop as there are often a range of policy responses to a particular use; for example, reductions in water consumption may be achieved through water pricing controls, education, simple technologies (dual-flush toilets, more efficient shower recess), or the availability of second-class (re-use) water. Such responses are not easily quantified directly. An indicator which measures total expenditure on water quality protection, for example, must be interpreted with caution. Increasing expenditure may imply that either the quality of the environment is improving, or alternatively, that more needs to be spent on it to maintain quality because the underlying pressures are increasing. Another type of indicator which requires careful interpretation is price. For example, if the price of water rises, it may mean that stocks are becoming depleted, or that demand is increasing for a given stock (that is, the resource is not being exploited sustainably). Alternatively, it may mean that stocks are being exploited more sensibly, perhaps as a result of increased prices driving down demand, or the introduction of a quota which deliberately limits harvesting of the resource. Or a tax may have been imposed to reduce demand and promote sustainability. The most likely reason for a rise in the price of water in Australia is that the full cost of water is being charged (ie., removal of subsidies). Moving toward 'full pricing' of water is current policy of all governments.

Mediating and transforming processes: the dynamics of human settlement

Urban design

Urban design represents one of several of the key processes subsumed under the general category of *'settlement dynamics'* in the extended metabolism model (see Figure 1.1). Other key urban processes involve the systems of financial and industrial capitalism. The financial capital system centres on the levels and sectors of investment that key institutions such as banks, insurance and superannuation funds and stock exchanges are prepared to invest in. The industrial capitalism system is concerned with the production of commodities, goods and services as a result of their respective abilities to attract financial capital to specific businesses and projects. Urban design produces the physical artefacts which flow from the intersection of financial and industrial capitalism – the built forms which we occupy variously as places of work, shelter, recreation, entertainment, etc. In short, urban design is one of the key components of the economic engine of urban development which shapes the pattern of human settlement evolution.

Urban Design is a complex (and controversial) object to define. For our purposes, it refers to:

> ...the spatial configuration of human settlements, entailing the distribution and clustering of built forms, particular land uses and human activities across space and through time.

From this perspective, a human settlement is a complex, spatially delimited and differentiated asset produced through time by the cumulative (unintended as well as intended) interactions between people, and between them and their environments. To the extent that past interactions are embedded in particular, enduring spatial forms, future possibilities are to a degree constrained by that history. For example, the existing pattern of roads, established over decades by its very presence, influences the future distribution of population and provision of ancillary services. Nevertheless, urban forms can and do change—sometimes quite rapidly and radically—as a result of broader societal changes in factors such as the rate of population growth, dominant technologies and environmental conditions. For example, current developments in information technology and telecommunications are influencing the distribution and concentration of employment within and between cities, and encouraging new patterns of mobility across different sub-groups in the urban population (Brotchie *et al.*, 1995).

Thus, the 'design' or evolving spatial form of a human settlement has a range of impacts on the type, rate and efficiency of resource use, and on the outputs generated. These impacts cross-cut the other domain areas.

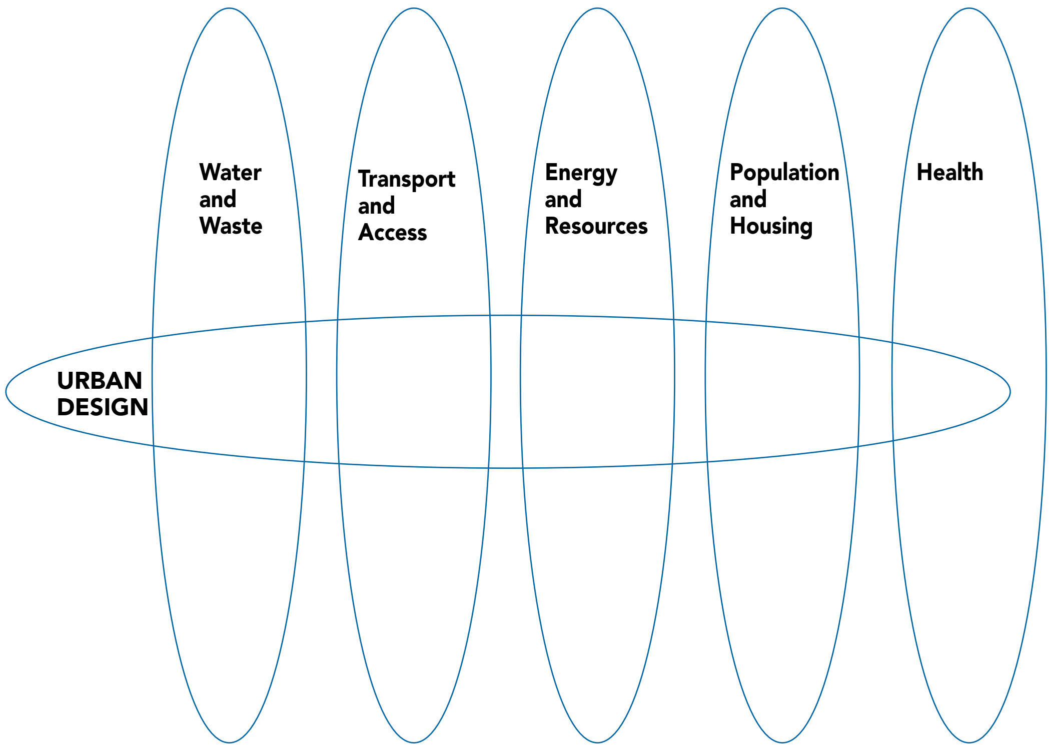


Figure 3.5: Urban design interactions.

The following *elements* of urban design can be distinguished:

Aesthetic The spatial—especially the built—form of a city has aesthetic and heritage significance. Historically important buildings or landmarks, public parks and gardens, particular streetscapes, vegetation and landforms, as well as the less tangible aspects of variety, visual surprise and 'feel', all impact on the perceived livability of cities. These features of urban life also impact on the health and well-being of resident populations, and have implications for the type and density of housing encouraged and demanded[8].

Environmental Cities consume greenfields land, resulting in its conversion from non-urban uses (or non use by humans at all) to housing, roads, parks, factories, shops, schools, and so on. Spatial form—especially the location and density of new residential development—influences the rate of land conversion and use, and the generation of particular forms of waste. For example, the traditional pattern of outward suburban expansion at low densities, characterising Australia's major cities for more than a century, has helped make Australians leading generators of green garden waste.

Natural resource and energy usage is also partly dependent on urban form and density. Low density cities—like Australia's—are highly car dependent, resulting in high rates of car ownership and usage as well as a third or more of urban land being devoted to roads. Extensive hardening of surfaces maximises storm water run-off, while high car usage implies a high usage of fossil fuels and high levels of greenhouse gas emissions and other air pollutants (Newton *et al*., 1997; McGlynn, Newman and Kenworthy, 1991; however, the exact nature, scale and trade-offs involved are complex and contentious as discussed in Troy, 1996). Similarly, the traditional geographic separation (and functional specialisation) of home and work place has prescribed work-related travel at an average level of one hour per day, an historic trend which could be reversed by changing communications technologies, work practices and employment structures which see a higher proportion of people working nearer or at home (Gipps *et al*., 1996; Reich, 1991). A number of feedback loops appear to characterise these interrelations; for example, high car ownership encourages further extensive suburbanisation.

The livability of urban areas is also dependent on the extent of and access to 'green assets' - remnant native vegetation in built-up areas, tree coverage, parks and open spaces, clean water, and areas of high landscape value (natural or heritage). The density and intensity of urban development places pressures on many of these assets.

Economic Viable human settlements have dynamic regional economies with: a moderate long term rate of economic growth per capita, a diverse industry structure, low unemployment, rapid growth of technologically advanced, export oriented industries, low (and falling) energy requirements in both production and consumption, clean production technologies in the manufacturing sector with information content replacing human and material inputs in many manufacturing and service industries. The income elasticity of demand for environmental goods is, generally, positive, indicating that the wealthier a society becomes the higher the value accorded to environmental benefits. This consideration has inter-generational significance. To the extent that future generations enjoy a higher standard of living than today's (this is, of course, *not* guaranteed), they will value environmental goods and resources even more highly than do the current generation.

Those regional economies will prosper which maximise resource efficiency and waste minimisation, by attracting investment and immigration of 'knowledge workers' drawn by superior environmental residential amenity and high value-adding employment opportunities. To the extent that environmental services and 'green products' industries continue to expand globally, significant export opportunities will open up for those regions where those industries first cluster. Urban exports are the key driver of sustainable urban growth, as Jane Jacobs persuasively argued more than 30 years ago (Jacobs, 1961; 1969).

The spatial form of cities can facilitate or discourage the emergence of virtuous or vicious environment-economy interactions. For example, uniformly high density areas may overload the absorptive capacity of the surrounding natural environment, requiring lengthy travel to enjoy attractive environments. Conversely, excessively low density sprawl may (as noted earlier) result in extensive energy demands and encroachment on regional environmental assets, while undercutting

8 This area is dealt with more fully in the Natural and Cultural and Heritage Indicators report (Pearson *et al.*, 1998).

market thresholds for, or reducing the clustering of, high value producers. Access to cultural capital and educational resources is important in attracting and keeping knowledge workers and managers.

Social Urban sustainability also requires acceptable distributional outcomes (Maclaren, 1996). Aggregate economic processes and indicators (like regional GDP) generally ignore distributional effects, at both the inter-generational and intra-generational levels. Growing regional economies are unlikely to deliver sustainable levels of *environmental* benefits if a significant proportion of the urban population are excluded from the *material* benefits of a steady job and income, access to adequate and affordable housing and health services, and so on. Urban poverty is strongly associated with poor and declining environmental quality. Similarly, current economic growth processes which undermine the economic prospects of our grandchildren, also reduces the latter's demand for and capacity to realise high quality environments. Safe urban environments are also a basic feature of livable cities, particularly for women and the elderly.

Patterns of socio-spatial segregation across large urban areas are entrenched through the interaction of product, labour and property markets. Extreme segregation is often associated with self-reinforcing cycles of urban regeneration and expanding opportunities in affluent areas, and urban decline, disinvestment and despair in poor areas (eg. reinforced through institutional practices such as red lining by lending institutions). The incentive and resources to improve local environments in the latter are absent.

Transport and accessibility

A framework which has been used by the Transport Research Centre (TRC) to categorise data and modelling needs in a wide variety of urban transport projects is shown in Figure 3.6. This framework clearly identifies the inputs to the system, the immediate outputs from the system, and the final impacts of the transport system on human settlements. A brief description of the elements of Figure 3.6 is as follows:

System characteristics: A description of the physical transport and land-use system, including transport rights-of-way, terminals and vehicle fleets and a description of the activity sites to which trips might be made. Prospective indicators include (see next page):

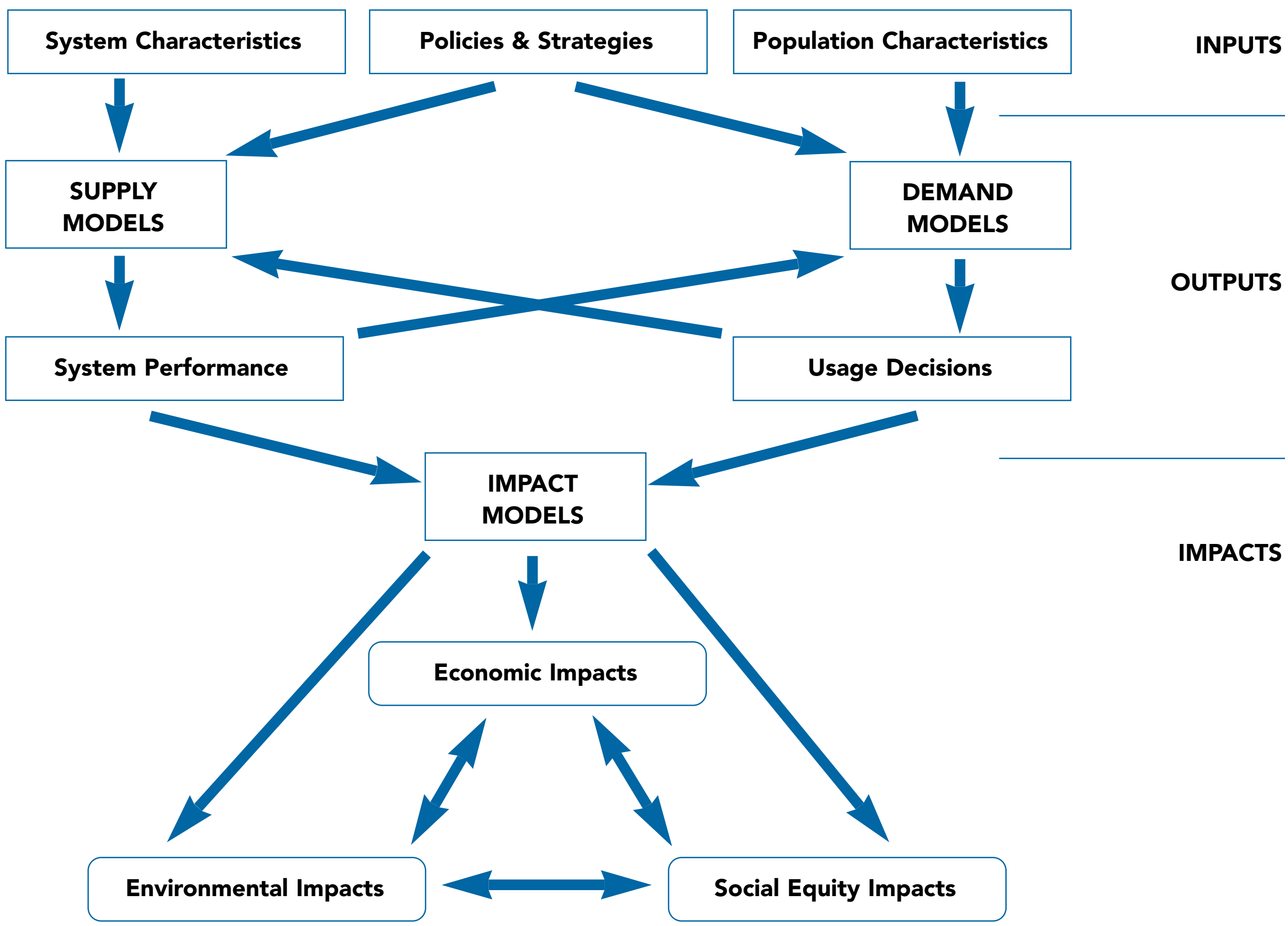


Figure 3.6: Domain model for transport indicators.

- length and type of roadways
- vehicle ownership
- characteristics of vehicle fleet
- length and type of cycleways
- bicycle ownership
- quantity and location of parking facilities
- route km and capacity of public transport by mode
- location and quality of public transport terminals
- public transport fleet characteristics
- geographic distribution of land-use facilities (eg. schools, shops etc)
- geographic distribution of homeplaces and workplaces
- access to public transport stops and stations
- access to land-use facilities by modes of transport

Population characteristics: A description of the human populations which might make use of the transport system to take part in activities at the various sites. Prospective indicators include:

- demographics of the population
- residential density
- licence holding characteristics of the population
- attitudes and preferences of population segments

Policies and strategies: A description of the non-physical policies and strategies which might be implemented to affect how the system works, how people use the system and what the eventual impacts might be. Prospective indicators include:

- price of inputs (eg. fuel, vehicles, regulatory charges, labour costs, parking costs)
- regulatory policies
- pricing policies
- cost recovery policies
- taxation policies
- parking policies

Supply models: Models of how the physical transport and land-use systems interact, including how they react to changes in usage of these systems.

Demand models: Models of how people make decisions about usage of the transport and land-use systems, including how they react to changes in the level of service provided by those systems.

System performance: A description of how the physical transport and land-use systems perform under loaded conditions. Prospective indicators include:

- spatio-temporal travel times and speeds by mode
- system reliability
- costs of operation
- comfort levels
- system safety
- capacity utilisation

Usage decisions: A description of how the population of potential users actually use the transport and land-use systems. Prospective indicators include:

- total quantity of travel (passenger and freight travel)
- spatio-temporal mode usage
- residential location decisions
- commercial location decisions
- choice of trip destination
- timing of activities and trips
- density of daytime populations
- chaining of activities and trips
- route choice decisions
- telecommunications usage

Impact models: Models of how the combination of system performance and system usage give rise to a variety of impacts.

Economic impacts: A description of micro-economic, macro-economic and financial impacts of the operation of the transport and land-use systems. Prospective indicators include:

- economic costs of congestion
- vehicle operating costs
- toll/fare revenue
- economic costs of fatalities and personal injuries
- impacts on employment and other macro-economic indicators

Environmental impacts: A description of impacts on the natural environment resulting from the operation of the transport and land-use systems. Prospective indicators include:

- fuel consumption
- air pollution emissions
- noise levels
- vibration
- water quality impacts from runoff
- impacts on flora and fauna
- greenhouse gas emissions by mode and fuel types for passenger and freight.

Social/equity impacts: A description of impacts on the social environment resulting from the operation of the transport and land-use systems, including consideration of the distributional impacts of economic and environmental costs and benefits. Prospective indicators include:

- social costs of congestion
- access by disabled
- distribution of costs and benefits
- social costs of fatalities and personal injuries

It is considered that Figure 3.6 provides a suitable framework for the development of human settlements indicators in the area of transport and accessibility. The eight boxes describing inputs, outputs and impacts provide a framework for the actual indicators, while the supply, demand and impact models provide the linkages between the various indicators.

Population

Population, both absolute numbers and rates of growth, is ultimately limited by carrying capacities, and affect the ability of the environment to regenerate and to cope with human intrusion. Population growth, urban growth and decline, internal migration between regions, household formation, household size and family type are vital background indicators in assessing demand for all kinds of resources. While tourism provides both a major economic benefit which can provide capital and rationale for environmental preservation, the level of temporary visits to cities will have impacts on peak usage of facilities and resources, and as such, constitutes a source of pressure on the environment.

The worldwide increase in population has been generally recognised since the time of Malthus as the major underlying cause of pressure on the environment and resources (Malthus, 1798). The last half of the present century has been a time of unprecedented growth in population, accompanied by rapid economic growth, and the rate of utilisation of all forms of resources and the impact of human settlement and activities on the natural environment is far greater than ever before.

Some demographers have maintained that there are positive aspects to population growth: by stimulating adaptive and technological change, and through synergy of improved interaction and economies of scale, population may increase prospects for development and improve the condition of human life; but this remains controversial. There is no doubt however that population growth and environmental degradation are engaged in a complex, multi-factor relationship, where one often serves to exacerbate the adverse impacts of the other (UNEP, 1995). The impact of population change is particularly significant in spheres of activity where technological change is slow: population growth is responsible for 80 percent of deforestation worldwide, and about three quarters of arable land expansion (UNFPA, 1992).

The concentration of population in human settlements has both positive and negative aspects. On the one hand, the dispersal of population throughout the countryside is a threat to the agricultural and environmental viability of large tracts of land, white concentration of population in particular locations both limits the extent of environmental damage and makes mitigation programmes such as the provision of infrastructure cost effective. However, the concentration of population in particular areas can have a particularly damaging effect on environments once critical pollution thresholds are exceeded. As Girardet

(1992) points out, in the past many cities were ultimately destroyed through the devastation of their hinterlands, which depleted resources, silted rivers and ports, and ultimately ruined agricultural production through overcropping and overcarrying. Current technologies are able to reduce many of these destructive effects, and most modern cities are able to live in balance with a productive hinterland. The reach of most modern cities is now global, however, which means that hinterland concepts must be augmented by ecological footprint concepts for a comprehensive accounting of metropolitan impacts.

Population growth, urban growth and decline, internal migration between regions, household formation, household size and family type represent vital background statistics in assessing demand for a wide spectrum of resources.

Population increase and population distribution

Over the last 30 years, world population has increased from 3.3 billion to 6 billion, and is forecast to reach 8.5 billion by 2025. Population growth in Australia is much slower, but is still rapid by developed world standards because of the relatively young population and continuing immigration. National population has increased from 13.7 to 17.8 million (1996 Census) over the past twenty years. This increase has been due 58 percent to natural increase, and 42 percent to international immigration.

The movements of population to new areas, particularly when growth rates are very rapid, may put pressure on the environment more rapidly than natural regeneration can handle or before environmental response measures can be put in place. Within Australia, population shifts have caused pressure on vulnerable areas. The most obvious of these are the fringes of the major cities and the 'sun belt' areas of coastal Queensland and New South Wales (Newton and Bell, 1996). The movement of population to the 'sunbelt' areas of Queensland and northern New South Wales, for example, has been occurring for over 15 years, and is putting pressure on these formerly sparsely populated areas, both in terms of impact on the environment and for the provision of jobs and infrastructure (Birrell *et al.*, 1995). For the first time in very many years, a number of settlements will pass the 40,000 population mark—mostly within the sunbelt region (House of Representatives Standing Committee on Long Term Strategies, 1994).

As shown in Table 2.2, more than 40 percent of the nation's population live in Sydney and Melbourne, and a total of 53 percent in the 5 largest cities. There are another 109 cities with more than 10,000 population, and these accommodate 23 percent of the population.

The growth of the 'peri-urban' areas has been the most persistent feature of population re-distribution in Australia. The fringes of the major cities are continually expanding into new areas, which can include both productive agricultural land and bushland. In the case of productive agricultural land, this will need to be replaced elsewhere. The subsuming of bushland into urban areas may destroy areas of natural beauty and the habitats of wildlife. The increasing spread or 'sprawl' of population to these areas also means that the infrastructure distribution networks of the cities continually need to be expanded, which both puts pressure on the existing networks and incurs considerable expense while using scarce capital resources. In some cases, parts of inner areas have been depopulated compared to pre-world war two levels, so that infrastructure in these areas are under-utilised while newly settled fringe areas remain without adequate services. Urban consolidation policies have been developed as a counter to this trend (see Troy, 1996) and there is evidence of re-urbanisation in Australia's larger cities (Newman *et al.*, 1996).

Inland there has, for many years, been a steady drain of population away from rural towns linked to farming and pastoral activity, leaving infrastructure under-utilised, housing vacant, and leaving smaller communities barely sustainable (see, for example, Newman *et al.*, 1996).

Not just permanent movements of population but temporary movements also can impact on vulnerable areas. Coastal areas have large numbers of visitors in summer months, with resort towns sometimes trebling in size, requiring infrastructure and facilities to handle this peak demand, not just the demand by the permanent dwellers (see Pollard, 1996). The level of temporary visits to cities, including business trips, will also have impacts on peak usage of facilities and resources.

International tourism has become Australia's biggest industry and major export earner, and the appreciation of areas of high environmental interest is a major factor bringing visitors to this country and a major economic reason for preserving and retaining these areas free of harmful effects of human activity. Unfortunately, tourism if not properly managed and regulated can severely damage areas of natural beauty, and the level and potential impacts of tourism must be taken into account in determining environmental sustainability. Tourism thus provides both a major economic benefit which can provide funds and rationale for environmental preservation, and a source of pressure on the environment.

Intra-urban movements and urban consolidation

Within cities, there has been a steady move of population out of the middle ring towards the fringe and also towards the city centre. This 'doughnut' effect as families move outward and the more well-to-do move inwards seeking the benefits of greater accessibility and neighbourhoods with 'character' has put pressure on the fringe. It has also caused land prices to rise rapidly in the centre, making the inner area increasingly unaffordable for older low-income inhabitants who may have depended on better access to health and other facilities. Under-utilisation of facilities in middle areas has been an area of concern, with schools in particular being consolidated and sold due to a lack of students.

Suburban areas of Australian cities have largely been designed around the motor car, and have been built at some of the lowest densities in the world. Urban consolidation has been a major response to perceived environmental problems caused by urban expansion, and a number of regulatory and fiscal measures have been put in place to encourage medium density infill development in traditionally low density areas. It is considered that encouraging higher densities will reduce the demand for land and infrastructure at the fringe, while making better use of existing under-utilised infrastructure. As well, higher population densities make public transport more viable, and reduce automobile and petrol use (Newman and Kenworthy, 1989). However, as Troy (1996) has pointed out, higher densities mean higher land prices and less affordable housing, and reduce access to a way of life on the suburban block which has become accepted as the Australian norm.

Changing population characteristics

The most noticeable demographic change over an extended period has been the steady reduction in average household size and changing family type, here and elsewhere in the developed world. The number of 'nuclear' two-parent families with dependent children, which was regarded as the standard around which Australian cities were built, has fallen to around 20 percent of the total. Single-person families are the most rapidly growing group, increasing to 18 percent in 1996; and couples without children are the largest group at 40 percent. Single parent families have also steadily been growing, and many of these have low incomes and require support.

The main impact of smaller family sizes, apart from changing patterns of consumption, is that larger numbers of smaller dwellings are required. The household formation rate in the cities has typically been about twice the population growth rate, with a concomitant increase in demand for dwellings in excess of what would be expected from population growth alone. The type of dwellings required is also different, as a large house on a suburban block is not as appropriate for single persons compared to families. This has encouraged moves to urban consolidation both directly through increased demand, and indirectly in that it has been perceived that the 'standard' Australian detached house needs to be supplemented by a greater range of property types.

Australia's population is relatively young, but is getting older, with the proportion of the population over 65 increased from 10.1 percent in 1984 to 11.8 percent in 1994, and this has already had substantial impacts on activity and the demand for a range of services including health care, education, the need for both government and private pension support, and demand for different kinds of housing units and estates.

Changing economic characteristics

The reduction of poverty is a major objective of all governments, and achieving a satisfactory standard of living for the whole population has generally been considered to be an integral part of sustainability. The number of people below the Henderson poverty line has remained fairly steady at about 11 percent over a long period, but the incidence of poverty falls very differently on different localities and on different social groups. The historically very high rates of unemployment at 8 to 9 percent, which largely reflect international economic restructuring, mean that a significant proportion of the population are unable to sustain themselves without government support. The level of unemployment is considerably greater in some areas, especially outside the State capitals and in former industrial zones.

The movement of women into the workforce has also had an impact on urban activity, with changes in transport trip distribution and usage.

The major economic effect on the environment however resides simply in the fact of economic growth and steadily increasing average wealth of the population. This results in greater usage of resources of all kinds, particularly energy; greater amounts of packaging and waste materials; and a greater capacity of the population to travel further afield into areas that formerly had little intrusion by humans. The challenge remains to do more with less, and to make use of this increased prosperity to reduce damage to the environment.

ENVIRONMENTAL LIVABILITY OF HUMAN SETTLEMENTS

HOUSING

Housing is the major locale for the conduct of the personal affairs of the general population, interacting strongly with all other aspects of the physical and human environment (Flood, 1997). It constitutes an important part of the economy and a major component of capital investment. It is the major user of a number of important resources, and is generally the place where the domestic sector engages in most of its consumption and other activities. It is also the locus for much productive activity which does not feature in the national economic accounts (Ironmonger, 1989)—through unpaid domestic, gardening, repair work, and general recreation. Housing has the capacity to contribute to the environment and quality of life through well-planned, appropriate, and affordable residential development and garden environments. It also has the capacity to impair the environment through the production of wastes, interference with areas of natural beauty, and through the activities of householders.

Housing also interacts strongly with environment in the wider sense: the human environment, the economy, and the institutional environment as it impinges on the quality of life (Flood 1997). Sustainable development stresses the interaction of all these different spheres of activity, so that housing is intimately connected with the economy and the financial and regulatory system, with demographic structure and change, with access to adequate means of existence, with materials and energy consumption, and with general security, privacy and the quality of life. This interaction is shown in Figure 3.7, which is the Sustainability Domain Model for housing.

The sustainability model demonstrates the interaction of the different spheres: economic, social, physical and institutional; with each being given equal weighting. The Extended Metabolism Domain Model for Housing, shown in Figure 3.8, concentrates more on the sphere of the physical environment, with physical inputs processed and turned into outputs, including livability and wastes[9]. The section which follows examines the various components of this model.

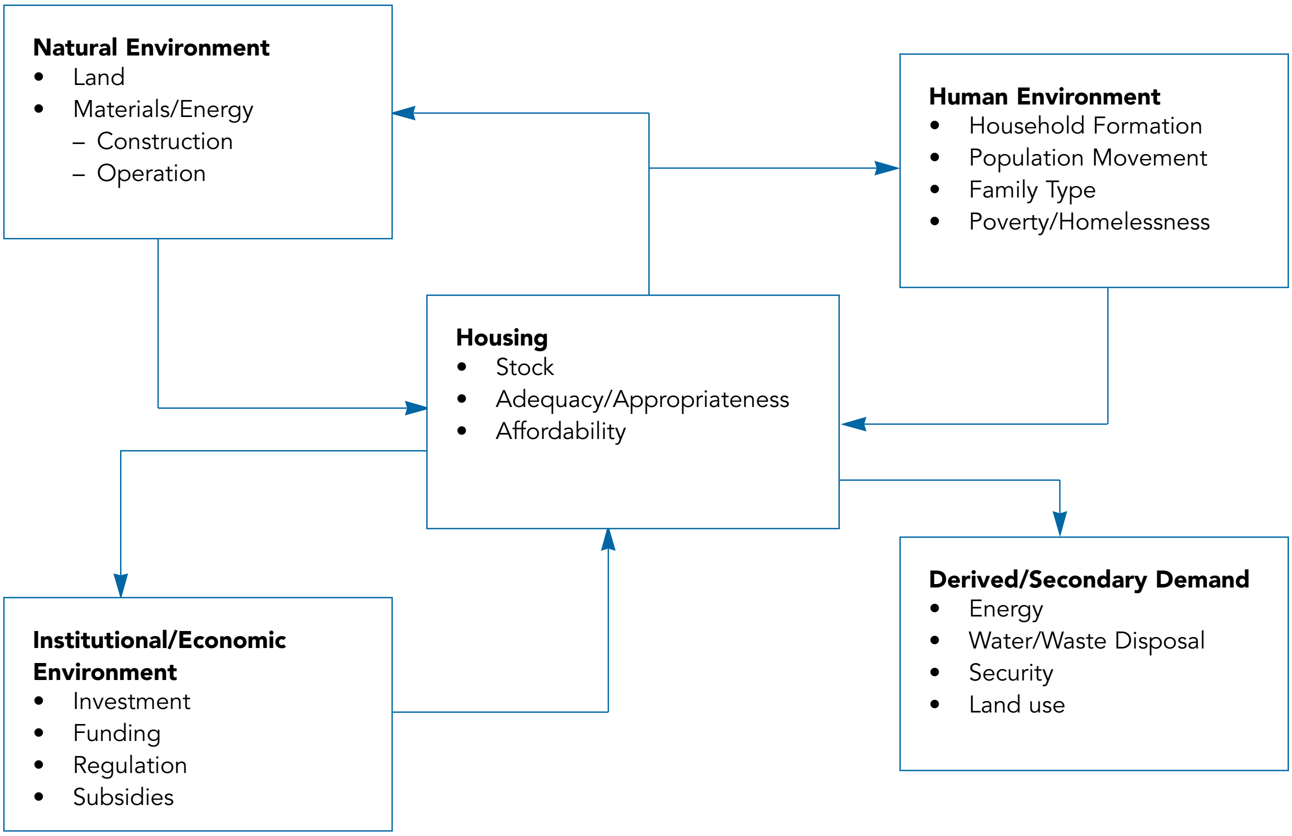


Figure 3.7: Sustainability domain model for housing,

[9] It is important to note that only in the physical sphere are resources diminished by throughput: economic, social and institutional spheres gain synergy from the throughput and are enhanced by it.

Materials Residential construction and maintenance is a major consumer of such materials as concrete, steel, timber, clay products, paints, fibreboard and various elaborately transformed manufactures. Table 3.2 shows the percentage of various materials used both directly and indirectly in construction rather than other sectors of the economy.

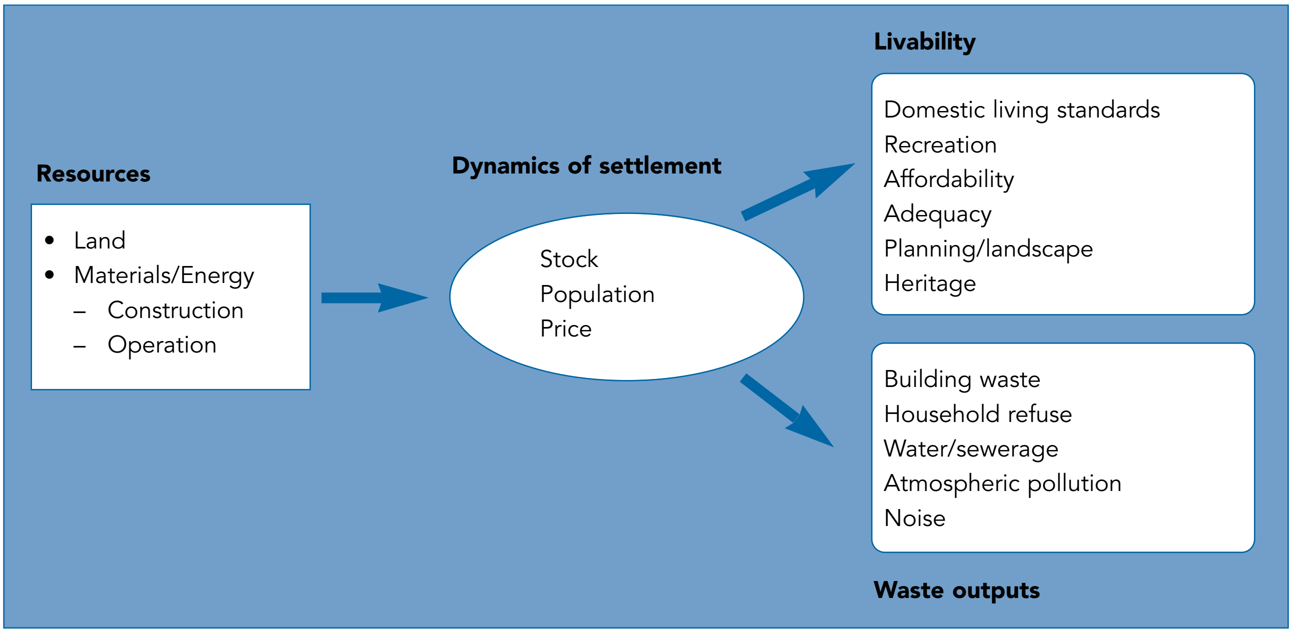


Figure 3.8: Extended metabolism domain model for housing.

Table 3.2

Use of materials in residential building and other building and construction

Industry sector	Residential construction (percent)	Other building and construction (percent)
Cement and concrete products	35.6	61.4
Non-metallic minerals	47.0	30.6
Clay products	53.2	19.5
Timber products	40.0	16.6
Paint	20.2	26.9
Basic iron and steel	12.4	31.4

Source: Tucker et al. (1993).

Energy A large amount of energy is consumed in the building process, both directly through movements of materials etc and indirectly through embodied energy in various energy-intensive products such as cement, steel and aluminium. Tucker *et al.* (1993) found that about 13.6 Gj of energy is consumed on average for every square metre of residential building (compared with 30.1 Gj/ m^2 for other building). Only about 7 percent of this is direct energy used in construction. Approximately 90 tonnes of greenhouse gas is linked to the 'manufacturing' of a detached 3 bedroom brick veneer house (Newton, et al. 1997).

The residential sector also consumes a significant proportion of energy—around 8 percent to 9 percent of total energy use (Bush, 1993). Various active and passive strategies are recommended for reducing this usage, including insulation, siting to best advantage, solar and other renewable energy forms, heat reservoirs, and efficient appliances and lighting. An energy rating system for dwellings has been developed and implemented in some States with the prospect of becoming compulsory under federal greenhouse policy programs launched in November 1997.

Land Australia has an abundance of land for building compared to more densely developed countries, but land development and urban extension, especially into bushland and areas of high agricultural productivity, has been of growing environmental concern. The development of land for residential purposes is, after agriculture, the major form of conversion of undeveloped land and natural bushland to human use, with significant impacts on wildlife, vegetation and on aquatic ecologies. Land development also uses significant quantities of material and energy resources. Residential development is not generally as harmful as the use of land for agriculture or industry, however, since well-planned subdivisions can provide habitats for some animals and birds while maintaining reasonable levels of vegetation; can integrate residences and workplaces to minimise travel; and can possibly re-cycle and re-use water rather than waste it as is presently the case.

Housing stock and condition There are about 6.7 million dwellings in Australia, of which around 85 percent are located in urban areas. About 85 percent of these are single family dwellings on their own plot of land, which in urban areas varies from 250 square metres up to a half hectare or more, with an average size of about 700 square metres.

The national dwelling stock is generally regarded as being in good condition although information has been only rarely been collected. Over half of all dwellings have been constructed since 1945, and the proportion of dwellings more than eighty years old is very small. Indeed, better quality older dwellings may actually fetch a premium because of heritage value and location. Almost all urban dwellings are connected to water, gas, electricity, sewerage and telephone, and have indoor toilets and bathrooms—increasingly, more than one toilet and bath / shower.

There is no general standard for poor or inadequate housing, apart from the very small number actually condemned or regarded as uninhabitable, and the development of housing quality measures or indicators is a subject for future research.

Housing and the quality of life Adequate, appropriate and affordable housing is vital to the achievement of a satisfactory quality of life, as expressed through indicators of housing size, substandard housing and housing expenditure stress.

Housing in Australia is generally regarded as among the best and most affordable in the world, and this has been a major attractor for international immigrants who have often sought a less crowded urban environment, better housing conditions and a higher quality of life. International housing indicators show that after the United States, Australian cities have the most space per person (the most commonly used measure of housing consumption) in the world, at 55 square metres per person (UNCHS/World Bank 1993). As well, housing is relatively affordable with the median urban house-price-to-income ratio at 3.3 being one of the lowest for OECD countries. This has been the result of successful policies which have made use of plentiful urban land, government encouragement for home ownership, and a highly competitive housing industry which has concentrated on construction of single detached dwellings.

However, while the average housing situation has been extremely good, conditions have been difficult for those households with the lowest 30 percent of incomes. Australia has only a very small public housing stock at around 5 percent, and many low income households are paying a high proportion of their incomes in private rent (typically about 30 percent of single parent households in particular are in after-housing poverty). Higher rates of unemployment and larger numbers of people on government benefits have meant a larger number of persons in unaffordable or inadequate housing, and homelessness, particular among young people, has become more evident.

Homelessness and poverty represent the extremes of inequality, which isolates disadvantaged groups from the benefits of society and its wealth, and manifest a poorer quality of life than Australians expect to be universally available.

There have also been increasing calls to provide more appropriate alternatives to the typical Australian detached dwelling lifestyle. This has occurred because of the increasing numbers of one- and two-person households, because of the increasing cost of providing infrastructure to new outer developments, and because of concerns that dispersed living encourages the use of private transport with consequent energy consumption and pollution generation outcomes (Newton, 1997). Accordingly, urban consolidation and the encouragement of residential redevelopment of inner city areas has become a policy priority. Regulatory restrictions on the construction of medium-density dwellings have also been progressively removed, so that increasing numbers of newly constructed dwellings have been medium density (over 40 percent in Sydney in 1996-97).

Sympathy for sustainable development and a more consolidated urban environment has increased, and is likely to shape the form of Australian urban settlements in years to come.

Waste Housing produces waste both through the building process and, particularly, in use. Of the 12.8 million tonnes of solid waste disposed annually (Industry Commission 1989), around 11 to 15 percent is building rubble. Demolitions account for much of this waste, but around 75 percent of a number of key materials such as bricks, timber, steel, doors and windows are recovered and recycled (Tucker *et al.*, 1993). There are around 10 000 dwelling demolitions per year.

Most solid waste (about 70 percent), sewerage and stormwater, also come directly from the household sector, as considered in more detail in the water and waste domains. Other waste products such as noise or atmospheric pollution also come through domestic activities.

Indoor air quality

Indoor air quality indicators are at an early stage of development. There are two major challenges for developing indicators for national state of the environment reporting. First, identifying parameters that need to be measured. Second, designing a sampling strategy that will enable the parameters to be reported on a national scale. This report concerns the former. The latter is the subject of a research project by CSIRO which addresses issues of sampling and measurement processes (Brown and Robinson, 1997).

For this report, indoor air quality is defined as the quality of air in all buildings, including homes, public buildings and places of work. Places of work are generally covered by occupational health regulations, which set maximum concentrations for a range of substances. Few regulations or monitoring programs apply to homes. Air quality in transport vehicles was considered to be outside the terms of reference of this Study, although it constitutes one of the environmental 'pathways' through which a majority of the population passes on a daily basis.

A key issue model for indoor air quality is presented in Figure 3.9. This model acknowledges the following major factors that impact on indoor air quality and their relative priorities:

- the bulk of indoor air pollution arises from the materials, appliances and processes that occur in modern buildings; by comparison, the level of pollution indoors that arises from the ingress of outdoor pollutants with ventilation/infiltration air is small and probably restricted to a few specific pollutants with no indoor source (eg. sulphur dioxide, automobile exhausts in some buildings). Thus, there is no general relationship between indoor air pollutants and outdoor air pollutants and each must be considered independently with an emphasis on pollutant sources for the former;

- building ventilation and air infiltration rates will influence the degree to which pollutants of indoor origin accumulate to high concentrations in indoor air; similarly they will influence the degree to which outdoor air pollutants penetrate into buildings;

- temporal variations in pollutant emissions from sources and in building ventilation rates will result in both short-term and long-term variations in pollutant concentrations in any building;

- building type will influence how the building is constructed, operated and occupied, all of which will influence indoor air quality;

- human occupation of buildings will vary over time according to the type of building and the occupant (eg. worker, student, other), although there is good evidence that most people spend over 90 percent of their time in an indoor environment;

- human susceptibility to illness from exposure to air pollutants will vary but will be especially critical for the very young or old, the asthmatic, and people with allergies and chemical hypersensitivity.

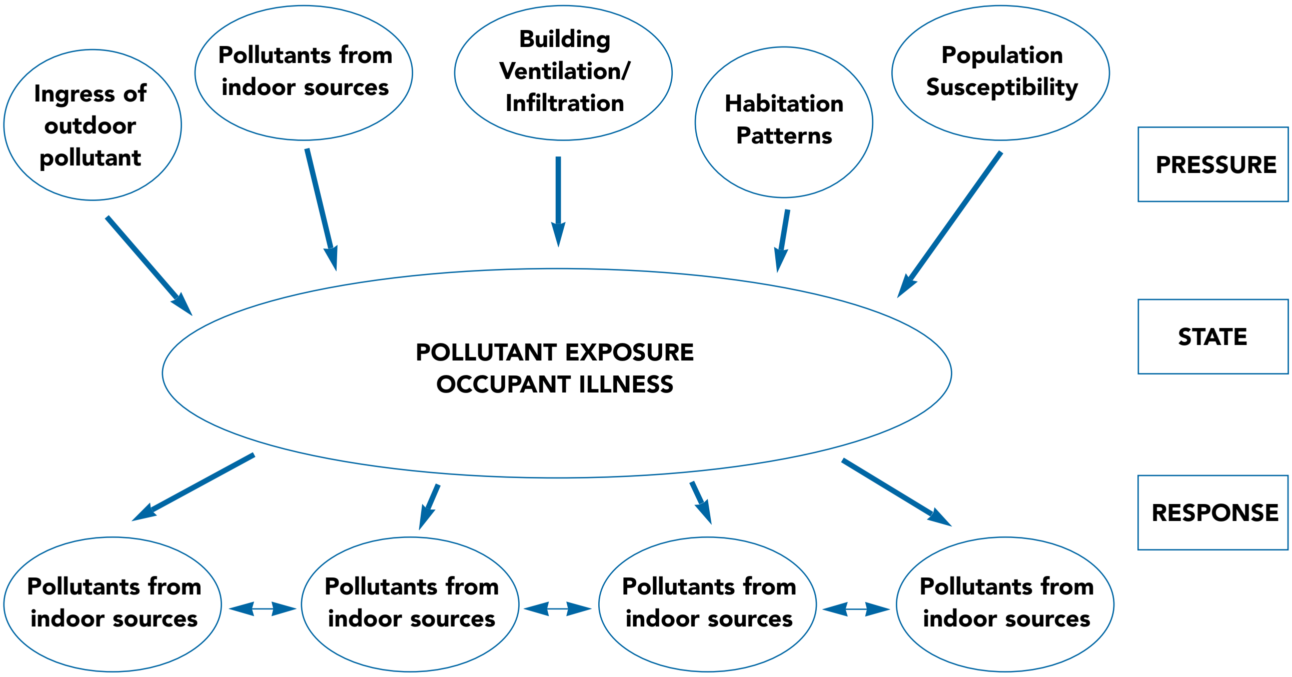


Figure 3.9: Domain model for indoor air quality.

The workshop on *Key Environmental Indicators for the Atmosphere in State of Environment Reporting* January 21–2,1997, Melbourne, nominated a range of pressure-condition-response indicators for IAQ. These form the basis of this selection with modifications after re-visiting the indicators relative to the SoE Technical Report on Indoor Air Quality (Brown 1997), and the consideration of other factors that have arisen. The selected indicators are presented in Table 3.3 in a structure where current issues (Condition Indicators) are organised such that they are identifiable according to their continuity in a pressure-condition-response framework. This is not an exhaustive list of indoor air quality indicators but consists of those currently considered most critical. The focus and emphasis of the table is on the Condition Indicators since there is a need for these to be better characterised. Generally the Condition Indicators are related to either occupant issues or pollutant issues.

Occupant issues

Two Condition indicators relevant to occupants are identified. The first, occupant satisfaction with the indoor environment, relates primarily to commercial buildings since usually there is little opportunity for occupants to control these environments (eg. cf dwellings). This satisfaction can be gauged by a standard environment/symptom questionnaire (eg. one has been developed by UK Royal Society of Health). Many countries have applied such surveys widely and have good estimates of this indicator. Australia does not. Related Pressure Indicators must consider the magnitude of pollutant sources placed in buildings (difficult to assess) and the level of fresh air supply (can be assessed relative to current standards; many buildings from the 1980s were constructed to codes requiring much lower ventilation rates). Response Indicators are varied and could include statistics on occupant illness and absence from work (generally considered as blunt measures of satisfaction) or some measure of occupant productivity.

The second indicator is the proportion of the population with sensitivity to air pollutant exposure. Such people may react adversely to air pollutants at low levels, which are of no significance to the general population. They include the very young and old, people with asthma and allergies and those with chemical hypersensitivity. People with chemical hypersensitivity may react at very low levels. Since all indoor air environments contain air pollutants (often at levels exceeding those outdoors), this hypersensitive population will react to a large proportion of indoor environments – chemical classification of these environments will assess the Pressure Indicator within the limits imposed by analytical procedures. The Disability Discrimination Act has been interpreted as requiring that 'people responsible for premises' take steps to eliminate or minimise reactions of the chemically hypersensitive.

Pollutant issues

The listed pollutants are those of concern within Australian buildings based on current knowledge. Based on this knowledge, it is possible also to nominate major sources of the pollutants (Pressure Indicators) and effective responses for their control (Response Indicators).

The major source of formaldehyde in buildings has been reconstituted wood products, especially where used in large quantities (eg. mobile buildings). Australian manufacturers now claim to manufacture only low-emission products but have no program for independent assessment of this claim. Also it is believed that quantities of products imported from Asia have no control of emissions.

Nitrogen dioxide is emitted from unvented gas appliances, especially heaters. No exact statistics are available but it is plausible that several hundred thousand of such heaters are used in dwellings and schools. Use and control has varied in each State in response to regulations. Least control occurred in NSW and a current response is widespread repair or replacement of existing heaters in NSW public schools. Also manufacturers now produce only low-NO_x unflued heaters although the criteria for 'low' must be open to discussion.

Australian dwellings have one of the highest levels of house dust mite allergen in the world due to our temperate climate and lack of prolonged, low winter humidities. Some evidence suggests this allergen induces childhood asthma; also it is well established that the allergen is a trigger for asthma attacks (and Australia has a high incidence of asthma). Since the mites live in plush furnishings (carpets, bedding, furniture), control of such items is necessary for low-allergy buildings (eg. Asthma Foundation of Victoria – Breathe Easy home design).

The occurrence of Legionnaires' disease has been well documented in Australia. Disease outbreaks can be significant and have been notifiable in all States and Territories since 1991. For example 672 cases occurred between 1991–4 and while fatality is not recorded it is estimated to be 10–15 percent of cases. It is caused by exposure to Legionella spp. which is a pathogenic bacteria. These are ubiquitous in soil and water at low levels, but their numbers can grow significantly in warm environments such as cooling tower water. Mist from cooling towers can drift into air inlets of buildings and this is believed to be the major cause of outbreaks in Australia. The Building Code of Australia now requires control of such sources but its enforcement for new buildings and impact on past buildings is unknown.

Environmental tobacco smoke (ETS) has been eliminated from many buildings (mainly commercial and public buildings) by smoking bans, but it persists widely in recreational buildings (clubs, pubs, casinos, restaurants), where separation of smokers and non-smokers in the same building space does not prevent ETS exposure to the latter. Also the high proportion of young women smoking means that the population sector at greatest risk (ie. children) may be exposed in the home.

Volatile organic compounds (VOCs) are present in most buildings due to the wide variety of source materials, but significantly high levels are encountered (generally for a few months) in new or renovated buildings due to emissions from building and furnishing materials. Procedures to assess product emissions and product labelling schemes are proving to be effective control strategies overseas and are expected to be adopted in Australia.

Lead levels in interior paints have been reducing for decades and are believed to have been highest in pre-1970 housing. Flaking of these paints and paint stripping in renovation are important sources of lead exposure to children (the latter is the major cause of lead poisoning in children).

An extensive survey of radon levels in 3413 Australian dwellings found that levels were low and exceeded guidelines in only 3 dwellings (0.06 percent of survey). Higher levels were found in earth-sheltered dwellings and this is the type of building focussed in the indicators.

Asbestos was widely used in Australian buildings up to the early 1980s, predominantly as asbestos-cement building products. For example, 1300 million square metres of asbestos-cement sheeting was manufactured and used up to 1983, as roofing, wall cladding, guttering, pipes, floor underlay etc. The use of friable asbestos insulation products (sprayed fire insulations, pipe and boiler lagging) continued to the late-1970s and is of greater concern because of the higher risk of airborne asbestos release from these products. An asbestos removal industry has been established in Australia to service a market now estimated at greater than $200 million/year. Such removal is estimated to require a number of decades before it is completed to acceptable standards for all buildings. Product disposal is to licensed tip sites and this will provide an indicator of removal activity, although some States do not discern friable from non-friable products.

Table 3.3

Indoor air quality—environmental indicators for human settlement

Condition Indicators	**Pressure Indicators**	**Response Indicators**
Occupant dissatisfaction	Pollutant sources/fresh air supply	Illness/absence statistics; productivity
Proportion of population with sensitivity to air pollutants	Chemical classification of indoor environment	Infringements of Disability Discrimination Act
Formaldehyde concentration	Loading of buildings with reconstituted wood products	Use of 'low'-emission products
Nitrogen dioxide concentrations	Number of unvented gas appliances	Replacement of heaters; production of 'low'-NO_x heaters
House dust mite allergens	Use of plush furnishings; higher indoor humidities	Low-allergy buildings
Incidence of Legionnaires' disease	Poorly maintained water cooling towers	Enforcement of Standards for control of *Legionella* spp
Environmental tobacco smoke	Proportion/distribution of smokers in population	Proportion/type of building with smoking prohibited
Volatile organic compounds in new/ renovated buildings	High VOC-emission materials	'Low' emission materials
Lead in paint in dwellings	Proportion of dwellings constructed pre-1970	Incidence of child lead poisoning
Radon concentration in dwellings	Buildings with earth shelter	Focussed monitoring program
Asbestos products in buildings	Number of buildings containing an asbestos product	Quantity of asbestos products removed annually

Table 3.3 lists several critical indoor air pollutants:

- formaldehyde concentrations in mobile buildings;
- nitrogen dioxide concentrations from unflued gas heaters;
- house dust mite allergens in housing from coastal climates; and
- environmental tobacco smoke in recreational buildings.

Ideally it would be desirable to sample buildings for concentrations of such pollutants as discussed in Brown and Robinson (1997). In the short term, however, the practicalities of sampling and measurement suggest that substitution of the surrogate indicators listed below represents the most appropriate route to assessing indoor air quality in human settlements:

- number of people housed in mobile buildings;
- number of unflued gas heaters in residences and schools;
- proportion of housing with high house dust mite allergen; and
- proportion of adult smokers with children/ proportion of commercial and recreational buildings with smoking prohibition.

Environmental health

Human health is influenced by a variety of environmental factors. The interaction between these factors and human health is complex, and in some cases controversial and/or incompletely understood. In most cases, health outcomes are affected by a range of non-environmental factors, and these can confound interpretation.

The domain model for environmental health is shown in Figure 3.10. The model conceives of health outcomes resulting from the interplay between a number of inputs which are transformed by a range of mediating processes.

INPUTS

Biophysical
- air quality
- water quality
- food quality
- land contamination
- public sanitation
- disease vectors
- radiation

Human biological resilience factors
- genetic factors
- herd immunity
- pre-existing disease
- nutritional status

Demographics
- age structure
- population density

Social factors
- housing
- cultural practices
- family structure
- literacy, income, etc.

Occupational Environment
- work and workplaces
- schools

→

MEDIATING PROCESSES

Public health system
- access to hospitals, etc.
- health literacy
- morbidity
- child and aged care
- technology

Lifestyle factors
- use of sunscreens, etc.
- exercise
- alcohol intake
- tobacco smoking
- travel

→

OUTPUTS

Human health
- mortality
- disability
- safety
- security
- mental illness
- hospitalisation and GP visits

Figure 3.10: Domain model for environmental health.
Note: inputs, mediating processes and outputs listed here are examples - the list is not intended to be comprehensive.

Inputs

The major inputs to human health include biophysical parameters, human biological resilience, demographics, and social factors.

Biophysical inputs encompass all aspects of the non-human physical, chemical, and biological surroundings, including both the built and non-built environments. Another important aspect is the nature and quality of foodstuffs, their production, distribution and preservation, and their consumption. A variety of food-borne diseases and lifestyle diseases have been associated with our changing societal patterns. Presence of a variety of pesticides and preservatives in food also pose serious threats to human health. The former also affect populations in food growing areas—principally those on the rural-urban fringes of our cities and rural towns and cities. The issue of radiation as a contributory factor to health needs to be added to this list. Exposure to both natural and man-made radiation beyond a threshold has significant implications for health outcomes.

Human biological resilience refers to factors such as the genetic characteristics of human beings which affect their susceptibility to a range of health risks, and acquired immunity to disease through previous exposures. The prevailing health care systems also enhance the repertoire of this resource (eg. via immunisation programs).

Demographics includes the age structure of the population (important because health issues vary across age groups), and population density (important because dense populations can, for example, exacerbate outbreaks of some contagious diseases).

A range of *social factors,* such as family structure, housing quality and income also have an effect on various health outcomes. Environmental exposure during work and in *work places,* as well as in schools and other settings, also contribute strongly to health outcomes. Occupational injury remains a significant cause of illness, disability and premature mortality.

Whereas in rural areas pesticides and injuries resulting from the use of farm equipment figure prominently as environmental health hazards, the ergonomics of seating and work stations is an issue in the office-based work environment (reflected in back injuries and repetitive strain injury as the basis of major compensation claims and lost working time). Another major unwarranted outcome of our modern workplace is unemployment, accompanied as it is by consistent and growing evidence of adverse effects on health.

Mediating processes

Mediating processes are human institutions, interventions and behaviours that affect the interplay between inputs and thus influence health outcomes. Mediating processes include the public health system, technology, and lifestyle factors.

Availability of, and access to, health care services is central to the issue of maintaining or improving good health. In this report, the health care system is conceived broadly to include the full range of medical services provided by medical practitioners, hospitals, clinics, nursing homes, dental practitioners, etc.

Lifestyle choices can strongly affect human health. Examples of lifestyle choices which are known to have health implications include physical exercise, alcohol intake, tobacco smoking, and degree of exposure to ultraviolet radiation.

Outputs

Traditional measures of the health of the human population include mortality, morbidity, and disability. Such statistics are routinely collected in Australia.

The critical question for the purposes of this report is the extent to which health outcomes are influenced by the biophysical environment. Table 3.4 shows estimated disability-adjusted life years lost each year, on a global scale, due to various diseases and disabilities, together with an estimate of the contribution due to environmental factors.

Table 3.4

Proportion of global disability-adjusted life-years associated with environmental exposures—1990

	Global DALYs (thousands)	Environmental fraction (%)	Environmental DALYs (thousands)
Acute respiratory infections	116 696	60	70 017
Diarrhoeal diseases	99 633	90	89 670
Vaccine-preventable infections	71 173	10	7 117
Tuberculosis	38 426	10	3 843
Malaria	31 706	90	28 535
Injuries			
unintentional	152 188	30	45 656
intentional	56 459	not estimated	not estimated
Mental health	144 950	10	14 495
Cardiovascular diseases	133 236	10	13 324
Cancer	70 513	25	17 628
Chronic respiratory diseases	60 370	50	30 185
Total these diseases	975 350	33	320 470
Other diseases	403 888	not estimated	not estimated
Total all diseases	1 379 238	23	320 470

Source: *Murray and Lopex (1996, cited in WHO 1997)*

These data clearly demonstrate the powerful effects that the environment can have on human health, with about a quarter of all disability-adjusted life years lost globally attributable to environmental factors.

Clearly, the health effects of the environment will follow a very different pattern in Australia to the global picture outlined in Table 3.4. Mortality and morbidity due to infectious disease is much lower, and the environmental fractions for these, and other diseases, may be also be lower.

Selecting indicators for environmental health

Indicators for environmental health could be selected from inputs, mediating processes, or outputs. In this report, most of the recommended indicators are drawn from biophysical inputs, for reasons explained below.

Some of the inputs affecting human health are direct functions of the quality of the biophysical environment. Multiple causation and the complexity of mediating processes mean that it is typically difficult to relate specific 'environmental' inputs to particular health outcomes. For example, the incidence of melanomas is a function of lifestyle, protective measures (or lack thereof), and inherent genetic susceptibility, as well as the intensity of ultra-violet radiation.

On the other hand, there are a handful of relatively straightforward examples of direct relationships between environmental factors and human health outcomes. The well-established relationship between exposure to heavy metals and various neurological disorders is one. Another is the link between bacteriological contamination of food or water and outbreaks of food poisoning. While some instances are the result of poor food handling practices, others have been traced back to contamination of water.

The approach to selecting indicators for environmental health has been to identify biophysical health inputs which are:

- known to affect health outcomes, and
- influenced by human activities.

In general, health outcomes are favoured as indicators where it is possible to draw clear links between biophysical inputs and the health outcomes, and where mediating processes are unlikely to confound interpretation. However, it is suggested that morbidity and mortality statistics be used as 'background information' for state of the environment reporting. Likewise, a set of mediating factors known to vary across the settlement hierarchy.

In the parlance of the condition-pressure-response model, indicators relating to health outcomes can be thought of as condition indicators, and those relating to biophysical inputs as pressure indicators. Response indicators may relate to attempts to ameliorate pressures. Alternatively, changes in the health care system (an aspect of the mediating processes) can also be perceived as response indicators.

Waste outputs

Noise

Noise as a waste product

The urban metabolism model of human settlements parallels the metabolic processes inherent in living organisms and reflects the second law of thermodynamics. In essence, it says that in the processes concerned with urban living, we must have resource inputs, such as energy, and wastes. Irrespective of how efficient settlement dynamics is, it cannot be 100 percent efficient and convert all inputs to useful outputs for livability. Some of the energy must be wasted, rejected to a sink at a lower energy level. The best systems, or at least the natural ones, put boundaries around many such processes such that one process uses as resource inputs the waste outputs of another. Nature has perfected this system of operation, whereas humanity has not. It is only recently, in relative terms that society has recognised the imbalance and we find that new industries are born to reuse and recycle, and that symbiotic alliances are formed to maximise waste utilisation, alternatively known as by-products, and restore the balance. In a sense, we are seeing the greening of industrial/urban eco-systems.

A national survey (Hede *et al.*, 1986) suggests that noise is perceived to be the most serious pollution problem affecting residential communities in Australia. This is one output of the urban eco-system that is difficult to recycle or reuse (despite the fact that noise is sometimes generated intentionally to enhance processes). The only response alternatives, as shown in Figure 3.11, are to:

- reduce/eliminate the noise at the *source,*
- disrupt the transmission *path* to protect the receiver (eg. sound barriers on roads),
- isolate the *receiver* (eg. use of ear muffs by machine workers).

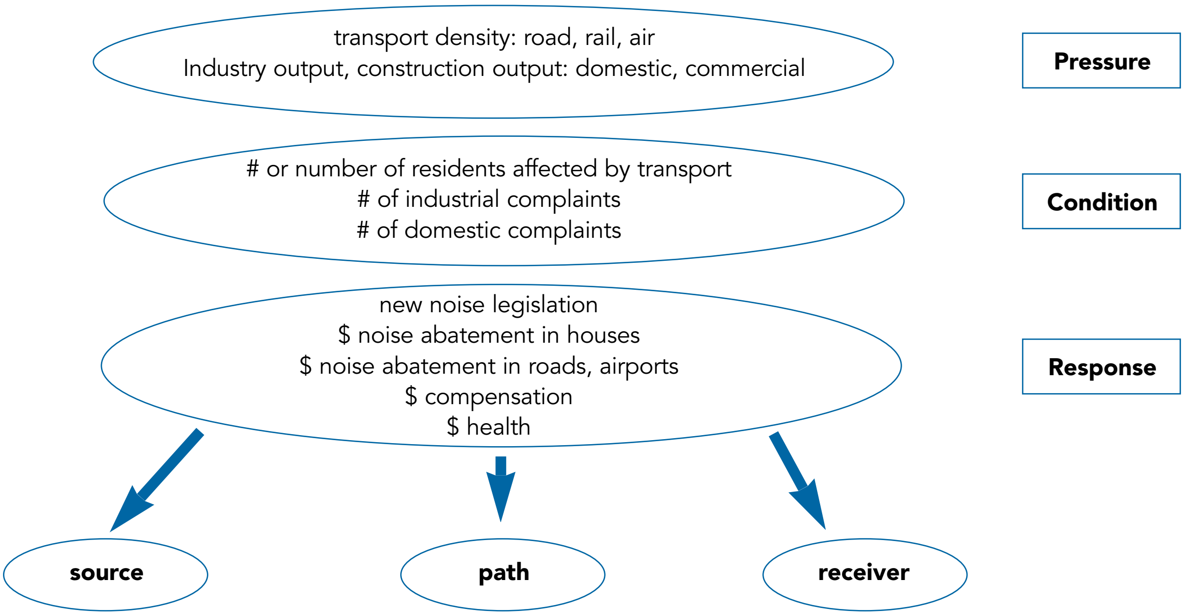


Figure 3.11: Domain model for noise.

In a sense, to reduce noise at the source is to work within the system. It corresponds to internal recycling since less waste is released to the environment for subsequent treatment. In some instances it may correspond to reducing the pressure source of Figure 3.11. For example, we may consider as alternatives:

- treatment of the tyre profile to reduce frictional interaction with the road surface and thereby influence the offending noise mechanism;
- alteration of the traffic flows to reduce traffic density or speed on offending roads (which does not affect the intrinsic offending noise mechanism).

However, to disrupt the transmission path (eg with a noise barrier), or to isolate the receiver (eg in a control chamber, or with ear-muffs) corresponds to treating noise as a waste product and deal with that waste after it is emitted to neutralise its effects. In a sense, interfering with the path or the receiver will influence the local environment and the 'condition', without altering the noise generation mechanism. The choice of solution depends on many factors, not the least one of which is cost.

The consequences of excessive noise, for which society must ultimately bear the costs, are:

- temporary and permanent hearing loss,
- interference with sleep,
- interference with communication,
- reduction in work and leisure efficiency,
- tension, irritability, headaches, and cardiovascular and digestive disorders.

These are not trivial, nor are the solutions. Litigation and compensation are increasing in frequency and this trend is likely to continue until sufficient attention is paid to the noise issue. In the past few years, governments have put in place legislation to attempt to solve the problem. Urban environments are particularly prone to noise problems because of the proximity of noise generating activities from living centres. With rising urban densities, we are likely to find that the problems become more acute unless appropriate measures are taken.

Noise and its measurement

Noise is unwanted sound which travels as pressure waves from a source, through a path, to a receiver. The loudness of the sound is a function of the amplitude (size) of the pressure wave and the frequency represents the number of waves passing a given point over a period of time. Higher frequencies correspond to higher pitches. The amplitude of the wave is measured in units called decibels (dB) and because the range of pressure is very wide, the scale is chosen to be logarithmic. A 10 dB rise represents a tenfold increase in noise, whereas a 20 dB represents a 100-fold increase. Noise levels cannot be added arithmetically and two 100 dB sounds do not add up to 200 dB, but in general, will result in a 103 dB sound. A 3 dB increase, which represents doubling of the sound energy, is not very noticeable to the human ear, whereas a 10 dB increase, which is a tenfold increase, is perceived as twice as loud.

Since the human ear does not respond equally to all sound frequencies, a useful way of expressing noise level is to apply frequency weighting that approximates the human response to noise. The resulting sound scale is called the A-weighted scale and the unit of pressure (and power) becomes the dB(A). As we have seen earlier, noise can be the source of a number of physical disorders, and importantly, dB(A) correlates well with hearing damage. The threshold of hearing is 0 dB(A), a quiet street may be 40 dB(A) and the threshold of pain is 140 dB(A).

Total sound energy received over a given period of time is expressed as the equivalent continuous sound level, averaged over that time. For example, $L_{Aeq, 8h}$ of 85 dB(A) is the noise in the A-weighted decibel scale from time-varying sources, which over eight hours is equal to the sound energy received from a steady source of 85 dB(A). This measure is very relevant in determining damage and other pathology.

In 1986, the OECD reported threshold noise levels L_{Aeq} for nuisance of 55-60 dB(A), and at levels above 65 dB(A) reported constrained behaviour patterns symptomatic of serious damage. Data from a number of countries indicate that people have a greater tolerance of rail noise than road noise and in some countries this is taken into consideration in the setting of standards, guidelines or recommendations, which are set around 5 dB(A) higher for rail than for roads.

Community noise

The survey by Hede *et al*. (1986) to assess the extent of community noise disturbance in Australia suggests that the noise sources of greatest impact are traffic, barking dogs, lawn mowers, aircraft, railways, neighbours and garbage collection. However, data on noise pollution are scarce and monitoring is generally inconsistent.

A recent study of traffic noise (Brown, 1993) shows that 9 percent of the population are exposed to excessively high traffic noise (>68 dB(A)) and that 22 percent experience undesirable levels (58-67 dB(A)). High noise levels would begin to interfere with comfort in residential buildings where the maximum recommended in the inner suburbs is 35 – 40 dB(A), and 30 – 40 dB(A) in the outer suburbs and rural areas. The parameters that determine traffic noise are traffic density, distribution of heavy to light traffic, speed and distance to carriageway. The principal noise description used by Brown is $L_{A10, 18h}$, which is the A-weighted noise level exceeded 10 percent of the time, over a period of 18 hours. This is a convenient measure where the noise, albeit of varying level, is continuous over long periods of time. Typical exterior noise levels from cars at a distance of 7.5 m can be 80 dB(A) and for trucks 90 dB(A). Since the goal for traffic noise in relation to new residences and roads is 60 dB(A) at a distance of 1 metre from the facade, traffic noise represents a serious annoyance potential.

Aircraft noise differs from road traffic noise in that the difference in noise levels between the front and backyard can be as much as 20 dB(A) for traffic noise but there is little difference for aircraft noise. Many measures are used to describe aircraft noise, usually related to the maximum A-weighted sound pressure level L_{Amax}. Corresponding time-integrated measures that allow for the variability of noise as the aircraft approaches and recedes from the receiver can be approximated, and special penalties added for night operation. To determine the aircraft noise exposure of a given receiver, the current Standard requires the long-term average maximum aircraft noise level to be less than 50 dB(A) in relaxing and sleeping areas, 60 dB(A) in recreational areas. This is higher than the values of 30 dB(A) and 40 dB(A) respectively that the Standard allows for continuous sound. The difference is recognition of the intermittent nature of the noise. For a given location, this places a requirement on the aircraft noise attenuation (ANA) of the property. The average house (with closed windows) has an ANA value of 20 dB(A), which is well short of the requirement for many properties in the vicinity of airports. Special treatment is therefore necessary for these. Australia has adopted an energy summation method over 24 hours to determine the suitability of certain zones for residential use. The measure known as the ANEF values (Australian Noise Exposure Forecast) can be projected on a map of the region to define contours of acceptability (ANEF <20), conditional acceptability (ANEF 20–25) or non-acceptability (ANEF >25). In the case of Sydney airport, it is estimated that 8000 dwellings are in the ANEF 25-30 range, 4000 in the ANEF 30-40 range and 150 in ANEF>40. Georgiou (1990) shows estimates for other capital cities in Australia, and the number exposed to ANEF>20 varies between 3.1 percent of the city population for Perth and 1.1 percent for Melbourne. Overall, 2 percent of Australia's population is exposed to ANEF>20, 0.7 percent to ANEF>25.

The objectives on rail noise are similar to those for road noise in that they aim to protect people near rail lines, they apply to similar periods of the day and are by and large based on L_{eq} type of indices. However, in contrast to road noise, rail noise is acoustically characterised by high noise levels of relative short duration. The European Commission Green Paper on Future Noise Policy (1996) recommends that the limits in residential areas be 62-69 dB(A) in the daytime and 53-62 dB(A) at night. The development of high-speed rail travel is of concern and the Very Fast Train (VFT) in particular would require special consideration in term of noise abatement within and upon approaching populated areas.
At low speed the main source of railway noise is the engine, while at travelling speed the noise produced by the interaction of the track and the wheels exceeds that of the engine. The level of this noise is dependent on factors such as the condition of the wheel, its characteristics, the construction of the rolling stock, speed and the condition of the track. Track and wheel irregularities can raise noise of a travelling train by more than 10 dB(A), suggesting that the importance of maintenance should not be underestimated. At very high speeds aerodynamic noise will be the most important problem and will require particular measures. The survey by Hede *et al*. (1986) does not place rail noise highly on the list of nuisances.

Narang (1994) makes the point that while in most single-family dwellings the main concern with noise is that of ingress of noise from outside, in multi-family dwelling or flats the main concern is with transmission of sound between flats which can be a source of aggravation. Urban consolidation is likely to exacerbate this situation. While the Building Code of Australia (BCA) stipulates sound transmission ratings for some parts of the structure, there is no data to confirm whether they are adhered to, that the performance has achieved expectation, the state of deterioration or indeed that the installation is according to acoustic specification. Furthermore, the only elements that attract attention are those covered by the BCA. Others are ignored.

Occupational noise

In addition to domestic noise, we need to consider the effects of noisy working environments on the workforce. In NSW for example, there were in excess of 16,000 occupational diseases reported in 1993/94 (Sampson, 1994) and this figure was increasing at the rate of 35 percent per annum. Deafness claims contributed 75 percent of this increase. The objective of any action is to reduce the incidence and severity of occupational noise-induced hearing loss.

There is strong evidence to suggest that the A-weighted sound exposure provides the best cause-effect relationship with hearing loss in noisy environments. Therefore, the equivalent (average) continuous sound pressure level is the most useful tool for dealing with industrial deafness with upper limits placed on that measure. Since a 3dB increase over the average daily limit corresponds to double the energy, half the exposure time to that noise level represents the same total exposure. The national standard for exposure to noise in the occupational environment is an eight hour equivalent continuous A-weighted sound pressure level $L_{Aeq,\,8h}$ of 85 dB(A). For peak noise, the national standard is a peak noise level of 140 dB, irrespective of exposure time.

The Confederation of Australian Industry works in close cooperation with the National Occupational and Safety Commission to identify those areas associated with noise where there is a need to revise Standards and regulations. Industry is held responsible for excessive noise levels that may contribute to deafness in the workforce.

Waste

Australia currently produces more waste than at any other time in history. Dual pressures of population increase and the demand for a high standard of living require additional inputs of natural resources, the result of which has been an increase in the production of waste (ABS, 1996).

All metabolic processes require energy. Waste is an inevitable, if undesirable component of all metabolic processes. The type and quantity of energy used contributes to the amount and composition of waste generated. Disposal of waste can be a source of pollution or it can provide secondary raw materials redefined as a resource.

'Waste' for the purpose of this study is defined as a product that has a negative value to its current owner, in its current location (Moore *et al.*, 1993a). This definition provides an opportunity for waste to be viewed also as a resource if the location or time frame change.

Solid and liquid waste generated by a community are collectively referred to as municipal waste. Municipal waste can be broadly divided into three waste flows, or streams (measured in units of mass per unit time). These waste categories are:

- Municipal waste: domestic and council;
- Commercial and industrial waste: major Australian Standard Industrial Classification (ASIC) industry groups, waste processing facilities;
- Building and demolition: domestic, council, major ASIC industry groups and waste processing facilities (Moore *et al.*, 1993).

Waste streams

A number of waste streams resulting from human settlement practices may be defined. These are discussed in ABS (1996) and Durney (1996) and comprise: special and prescribed waste; industrial waste composition; domestic solid waste composition; and toxic wastes.

Special and prescribed wastes include: infectious, pharmaceutical, radioactive and incinerated wastes.

Industrial waste composition comprises: ash and dust (which can cause chronic respiratory disorders including asthma); liquid waste, sewage, sludge and slurry; waste water; aggregate rubble and overburden; and gas and fumes.

Domestic solid waste composition consist of: organic compostable matter (food / kitchen scraps, garden matter, other putrescible); other organic (textiles, rags, wood, rubber, oils, leather); household hazardous items (household chemicals, dry cell batteries, paint); paper waste (newsprint, printing—writing paper, magazines, package board, corrugated cardboard, disposable paper product, paper composite, miscellaneous packing); plastic waste including polyvinyl chloride (PVC) which may cause liver angiosarcoma, high density polyethylene (HDPE), polyethylene terephthalate (PET) and composite plastic; glass (packaging glass/ containers and other glass); ferrous material (steel packaging and composite ferrous); non-ferrous (aluminium, copper); and other wastes (carpet, plaster board, dust/dirt/rock/inert, concrete, ceramics, and asbestos products such as building material, brake pads; which may cause lung cancer, mesothelioma).

Toxic waste include: PAH (polycyclical aromatic hydrocarbons; produced from incomplete combustion of fuel; some are carcinogens); PCB (polychlorinated biphenyls; affect growth and reproduction); TBT (tributyltin from paints used for marine anti-fouling); cadmium, mercury, dioxins and furans (produced as a byproduct of manufacturing oranochlorines, chlorination of waste materials and combustion); natural toxins (poisonous substances from bacteria, plant and animal); and pesticides (which can cause cancers, birth defects, reproductive defects, neurological and respiratory conditions).

Waste management and monitoring

Information on the processing, disposal, transportation, measurement mode and mix of material types provides additional vital data for waste management and monitoring. Output from each stream is ultimately delivered to land, water and the atmosphere.

Urban solid waste characterisation can be determined by waste product, market product and direct sampling analysis. Direct sampling is the most common in Australia. Market product analysis determines the material balance of a selected product to derive the quantity expected for a given waste stream. Advantages of this system are that it is quick, cheap and effective in determining items that comprise a small percentage of the total waste stream. Market product analysis is also particularly useful for recording hazardous items (such as batteries) that may be missed by other methods (Moore *et al.*, 1993).

The amount and composition of waste generated by a community (that is the quantity of material types in a particular stream as a percentage of total waste, or as a weight ratio) increases in line with increases in consumer spending (World Resources Institute, 1996). In Australia, households generate approximately 40 percent of total urban solid waste produced (ABS, 1996). The majority of solid waste currently produced is disposed of to landfill, with less than 1 percent disposed of by incineration (ABS, 1996).

A major priority for waste management highlights the need to reduce the amount of waste generated per capita. This can be achieved through a mix of options, including: changing community perceptions: voluntary private sector compliance; and compulsory legislative processes.

In accordance with the OECD practice of waste minimisation, a movement away from wholesale disposability to one which embraces a life cycle assessment approach will ensure that minimum resources are used and maximum recycling amenity is established. Cleaner production techniques that foster energy efficient manufacturing processes are required. Examples include: the elimination of toxic raw materials using material substitution; treatment and reduction of harmful by-products as they occur; reductions in waste volumes by redesign including lightweight packaging and no packaging options (Moore and Tu, 1993c). In addition, re-use and kerbside recycling initiatives linked to community based education programs will further the aims of best management practice for waste reduction. Kerbside collection has been so successful that commodity prices for recycled materials have fallen to an economically unstainable level. Some councils have resorted to dumping collected materials at municipal landfill sites. Policy options are being discussed to ensure kerbside collection initiatives do not collapse (Environment Business, 1997). The issue of recycling is currently being addressed by the National Waste Minimisation Strategy.

Assessment of waste has been seriously constrained by the lack of cohesive data. Australia is obliged under international agreements to collect and report waste data in accordance with the OECD council decision C(90) 178/FINAL, 31/1/1991 and Agenda 21 recommendations. Specifically, the government of Australia is required to strengthen procedures for assessing waste quantity and composition while reducing waste destined for final disposal (UNCED, 1992). Initiatives to address this issue are being implemented by both government and industry. Programs initiated by the government include: the Intergovernmental Agreement on the Environment (IGAE, 1992); State of the Environment Reporting; the National Pollution Inventory; and the 1992 National Waste Minimisation and Recycling Strategy. Industry-adopted initiatives, which are sometimes ahead of government requirements, include: the Australian Chemical Industry Council (ACIC) Responsible Care Program; and the Australian Chamber of Manufactures (ACM) Best Practice Environmental Management Program (Moore and Tu, 1993c).

Although waste minimisation policies are formulated at State and Commonwealth levels, they are generally implemented by local governments. Local government usually have few legislative means available and must therefore decide on a policy that uses a combination of pricing, infrastructure, survive provisions and education to achieve their objectives.

Importance of developing waste indicators

Waste generation detracts from wealth and welfare within communities and the environment. Consumption of goods and services increases the amount and complexity of those wastes. To meet government and industry waste policies objectives, as well as international obligations, it is necessary to have a uniform set of monitoring guidelines that include classification, data collection, storage and reporting.

To gauge the success for human settlement livability on both a regional and national level, a demonstrated improvement in metabolic efficiency is required. This can be gauged by the amount and composition of waste material re-used, repaired, reclaimed and recycled. Waste indicators can be categorised according to the following themes:

- *Waste minimisation indicators:* help to determine activities that reduce quantity, toxicity and hazardous properties of waste, conserve natural resources by reducing the use of raw materials and reduce the use of toxic materials in production .
- *Safe management indicators:* measure the effectiveness of program activities to prevent harm to human health and well-being and the environment from mismanagement of waste after it has been produced.
- *Corrective action indicators:* measure the effectiveness of activities to control and clean up contamination.

Key indicators for waste act as a benchmark and provide an early warning system. This will allow qualitative and quantitative measurement so that trends can be easily communicated to specialists and the general community. They also provide an informed and methodical approach to implementation of best management practices.

Existing waste models

There are a variety of domain models used for state of the environment reporting. Those used for waste include the OECD's pressure-state-response model and the industrial metabolism models first developed as part of the International Geosphere-Biosphere Programme conference in 1988, Tokyo, and recently extended (Durney, 1996).

Tools like Material Flux Analysis (Baccini and Brunner, 1991) and Life Cycle Assessment provide waste stream characterisation by a combination of direct sampling and analysis with indirect materials balance approaches. Material Flux Analysis measures the flux of materials in products through a region over time (Moore & Tu, 1993c). These tools, together with additional information on materials and energy balances, may enable predictions to be made on the quantity and composition of future waste streams.

Extended metabolism model for waste

In line with *Australia: State of the Environment 1996* (State of the Environment Advisory Council 1996) the Extended Metabolism model reported here is wellplaced to characterise anthropological factors driving material flows, as they relate to waste.

The instruments of an extended metabolism model for waste (Figure 3.12) include resource inputs, dynamics of settlement, livability and waste output. To best characterise material flows within the waste indicator stream outputs are dealt with first. Energy and materials recovered from waste are treated as resource inputs.

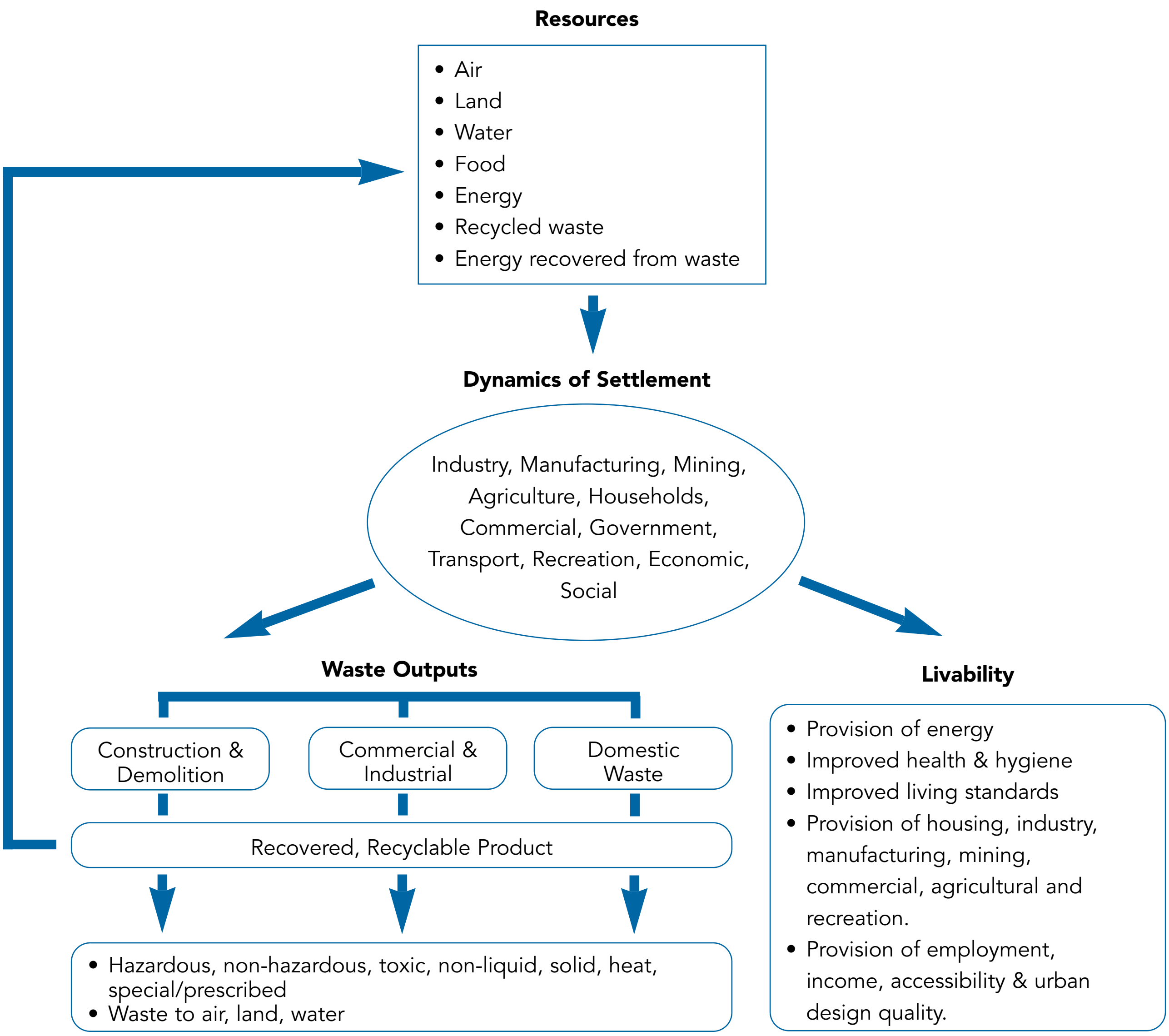


Figure 3.12: Extended metabolism model for waste.

Through the dynamics of settlement (such as industrial, manufacturing, household and agricultural practices), a range of benefits are produced which increase the standard of living within human settlements. These include: provision of energy, improved health and hygiene, the provision of housing, recreation, employment and urban design quality. A consequence of this livability improvement is the generation of wastes.

In general, three principal waste-outputs are generated as a result of economic activity. As previously defined, these are: domestic waste; commercial and industrial; and construction and demolition. Waste outputs may also be represented as resource inputs, in so far as they can be recycled into alternative energy sources or products. Examples here include: converting methane gas at landfill and wastewater treatment plants to produce energy or use as a fuel (which also reduces greenhouse gas emissions from these sources); and paper, rubber, glass, aluminium and steel recycling.

Waste management and minimisation can be achieved within all categories of the domain model: from the use of recovered energy and recycled wastes (as an alternative to traditional resource inputs), to waste minimising production process, appropriate packaging methods, greater collection and recycling of products (within industry, agriculture and other sectors), and by encouraging livability to proceed in line with environmental limitations.

Key Environmental Indicators

This chapter describes the key indicators chosen for each domain. They are ordered by domain (with numbers of indicators given in brackets):

0	Macro-level Indicators (4)
1	Energy (8)
2	Water (14)
3	Urban Design (12)
4	Transport and Accessibility (13)
5	Population (4)
6	Housing (8)
7	Indoor Air Quality (13)
8	Environmental Health (19)
9	Noise (7)
10	Waste (9)

A list of indicators is given at the start of each domain section, with a brief overview.

Each individual indicator has a description and rationale, including related policy objectives; comments on analysis and problems of interpretation of the indicator; a possible monitoring strategy for those indicators which are not already publicly available; reporting scale; possible outputs suitable for a national SoE report; data sources; targets or goals where appropriate; and links to other indicators.

Macro-level

Indicator 0.1:	International Migration to Australia
Indicator 0.2:	Gross Domestic Product (GDP)
Indicator 0.3:	Globalisation—Economic Dependency
Indicator 0.4:	Information Economy

The macro-level indicators are major, overarching measures which refer either to global changes or to macro-economic pressures or states. The five key indicators are—*international migration*, which has accounted for 45 percent of the population increase seen in Australia since 1945, and which is a major external pressure which remains under government control; GDP per person, which is the usual measure of total economic activity and which correlates strongly with a whole range of environmentally sensitive data including energy use; *economic dependency* or terms of trade, which refers to the relative prices of exports and imports, and which if declining represents a less sustainable future; *information economy*, or proportion of workers in information occupations which tracks the transition of society to one where information and knowledge—both renewable resources—are becoming increasingly central to economic development and well-being; and *renewable energy,* or proportion of energy from renewable sources (this is dealt with in Energy Indicators). It is considered that these indicators will have a major effect on the way people live and their response to the environment in the future.

Indicator 0.1: International Migration to Australia

Description

Net international migration to Australia (temporary plus permanent) per year.

Rationale

International migration has been a significant contributor to Australia's population growth through much of its recent history. Since the end of the Second World War, over five million immigrants have settled in Australia, representing the world's second highest immigration intake per capita (Newton and Bell, 1996). Net overseas migration is estimated to have contributed 45 percent of Australia's total population increase between 1982 and 1992 (ABS Yearbook, 1995, p.118).

The projected growth of world population and Asia's population in particular, and the extent to which Australia is increasingly integrating economically into this region has significant implications for levels of immigration to Australia in the 21st century.

Analysis and interpretation

Global flows of population have combined with global flows of capital, goods, services and information as key processes of late 20th century economic development.

For Australia, the impact of international immigration on human settlements—in particular, the capital cities—is considerable, given the preference of new immigrants for residence in the largest cities in the largest states (viz. Sydney, Melbourne; NSW, Victoria—see White and Williams, 1996). The international flows of population into these cities is a key factor in their sustained growth in the face of losses due to inter-regional migration which has favoured the sun-belt states in recent decades. The implications for provision of economic and social infrastructure, and demand for housing are significant.

Monitoring design and strategy

This indicator should be monitored annually with breakdown according to location of new arrivals—at least in relation to the principal destination cities.

Reporting scale

National, major urban (MU).

Outputs

A table presenting number of new overseas immigrants in each settlement category (MU).

Data sources

Department of Immigration and Multicultural Affairs, Canberra.

Linkages

Indices of Socio-Spatial Segregation (3.12); New Dwellings Completed (6.3).

Indicator 0.2: Gross Domestic Product

Description

Real growth in Gross Domestic Product (GDP), (ie., adjusted for inflation).

Rationale

GDP represents the sum total in any period of economic output of selected goods and services traded on the monetary market. It includes the production of new consumer goods and services, new houses, offices, hotels and factories, the capital equipment to furnish these places, plus public sector provision of a range of goods (like roads and ports) and services (like education, health, law and order and defence). It is output produced in Australia: hence the inclusion of 'domestic' in the title. Imported goods available for sale in Australia are part of some other country's GDP, but our exports, though not destined to be used here, are nevertheless part of Australian production and GDP. It is criticised by some as not including, among other things, costs to environment of economic development (Eckersley, 1998).

Analysis and interpretation

Economic growth in the 21st century will be centred primarily within cities. As engines of such growth, human settlements will draw heavily upon key resources, such as energy and materials. Outputs of manufactures and services are predominantly urban-centred.

Given that Australia's economy is also strongly commodities based—almost 50 percent of Australia's exports are extractive in nature (ABS Yearbook 1995, p.761)—economic growth, as reflected in GDP will also affect rural and remote settlements associated with mining and agricultural activity.

From an environmental perspective, it is highly desirable that economic development take place in a way that minimises the use of natural resources. In the past, there have been strong positive correlations between economic growth and resource consumption. However, ecologically sustainable development demands that this nexus be broken, or at least that the form of the relationship be changed.

The Australian Bureau of Statistics is developing a set of 'satellite accounts', which document the flow through the economy, in physical units, of a range of natural resources, including land, water, forests, fish, energy, and minerals. The satellite accounts also examine the production of wastes and spending on environmental protection.

Using the satellite accounts, it will be possible to identify the relationship between GDP, resource consumption, and waste production on a whole of economy and sectoral basis. This will facilitate study of the form of the relationship between GDP and resource consumption. At this stage, there are no plans to produce accounts on a regional basis.

Monitoring design and strategy

This indicator should be monitored annually at national and regional levels.

Reporting scale

National, regional (where practicable).

Outputs

A table presenting real GDP growth per year.

Data sources

Australian National Accounts: National Income, Expenditure and Product (ABS, Catalogue No. 5204.0).

State governments in Australia periodically undertake input-output analysis of regional economies.

Linkages

Total Energy Use (1.1); Energy Use in Industry (1.2); Total Annual Water Usage by Sector (2.4); Cost of Congestion; Population and Household Growth Rate (5.1); .Unemployment Rate (5.3); House Price to Income Ratio (6.2); Quantity and Composition of Commercial and Industrial Waste Generated (10.4).

Indicator 0.3: Globalisation—Economic Dependency

Description

Ratio of export prices to import prices.

Rationale

According to INDECS (1992, p.156), the fact that most Australian exports are standardised primary products means that they are traded in world commodity markets at prices determined by the forces of *global* demand and supply. The main practical consequence of this is that, as a supplier, Australia cannot significantly influence the world prices of its principal exports (the main exception being wool, since Australia is the world's largest supplier of that commodity).

Similar considerations arise on the import side. Because Australia accounts only for a tiny fraction of the total world demand for manufactures, variations in domestic economic conditions and policies will again have little influence on the prices we pay for our imports. An economy which is a 'price taker' in the world markets for *both* its exports and imports is called a *dependent* economy.

Analysis and interpretation

Despite the lags that occur between global economic downturns and local private sector investment in infrastructure (viz. commercial and industrial buildings, etc.), settlements that are strongly linked to the global economy will experience the impacts of highs and lows in Australia's trade performance through construction activity rise and fall. Governments can, and do, compensate during downturns via counter-cyclical investment in key infrastructure projects, but are tending to look to the private sector for an increasing role in the city-building process.

Monitoring design and strategy

This indicator should be monitored annually.

Reporting scale

National.

Output

A table depicting terms of trade (see INDECS 7, 1992, p.159).

Data sources

Australian Bureau of Statistics.(ABS)

Linkages

Gross Domestic Product (0.2).

Indicator 0.4: Information Economy

Description

Percentage of workforce employed in information occupations.

Rationale

Australia, in common with other advanced western societies, is undergoing a societal transition, where the new economic engines of growth are based no longer on industrial manufacturing, but on new information and service industries—on information workers and the information economy.

The significant contrast between this and earlier technological/societal transitions (viz. agriculture → industrial) relates to the fact that wealth is being created through the vehicle of information and knowledge—both renewable resources, unlike their predecessors.

A further contrast relates to the underlying technology platform (distributed high bandwidth communications and computing) which holds the potential for radically transforming space-time relationships (ie. which activities are undertaken where) from those characteristic of the industrial era which is passing.

Analysis and interpretation

The full spatial ramifications of this societal transition are still unclear, but from recent Australian studies (Gipps *et al.*, 1997; Newton *et al.*, 1997). there is evidence of a radical turnaround in the locational preferences of manufacturing versus information (producer services) industries. Manufacturing industries are decentralising, while producer services industries are centralising. Information industries are locating in close proximity to information workers (inner and middle ring suburbs of cities).

The full impact of this technological/societal transition on human settlements can be expected to be significant and warrants monitoring.

Monitoring design and strategy

The key features to be monitored relate to the changing industrial and occupational profiles of cities and regions which provide important pointers to fundamental shifts in the demand for particular locations by different groups of workers and different types of industry. Metrics suitable for charting shifts in Australia's information economy are found in Newton (1995).

Reporting scale

Urban hierarchy (UH).

Outputs

Tables presenting distributions of different occupational groups (and different industry groups) across the full spectrum of Australia's settlement.

Data sources

Australian Bureau of Statistics (ABS) Census of Population (held five yearly).

Linkages

Percentage of Home-Based Workers (3.8); Total Time and Distance Travelled (4.9); Costs and Congestion (4.13); Floor Area per Person (6.1).

Energy

Indicator 1.1:	Total Energy Use
Indicator 1.2:	Energy Use in Industry
Indicator 1.3:	Energy Use in Transport
Indicator 1.4:	Domestic Energy Use
Indicator 1.5:	Commercial Energy Use
Indicator 1.6:	Expenditure on Energy Programs
Indicator 1.7:	Renewable Energy
Indicator 1.8:	Cost of Energy

Energy is a broad input into human settlements which is used in virtually all classes of activity. It is strongly linked to GDP; however the search for more energy-efficient ways of living and producing is a major target of environmental programmes. The energy use indicators consider total energy use, and energy by end-use in the major sectors: industry, transport, domestic and commercial areas where efficiencies are increasingly being sought; as well as a response indicator: expenditure on programmes for energy conservation, and the push towards renewable energy.

Indicator 1.1: Total Energy Use

Description

Total energy use is a state indicator of aggregate energy use (in PJ); of intensity, the latter expressed in PJ/GDP (at constant prices) and as a percentage of the total for each major sector: industry, domestic, commercial and transport and by fuel, including renewables.

Rationale

Total final consumption in Australia has increased by about 2 percent per annum, while GDP increased at about 3 percent per annum. The basic approach for this indicator is to disaggregate total energy use into component sectors, each sector being defined by a particular activity, output or end-use. The indicators will show, *inter alia*, changes in the energy use over time and changes in sectoral composition. Indicators of sectoral/divisional (and sub-sectoral) activities are crucial in evaluating the impact of energy policies and other forces on sectoral energy use.

Analysis and interpretation

Analysis can be developed to relate total energy end-use (for all sectors) to the activity or output of each sector. The energy use indicator may be absolute or normalised with respect to the GDP contribution or output of each sector. Changes over time can then be explained in terms of changes in these components. The main sectors are: industry (manufacturing, mining, agriculture and construction), services (commercial), transport, energy conversion and domestic. These data can be used to compare urban settlements and indicate relative sector intensities, combined with structural effects. A more detailed analysis is needed to separate the two. (Structural differences, which define the sectoral output shares, are explained by ratios of output to GDP. These may be the subject of other indicators for in-depth factorisation of the different effects). The environmental impact of each sector vis-à-vis energy use is readily estimated from the fuel mix in that sector.

There are those who argue that it is inappropriate to combine two factors, such as energy use per unit of economic input (Lowe, 1998). By such an indicator, increasing energy use would appear not to be a problem as long as the GDP increases faster, but the environment does not recognise the pressures as being divided by economic output. A doubling of energy use in urban areas would create air quality problems, whether the GDP trebled or remained static. Consequently, the indicators of total energy use, commercial energy use, etc., should be simple indicators of energy rather than composite indicators of energy intensity.

Both types of indicator are recommended.

Monitoring design and strategy

The Australian Bureau of Agriculture and Resource Economics (ABARE) and the Department of Primary Industry and Energy (DPIE) collect the data by surveys.

Reporting Scale

Variability of energy indicators is principally related to sectoral activity such as national industry profile, national housing profile, etc. The reporting scale should reflect this to capture the environmental character of human settlements. An appropriate frequency would be every five years.

Output

Cumulative bar chart of *fuel intensity* (PJ/GDP) and/or *fuel use* (PJ) for each sector.

Data sources

Fuel and electricity surveys and reports by ABARE and by the DPIE. The survey by ABARE is confined to mining, manufacturing, communication, rail transport, electricity generation and gas production sectors. These data need to be supplemented by sales figures as a proxy for consumption. Typically, data are available from Electricity Supply Association of Australia (ESAA), Joint Coal Board (JCB) and Queensland Coal Board (QCB) and the Australian Bureau of Statistics (ABS).

Links to other indicators

Share of GDP of each sector (this is relevant to determine the structural make up of the economy); Energy Use in Industry (1.2); Energy Use in Transport (1.3); Domestic Energy Use (1.4); Commercial Energy Use (1.5); Expenditure on Energy Programs (1.6).

Indicator 1.2: Energy Use in Industry

Description

Energy use in industry is a state indicator of aggregate intensity, expressed in PJ/GDP (at constant prices) by major Australian and New Zealand Standard Industrial Classifications (ANZSIC) Sub-division (2-digit) and by fuel (including renewables).

Rationale

Industry, as classified here, incorporates mining, manufacturing, agriculture and construction. The largest single user of energy is the manufacturing sector (>25 percent). Combined, agriculture, mining and construction consume approximately 7.5 percent of the energy. Within the context of the large urban settlements, not all centres will necessarily have constituents from all sectors of industry. Energy policies have devoted some efforts to reduce the energy consumed by this sector and a number of voluntary measures are in place to encourage more efficient technologies and reduce environmental impacts. The energy used is normalised with respect to the GDP contribution of the sub-sector.

Analysis and interpretation

Innovation contributes to increased end-use efficiency and could lead to fundamental changes in the energy sector, particularly on the supply side. The rise in solar technologies or fuel cells would lead to a greater emphasis on decentralised electricity generation. The indicator identifies the fuel mix in the sector and suggests structural changes. Therefore, it helps understand how fuel intensity evolves in the industrial sector and whether energy consumption changes as a result of attitude, legislation or other initiatives. The change in energy use over time could reflect production (GDP) effects, structural effects or real intensity effects. The latter comprise technical or fuel changes. Since the indicator is normalised with respect to contributions to GDP, the production equation is eliminated from the equation. The distribution among different sectors will give a qualitative evaluation of the structural mix, but will not separate technical effects from the aggregate intensity indicator. Clearly, energy intensive industries in a particular urban settlement will bias the results toward the high end of energy use per $GDP for the settlement. A more detailed analysis would require an indicator of structural composition (say, output per capita) to uncover the real intensity effect, ie the efficiency of the industry sub-sector.

Monitoring design and strategy

Surveys are undertaken by ABARE every two years, providing extensive data on the amount and type of fuel used by 5300 establishments covering a range of industries.

Reporting scale

Variability of energy indicators is principally related to sectoral activity such as national industry profile. The reporting scale should reflect these changes when they occur to capture the environmental character of human settlements. An appropriate frequency would be every five years.

Output

Cumulative bar chart of aggregate intensities for consecutive periods for each sub-division, identifying for each column, the fuel used.

Data sources

Fuel and electricity surveys and reports by ABARE and by the DPIE. The survey by ABARE is confined to mining, manufacturing, communication, rail transport, electricity generation and gas production sectors. This data needs to be supplemented by sales figures as a proxy for consumption. Typically, data is available from ESAA, JCB and QCB, ABS.

Links to other indicators

Structure of industry; Exposure to Industrial Noise (9.3).

Indicator 1.3: Energy Use in Transport

Description

Energy use in transport is a state indicator, expressed in MJ/capita for each transport mode (as well as total transport), accounting for effects such as population densities and remoteness.

Rationale

Transport accounts for about a third of the energy used in Australia with road transport accounting for about 80 percent of the transport energy consumed. Petroleum products are the major fuels in this sector. The country is highly urbanised, with ten urban localities accounting for 70 percent of the population. The design of our cities frequently involves large distances between residential and work locations and urban passenger transport relies heavily on the private car, with a corresponding limited reliance on the public transport system. The stock of Australian road vehicles has approximately doubled over the last 20 years, with passenger cars accounting for 80 percent of the fleet. Family cars are the second largest investment for most families and are no longer seen as a luxury. Rising incomes appear to drive rising car ownership and travel, away from less energy intensive modes of transport and less energy demanding activities. The movement of freight, particularly for urban and inter-city movement of non-bulk goods also relies on road transport and to a lesser extent on rail. This is an important indicator of energy use and the focus of legislation to reduce the many impacts on the environment.

Analysis and interpretation

The main drivers of energy efficiency in this sector are taxation, the recognition of the need to mitigate against energy profligacy and reduce environmental impacts, and the imposition of Australian Design Rules that control emissions and fuel consumption. Some of these, however, do not resolve the energy profligacy issue and may indeed encourage greater use to satisfy set criteria. Indirectly, the indicator addresses complementary aspects of the urban lifestyle. Over time, the indicator will show the structural changes in transport, help to understand how fuel intensity of travel evolves and whether energy was saved in the sector as a result of changes in attitude or legislation. Combined with indicators of travel in (say) km/capita, the energy indicators can be factored to differentiate between distance and efficiency effects. Aggregate energy intensity indicators do not present the whole picture, and particularly for inter-urban comparison, structural differences must be considered. Typically, the information needed is concerned with a measure of activity (or output in kms) per unit of GDP (or capita) for each of the transport modes.

Monitoring design and strategy

The data are monitored and reported by ABS and the Bureau of Transport and Communications Economics (BTCE). Analysis is also carried out by ABARE.

Reporting scale

Transport modes within sample settlements representative of urban, rural and remote centres. Indirectly, this accounts for differences attributed to population densities and lifestyles.

Output

Cumulative bar chart of fuel intensity (GJ/capita) for consecutive periods for each transport mode. For urban centres, the only urban modes of relevance are road (car, bus, freight) and rail (heavy rail freight, heavy rail passenger, light rail train and tram).

Intensity for each mode is one indicator, but by itself it could be misleading. The figure for each *mode* may be improving but the overall picture deteriorating as a result of changes in the modal split (as has happened in the last 10 years for freight, and the last 30 years for urban passenger transport).

Data sources

ABS, BTCE, ABARE

Links to other indicators

The trends should be seen in conjunction with transport indicators which identify car numbers and kilometres travelled per mode. Energy used in transport relates to environmental impacts through the emission of Greenhouse gases, particulates, toxic gases (CO, NO2) and generally, air quality. Other indicators relate to fuel efficiency of the different modes, car power to weight ratio, which can be used to refine the sector analysis. This indicator is also linked to air quality.

Car Ownership (4.2); Fuel Pricing and Taxing (4.6); Total Time and Distance Travelled (4.9); Fuel Consumption per Transport Output (4.12).

Indicator 1.4: Domestic Energy Use

Description

Domestic energy use is a state indicator, expressed in GJ/capita by end-use and fuel (including renewables).

Rationale

This sector is responsible for approximately 8 percent of the energy used in Australia and the level of population is a major determinant of the demand for energy and the consequent pressures on the urban environment. Residential sector energy policies have focused on energy end-uses, typically on reducing the energy intensities of new devices, on conservation measures in buildings, insulation, windows, appliances etc. For this reason it is useful to disaggregate the energy used into its various components. The indicator will show allocations of energy to each major use, namely: lighting, space heating and cooling, water heating, cooking and appliances. The dominance of any one end-use will be obvious, as well as changes in time. The indicator addresses complementary aspects of the urban lifestyle. Over time, it indicates structural changes, help to understand how fuel intensity evolves in the domestic sector and whether energy was saved in the sector as a result of changes in attitude or as a result of legislation.

Analysis and interpretation

The distribution, shown for different time periods, will not discriminate between the changes in device intensities (efficiencies or technical effects) and changes in behaviour (that is, the propensity for greater comfort, amenities etc, which may be more energy intensive). The indicator will however, show in the aggregate the substitution of one fuel for another and the energy intensity. A more detailed analysis would require factorisation to separate fuel mix, technical effects and sectoral mix. For inter-urban comparison, at least some structural differences must be allowed when concerned with different pressures. For example, we expect different aggregates and structural components in Hobart and Sydney because, for example, of differing climates. Other indicators would be needed to elaborate on these, and their consequences on heating, or for cooling.

Monitoring design and strategy

Arriving at energy figures by end-use within the sector is not simple. Sub metering is the most reliable method, but also the most expensive. Often, the information is deduced from surveys and models of the performance of equipment, buildings etc, combined with what data are available from metering. A number of studies have been carried out in the past, and models are available.

Reporting scale

Variation in energy use for the domestic sector is mostly influenced by climatic and social factors. The scale should therefore be based on sample settlements representative of urban, rural and remote locations, accounting for climatic variability.

Output

Cumulative bar chart of fuel intensity (GJ/capita) for consecutive periods for each end-use, typically heating, cooling, ventilation, lighting and cooking. Variations can be expected across Australia due to climate effects.

Data sources

Sustainable Energy Development Authority (SEDA), ABARE, ABS, DPIE, State Energy Authorities and utilities. Typically, The Queensland Electricity Commission carried out surveys of domestic appliance usage, which identified the penetration and use of electric as well as other appliances.

Links to other indicators

This indicator should be viewed in the context of other statistics of the housing sector. Typical links are to the average size of dwelling, climate, occupancy, all of which affect energy use.

Floor Area per Person (6.1); Building Materials (6.7); Operating Energy Efficiency (6.8).

Indicator 1.5: Commercial Energy Use

Description

Commercial energy use is an aggregate state indicator of intensity, expressed in GJ/GDP (at constant prices) by end-use and fuel (including renewables).

Rationale

This sector is sometimes referred to as the services sector and includes offices, hospitals, schools, entertainment halls, shops, and other activities in non-residential, non-industrial and non-agricultural buildings. It is an important sector, consuming approximately 4 percent of the energy use in Australia. GDP, floor areas and employment levels are indicators of activity in the sector, each providing a measure of the efficiency when appropriately paired. For this exercise, the contribution to GDP is used to normalise the aggregate intensity indicator. Aggregate indicators of energy intensity do not separate the effects of changes in sectoral structure, efficiency and end-use utilisation levels. To provide some understanding of these effects, the indicator discriminates in terms of end-use and fuel type. Further analysis is needed to define the real intensity effect and particularly technological effects. The indicator will show estimated allocations of energy to each major use, namely: lighting, space heating and cooling, water heating, cooking and appliances.

Analysis and interpretation

The distribution, shown for different time periods, will describe final (delivered) energy use, normalised to output and therefore describe important trends. However, it will not discriminate between the changes in device intensities (efficiencies or technical effects) and changes in behaviour, that is the propensity for greater comfort, amenities etc, which may be more energy intensive. The indicator will show in the aggregate the substitution of one fuel for another and the energy intensity, but not specific technical effects. A more detailed analysis requires factorisation to separate fuel mix, technical effects and sectoral mix. For inter-urban comparison, structural differences must be allowed for, concerned with different pressures. For example, we expect different aggregates and structural components in Hobart and Sydney. However, other indicators would be needed to quantify these, typically, for heating and cooling, indicators describing the severity of the climate.

Monitoring design and strategy

ABARE and ABS collect data through surveys according to well-established protocols. Much of these data are reported in the literature.

Reporting scale

Variation in energy use for the commercial sector is mostly influenced by climatic and economic factors. The scale should therefore be based on sample settlements, representative of urban, rural and remote locations, and discriminate for climatic variability.

Output

Cumulative bar chart of fuel intensity (GJ/GDP) for consecutive periods for each end-use: typically heating, cooling, ventilation, lighting and cooking.

Data sources

Reports by ABARE and by the DPIE. A survey undertaken by ABARE every two years is confined to mining, manufacturing, communication, rail transport, electricity generation and gas production sectors. The survey results are complemented by data from other sources, typically Supply Associations, Utilities, and DPIE among others. This data is segmented in terms of fuel source but not end-use. Further work is needed to develop the necessary data.

Links to other indicators

Other indicators, which describe the operation of the services sector find relevance in the context of energy use: per capita area of building, climate and amenity.

Mechanical Ventilation Rate of Commercial Buildings (7.2).

Indicator 1.6: Expenditure on energy programmes

Description

Expenditure on energy programmes is an aggregate response indicator of expenditure in $ by the public sector, industry, households and the service industries on energy management, conservation and efficiency programmes.

Rationale

Expenditure on energy programmes reflects some of the efforts to reduce pressure on the urban environment. The Commonwealth Government, together with other jurisdictions, is upgrading energy end-use data for benchmarking and has developed a range of programmes to encourage energy efficiency measures. Typically, the Entreprise Energy Audit Programme (EEAP) shares the cost of energy audits between Government and industry to avail industry of the opportunity of introducing more efficient energy measures. The National House Energy Rating Scheme and the Insulation Code are examples of initiatives in the residential sector, while the agreement with industry on new targets for fuel efficiency of new motor vehicles announced in Greenhouse 21C is an example of initiative in the transport Industry.

Analysis and interpretation

The pervasive nature of energy means that social impacts are inevitable. Increasing end-use efficiency is one of the most effective ways to reduce the environmental impacts of the energy sector. Realising all economically feasible gains in energy end-use efficiency is a key strategy for a sustainable energy policy. Because of the wide range of initiatives and interpretations possible, it is essential that this indicator be well defined. A database of relevant information should be established in the first instance.

Monitoring design and strategy

Some of the data for this indicator are available from ABS and budget papers. Care should taken to avoid double counting, for example to count as Government expenditure where industry receives grants and subsidies (from governments) and to count as industry expenditure where fees and charges are paid to Governments.

Reporting scale

Variability of energy indicators is principally related to sectoral activity such as national industry profile. The reporting scale should reflect this to capture the environmental character of human settlements, with the major sectors being industry, households, services and energy conversion. An appropriate frequency would be every five years.

Output

Table of expenditure by the public sector, industry, households and the service industries on energy management, conservation and efficiency programmes.

A report released in 1996 by the Department of Environment, Sport and Territories (n.d.) shows that government expenditure (or foregone revenue) on financial *subsidies* to natural resources use and that encourages profligate resource use, is huge (approximately $13 billion/pa) compared with spending on energy management, conservation and efficiency—and tends to encourage profligate resource use. This indicates the desirability of indicators capable of differentiating programs that encourage conservation and efficiency versus use.

Data sources

Estimates of pollution abatement and improved energy conservation and or management costs for industry are available from ABS surveys, while estimates of pollution abatement expenditure by the public sector are available from ABS public sector accounts, Commonwealth and State budget papers, State energy authorities and utilities, SEDA. Energy conservation and management costs need to be separated from other environmental costs.

Links to other indicators

This indicator links to other expenditure indicators for relativity.

Indicator 1.7: Renewable energy

Description

Percentage of annual energy supplied from renewable sources. These include hydro-electricity, solar, wind, geothermal and biomass (wood, bagasse, manure and crops for ethanol).

Rationale

The industrial era, now being superseded by the informational era (refer to Indicator 0.4) was fundamentally linked to the consumption of fossil fuels as the principal source of energy. It produced new modes of economic organisation characterised by increased scale of production. As Ryan (1980, p.202) describes it in the context of the United States industrialisation and urbanisation:

> *'The concentrated nature of fossil fuels had the effect of organising American life in a more concentrated physical and social structure…Larger production units necessitated gathering larger quantities of the factors of production—labor, materials, machinery, and services—into a relatively small area around factories. This resulted in the growth of urban centers, and people left the site of the former energy source, rural America, for the economic advantages of the centers where the new fuel was used, the city. Social concentration grew out of physical concentration in the form of crowding in cities, the accumulation of wealth in large organisations, and the greater political power these organisations exercised in national affairs.'*

The fundamental reality has been highly dependent upon access to energy. Substitution of renewable for non-renewable sources of energy is a necessity for sustainable economic development and demand side management and improvements in energy efficiency offer scope for reducing this dependency as well as providing greenhouse and other environmental benefits.

Analysis and interpretation

Renewable energy accounts for 6 percent of energy use in Australia, and government policies are in place to promote growth of this sector. However, since energy from renewable sources is not devoid of environmental impacts, it is important to identify the individual sources of energy. For example, whereas solar, thermal and photo-voltaics are mostly free of environmental impacts in use, biomass and hydro-electric sources carry certain penalties.

Monitoring design and strategy

The key changes to be monitored relate to the growth of different sources of energy.

Reporting scale

Urban Hierarchy

Outputs

Table of percentages and totals for different energy sources

Data sources

ABARE and the DPIE collects the data by surveys.

Linkages

Total Energy Use (1.1); Energy Use in Industry (1.2); Energy Use in Transport (1.3); Domestic Energy Use (1.4); Commercial Energy Use (1.5); Expenditure on Energy Programs (1.6); Housing Operating Efficiency (6.8)

Indicator 1.8: Cost of energy

Description

Average costs of energy by fuel (including renewables and electricity) is a state indicator expressed in \$/GJ or \$/GWh for each sector of the economy.

Rationale

This indicator acknowledges the role of price in determining the energy mix. Energy prices are low in Australia compared with the other OECD countries and this has consequences on energy conservation, levels of energy utilisation, energy mix and environmental impacts. With the exception of oil, taxation is not used as an instrument to internalise externalities or influence the energy mix.

Analysis and interpretation

A link exists between energy prices and energy mix in different sectors of the economy. In many industries, and to some extent in the domestic and commercial sectors, demand is inelastic in the short term. Changes in utilisation trends that demonstrate a causal relationship to changing prices are only seen in the longer term. The link is particularly important vis-à-vis the commercial development of non-renewable energy. The price of energy from renewable sources is currently not competitive with other sources of energy, reflecting the cost of inputs to the production of that 'clean' energy. The economics of renewable energy, including recovery of the capital costs, and the assumption of negligible environmental impact need to be evaluated.

Monitoring design and strategy

ABARE and the DPIE collect relevant data.

Reporting scale

Variability of energy indicators is primarily related to sectoral activity such as national industry profile. The reporting scale should reflect this to capture the environmental character of human settlements. An appropriate frequency would be every five years.

Output

Charts of prices for each sector, over time.

Data sources

Fuel and electricity surveys and reports by ABARE and by the DPIE.

Links to other indicators

Energy Use in Industry (1.2); Energy Use in Transport (1.3); Domestic Energy Use (1.4); Commercial Energy Use (1.5); Expenditure on Energy Programs (1.6); Renewable Energy (1.7).

Water

Indicator 2.1:	Proportion of Settlements Served by Treated Water
Indicator 2.2:	Municipal Household Water Consumption Patterns
Indicator 2.3:	Annual Water Usage by Sector
Indicator 2.4:	Sewage Disposed to Oceans, Inland waters, Land and re-used
Indicator 2.5:	Wastewater Discharged by Domestic, Industrial, other
Indicator 2.6:	Municipal Population Serviced By Treated Wastewater
Indicator 2.7	Volume of Stormwater Discharged to Receiving Waters
Indicator 2.8	Type of Contaminants in Stormwater Discharge
Indicator 2.9:	Stormwater Recycled
Indicator 2.10:	Wastewater Re-used by Type of Application
Indicator 2.11	Residential Water Consumption Under Fixed versus Flexible Water Pricing Regime
Indicator 2.12:	Investment Ratio in Wastewater and Stormwater Technology/Conservation Practices
Indicator 2.13:	Community Drinking Water Violations

The water indicators represented here reflect both the state of the economy (ie. extent to which governments and/or population at large can afford to invest in the technology and infrastructure capable of delivering high quality urban water systems) as well as the environment. Examples of environmental *state* water indicators include Biological Oxygen Demand (BOD) concentrations in treated wastewater, nitrate levels in water, etc. Economic state indicators include: proportion of population with access to standard drinking water supply; proportion of households with mains connections; proportion of health problems resulting from water-related problems. Pressures represent adverse impacts (consumption of limited water resources, discharge of wastewater, discharge of pollutants into water). Responses are the beneficial impacts (actions to reduce water pollution; investment in better wastewater treatment plants and re-use facilities).

Water indicators can be sub-divided into six categories due to the various roles that water plays within human settlements. These categories are: water supply (and storage), water demand (or consumption), water quality, disposal and treatment of water (predominantly wastewater), recycling and reclamation of water; and pricing, economic and water management issues.

There are a number of critical 'key' water indicators that result not only from human settlement practices, but also impact upon inland waters, estuaries and the sea. Four such indicators are:

- community drinking water violations, which reports on the percentage exceedances of water quality guidelines for a suite of bacterial and chemical water quality parameters;
- BOD discharged to coastal and inland water bodies;
- total suspended solids (TSS) discharged; and
- nutrient loads in water bodies (estimates of the phosphorus and nitrogen concentration in waterways).

These have been presented in detail by Fairweather and Napier (1998) for 'Inland Waters' and Ward *et al.* (1998) for the 'Estuaries and the Sea' Indicator Series.

Indicator 2.1: Proportion of settlements served by treated water

Description

This indicator provides a measure of the proportion of the Australian population that has access to treated water for consumption and general living purposes. This includes water for drinking, cooking, bathing, washing, garden watering etc.

Rationale

Throughout Australia, particularly in remote areas and small rural settlements, the provision of treated water to dwellings may be limited. This is due primarily to cost, and resource/environmental limitations. Due to the low rainfall, low runoff and high evaporation situation in Australia, the inability to provide treated water to all settlements may have negative impact on the health, hygiene and general living standards of those settlements.

Analysis and interpretation

Analysis may be performed to determine whether any correlations exist between settlements without treated water supplies and health problems. It may also be useful in identifying whether settlements without treated water supply are the result of geographic or economic impediments.

Monitoring design and strategy

Monitoring should be carried out on across settlements of all population sizes (that is metropolitan, rural and remote), as it is expected that the smaller and more remote the settlement, the less likely it is to be connected to treated water supplies. In the event that this is prohibitively costly, sample settlements may be identified that are representative of urban, rural and remote milieu.

Reporting scale

This indicator should be measured on a 3-5 yearly basis., and reported on a State/Territory (and national) basis, under the three settlement categories: urban, rural, remote (URR).

Output

Tabulation of population with access to treated water supplies.

Data source

The proportion of settlements served by treated water should be obtainable from the water utilities responsible for water supply to each location. In the case of Victoria, for example, this would be available from both Melbourne Water or the retail businesses such as Yarra Valley Water and South-East Water.

Links to other indicators

This indicator may also be linked to Indicator 8.1: Bacteriological and Inland Waters Contamination (Fairweather and Napier 1998) Indicator 2.1 (Human criteria exceedances, which report on the percentage exceedances of water quality guidelines for a suite of bacterial and chemical water quality parameters).

Indicator 2.2: Municipal household water consumption patterns

Description

This Indicator measures municipal water use per person in Australia, on a daily and total annual volume basis. This can be further divided into a pattern of water use by municipal households. For the purposes of this indicator, household 'water use' comprises: toilet flushing; bathing and showering; washing machine and dishwashing; drinking and cooking; external use (such as garden watering, vehicle washing); and miscellaneous.

Rationale

Like Canada, and many other parts of the developed world, Australians may be accused of taking water for granted, particularly in urban environments. Changes in water demand patterns may be placing greater stress on supplies at times when they are already under pressure from abnormal weather patterns (UK Department of Environment, n.d.). This is particularly the case in Australia, which often has periods of below average rainfall and drought conditions. By identifying household water usage patterns, it will be possible to target education and management practices towards high use areas. For example, in Perth, external water use would be expected to be much higher in summer (due to their very low rainfall) compared to cities such as Melbourne and Sydney. In addition, by monitoring water use patterns across municipalities, it may also be possible to determine whether water use consumption patterns differ across locations. For example, increasing affluence, higher standards of living, and increasing populations may all change water demand patterns.

Analysis and interpretation

Reporting average daily water consumption patterns per year will be useful in determining whether consumers are reacting positively to water conservation education and advertising programs over time. A reduced water consumption rate per household which coincides with an increased total annual water consumption per municipality indicates that the problem is one of demographics (such as the relocation of the community from rural into urban areas), or population increases. Further, as discussed above (see *rationale*), by identifying the break-down of water use consumption patterns, water management policies and programs can be better targeted.

Monitoring design and strategy

Municipal water use per person in Australia should be reported annually. It should identify average daily and total annual water consumption per person in urban centres greater than 50,000 people. Results may also be summarised on a state/territory and national basis. Sample settlements can be identified (one per state/territory) and the pattern of water use by municipal households can be identified. As discussed above, household 'water use' will comprise: toilet flushing; bathing and showering; washing machine and dishwashing; drinking and cooking; external use and other.

Reporting scale

Results should be presented for major urban (MU) centres as well as at a state/territory and national basis.

Output

The results should be presented in a series of table and pie-charts. One table will show average water consumption per person (in Ml/day/head), and total for each municipality identified. A second table will show average water consumption per person (Ml/day/head) for the various years of monitoring. A pie-chart could be used to identify the percentage of water used by all households for toilet flushing; bathing and showering; washing machines and dishwashing; drinking and cooking; external use; and miscellaneous.

Data source

Water utilities from customer records of water usage.

Links to other indicators

This also links to Indicator 2.3 (total annual water usage by water body and by sector) and 2.11 (Volume and cost of residential water consumption under fixed versus flexible water pricing regime).

Indicator 2.3: Annual water usage by sector

Description

This Indicator measures total annual water usage by the following economic sectors: domestic, industrial, commercial and rural (irrigation and dryland) sectors. This Indicator also features in Fairweather and Napier (1998) as Indicator 4.7.

Rationale

The growing demand for water, combined with current water resources management and increasing pollution levels, places increasing pressures on existing water bodies. Although municipal water use accounts for less than one tenth of the world's overall water use, urbanisation increases the per capita demand for water for domestic purposes. Part of this demand growth is attributed to better access to water supplies in cities than in remote settlements. Industrial demand for water also rises. As the number of people in urban areas grows, so does the demand for food and, hence, for irrigation in agricultural areas close to cities. These pressures can sometimes lead to water demands exceeding supply (World Resources Institute *et al.*, 1996). The aim of this indicator is to monitor water usage by the different sectors within the economy. This will be useful when determining suitable areas to introduce re-use technologies, alternative water supply sources (such as Aquifer Storage Recovery, groundwater) and for targeting demand management practices.

Analysis and interpretation

Increases in water usage by a particular sector (or group of sectors) will indicate target areas for the introduction of alternative supplies, demand management, research and development and investment in re-use technologies in the future.

Monitoring design and strategy

Water utilities (both government operated and private) monitor the distribution of water to their various clients (domestic, industrial, agricultural etc). By accessing this information, the indicator will monitor trends in water usage over time.

Reporting scale

Total annual water consumption should be recorded at the level of drainage division (and state/territory), for the domestic, industrial, commercial and rural (irrigation and dryland) sectors. This should be reported annually, as it is expected that changes in population over time will steadily increase demands for water. The distribution of those demand changes (that is, between urban versus rural needs) will be less obvious. The results should be reported on a volumetric basis (gigalitres per year) and as a percentage of total consumption across the sectors.

Output

Volumetric and percentage results should be in tabulated form. National changes in total water usage (for the various sectors) should be represented graphically each year.

Data source

Water authorities routinely maintain these sorts of records. At several times in the past (eg. by the Australian Water Resources Council in 1980s) these have been collated for a national report. Both the Land & Water Audit and ABS's physical water account will do this again in the near future. Remote sensing may be particularly useful to estimate the number of farm dams. The water retail and wholesale utilities, also have information on water usage by the different sectors. In Victoria, for example, this information is provided by selected water retail business, which is available in published reports and summarised on the world-wide-web.

Links to other indicators

This is linked to Indicator 2.2 (Municipal daily and annual household water consumption).

Indicator 2.4: Sewage disposed to oceans, inland waters, land and re-used

Description

This Indicator records the total volume (and percentage) of treated wastewater disposed to oceans, inland waters, land and re-use. Methods of land disposal include evaporation ponds, irrigation, soakage systems and artificial wetlands. Effluent discharge to inland waters in Australia is usually from smaller inland communities with a few exceptions (such as Canberra, and large cities and towns in Queensland). Effluent discharged to oceans is the most common form of disposal. The proportion of sewage treated and re-used is very small (Australian Water Resources Council, 1992).

Rationale

As populations increase and the demand for limited water resources also continues to rise, there are increasing concerns regarding the disposal of treated wastewaters to natural environments. Most of the effluent from metropolitan wastewater treatment plants is discharged to the coastal marine environment, and currently there are about 700 ocean sewage outfalls around Australia (ABS, 1996). As stated earlier in this report, survey results reported in Thomas *et al.* (1997) indicate that wastewater discharged to coastal waters are predicted to rise by more than 400 GL by the year 2020 across Australia. It is important that the volume and percent of water discharge to the various environments (oceans, inland water, land) and wastewater re-used is monitored.

Analysis and interpretation

The discharge of sewage to oceans, inland waters, land and re-use represents a *pressure* indicator, which is continuing to rise, in line with increasing population. The proportion of treated sewage re-used represents a *response* aimed at protecting the environment. This indicator will therefore not only monitor any increase in sewage disposal to the environment over time, but will also help to gauge the effectiveness of wastewater re-use policies, practices and technologies at curbing disposal.

Monitoring design and strategy

Sewage disposals to oceans, inland waters, land, and the proportion re-used should be available from water utilities responsible for wastewater treatment plants.

Reporting scale

This indicator should be recorded annually. The unit of measure should be in gigalitres and recorded on a state-wide and national basis. If collected on a smaller scale (local government) it could monitor penetration of new water-saving devices. For example, there are significant opportunities in both dry (composting) toilets and flushing (on site treatment and re-use) toilets to reduce water consumption and waste disposal. Composting toilets offer the opportunity to avoid using water in toilet flushing and also turn the solid waste into a beneficial soil conditioner. Such systems are fully self-contained and can be easily replicated for larger developments. Current market penetration is low due to lack of knowledge and experience in local councils. Such barriers could be overcome with effective education of council staff and review of health hazard legislation.

Larger scale systems that treat either/both grey and black water are viable in an urban setting. Several grey water systems have already been installed (ie., Condamine Court public housing in the ACT) and are working well.

Combined grey and black water systems have also been built (New Haven Village, SA Housing Trust) that treat all waste on site. Such systems can be financially viable through operating cost and capital cost reductions.

These on site treatment systems can save substantially on water consumption, as the treated water can be used for irrigation and toilet flushing. The recovered solids can replace other mineral/nutrient sources.

Output

Volumetric results should be in table form, on a state/territory and national basis. Graphical representation (such as a pie-chart) should be used to display the proportion of treated wastewater disposed to the receiving waters, land and re-use domains.

Data source

Regional water authorities; private wastewater treatment plants; Water Services Association of Australia. Each state agency has data on the amount of water collected for treatment and discharged.

Links to other indicators

Linkages exist to Inland Waters (Indicator 2.3) and Estuaries and the Sea (Indicator 7.5).

Linkages also exist to Indicator 2.5 (Volume and percent of wastewater discharged by domestic, industrial, other), 2.6 (percent and number of municipal population serviced by treated wastewater to various levels) and 2.12 (Investment in wastewater and stormwater technology as a proportion of total water utilities' expenditure).

Indicator 2.5: Wastewater discharged by domestic, industrial, other

Description

In line with Indicator 2.8, this will report on the volume and percent of total wastewater discharges coming from domestic (effluent), industrial (trade waste, industrial waste) and other sectors.

Rationale

It is important to monitor the relative sources of wastewater discharges from the various sectors within the economy. Not all wastewaters are the same. Domestic wastewater, for example, is the water-borne waste derived from human origin, comprising faecal matter, urine and liquid household waste from sinks, baths and basins. Industrial (or trade) waste, alternatively, is the liquid waste that is generated from any industry, business, trade or manufacturing process (ARMCANZ & ANZECC, 1994). The variations in physical, chemical and biological characteristics of domestic and trade wastes, for example, may have different affects on receiving waters. Therefore, it is important to monitor the source of wastewater discharges to water over time.

By identifying the sectoral discharges, policies and practices, research and development, and technologies can be devoted to high discharging sectors, in order to reduce pollution loads on the environment.

Analysis and interpretation

As mentioned above (Indicator 2.8), the discharge of wastewater to the environment represents a pressure indicator, which is continuing to rise in line with increasing population. This indicator will therefore not only monitor any increase in total sewage disposal over time, but will also help to determine the distribution of those increases by the various sectors within the economy.

Monitoring design and strategy

Wastewater disposals by sector should be available from water utilities responsible for wastewater collection and treatment.

Reporting scale

This indicator should be recorded annually. The unit of measure should be in gigalitres per sector and recorded on a state-wide, national, and drainage division level.

Output

Volumetric results should be in table form, on a state/territory, national and drainage division basis. Graphical representation (such as a pie-chart) should depict the proportion of wastewater coming from each sector.

Data source

State water authorities responsible for the operation of wastewater treatment plants should have records of the amount and sources of effluent (domestic and industrial) reaching the treatment plant, and discharges to the environment following treatment; private wastewater treatment plants; Water Services Association of Australia, Australian Bureau of Statistics.

Links to other indicators

Linkages exist with Indicators 2.4 (Volume and percent of sewage disposed to oceans, inland waters, land and re-used), 2.6 (Percentage and number of municipal population serviced by treated wastewater to various levels).

This is also linked with Inland Water Indicator 2.3 (Wastewater Treatment), which reports on the number of water treatment plants and the levels of water treatment or filtration adopted per drainage division.

Indicator 2.6: Municipal Population serviced by treated wastewater

Description

This Indicator records the number and proportion of municipal population serviced by treated wastewater to a primary, secondary, tertiary or nil level of treatment.

Rationale

Depending on the level of treatment, the discharge of treated wastewater into receiving waterbodies may potentially affect downstream water quality and quantity for both human use and aquatic ecosystems. This indicator monitors society's response to this quality issue by treating wastewater (to various levels) before releasing it back into the water body.

Analysis and interpretation

This indicator will provide a breakdown, not only of the number of population serviced by municipal sewerage systems, but the extent to which these systems treat water before discharging to the environment (or re-using). It would be expected that as environmental considerations are realised, treatment levels will rise. Treatment of wastewater prior to disposal represents a *response* to concerns for maintaining environmental integrity.

Monitoring design and strategy

The population serviced by municipal sewerage systems and the level of treatment at each plant would be available from the state water utilities.

Reporting scale

It would be sufficient to monitor the changes in municipal sewerage connections on a three to five year frequency. This could be done at both the state and drainage division level, with national figures also record.

Output

Results would be in the form of a table that reports on the proportion (and number) of people serviced by municipal sewage systems on a four-yearly basis. Graphic results (such as pie-chart) would show the proportion of sewerage systems treating to primary, secondary, tertiary or nil levels.

Data source

Data are available from state water authorities; private wastewater treatment plant operators; Water Services Association of Australia and the Australian Bureau of Statistics. The water utilities in Melbourne, for example, have detailed information on localities connected to sewer and septic systems and the populations serviced by those provisions. The level of treatment is also available.

Links to other indicators

Linkages exist with Indicators 2.4 (Volume and percent of sewage disposed to oceans, inland waters, land and re-used), and 2.5 (Volume and percent of wastewater discharged by domestic, industrial, other).

This is also linked with Inland Water Indicator 2.3 (Wastewater Treatment), which reports on the number of water treatment plants and the levels of water treatment or filtration adopted per drainage division.

Indicator 2.7: Volume of Stormwater discharged to receiving waters

Description

Stormwater runoff comprises all surface runoff and infiltration within an urban area, and includes both dry-weather flows, wet-weather flows and flood discharge. It may also contain overflows from sanitary sewers or combined sewer overflow systems (Thomas *et al.*, 1997).

Stormwater runoff is transported to waterways by a variety of natural and constructed drainage features. In Melbourne, for example, stormwater is discharged at over 1000 locations (outfall pipes), of which nearly 100 discharge directly into Port Phillip Bay (Melbourne Water, 1993).

This indicator records the amount of stormwater discharged to receiving waters.

Rationale

The system of stormwater collection and discharge forms a very important component of the human settlements water cycle. Surface water runoff is enhanced in urban areas by the replacement of relatively porous natural surfaces and water detaining vegetation with impervious roofs, roads, footpaths, car parks and other buildings and structures. In order to monitor the impact of stormwater discharges on receiving waters, it is important to recognise the volumes and locations of discharges. Further, these discharges are expected to increase over time in line with population increases and urban expansion.

Analysis and interpretation

This indicator provides a breakdown on the volume of stormwater discharges to different receiving environments: oceans, lakes and inlets. The indicator will be useful not only in monitoring any volumetric changes in discharges over time, but will help gauge the effectiveness of re-use policies and practices at curbing disposal.

The discharge of treated stormwater to receiving waters represents a *pressure* indicator, which will continue to rise, in line with increasing population. It would be expected that, as environmental considerations are realised, stormwater recycling will increase.

Monitoring design and strategy

Stormwater disposal data should be available from the water utilities responsible for stormwater collection and disposal.

Reporting scale

This indicator should be recorded annually. The unit of measure should be in gigalitres/year, and recorded on a state-wide, national and drainage division level for the different receiving environments.

Output

Volumetric results should be in table form, on a state/territory, national and drainage division level.

Data sources

Surveys of stormwater discharges have been reported by Melbourne Water (1993) for Victoria and, more recently, in Thomas *et al.* (1997) for Australia. Current readily available information on stormwater discharges is limited. However, as Australian water industries move to a more decentralised system, the importance of monitoring and accountability will increase. Potential sources for the collection of stormwater discharge information include the state water authorities, private stormwater treatment plant operators; Water Services Association of Australia and the Australian Bureau of Statistics.

Where there is an absence of such data (in the short term) the following response indicator may be a useful surrogate: Implementation of Stormwater Controls (viz. the proportional compliance with stormwater quality control guidelines. The National Water Quality Management Strategy's Guidelines for Urban Stormwater Management will provide measures for the effectiveness of response.

Links to other indicators

In general, studies related to stormwater discharges have confirmed the impact on the receiving environment is related to the extent, level, nature and intensity of urban and industrial development in a catchment (Melbourne Water 1993). Consequently, this indicator is linked also to Urban Design Indicators (3.2: Land converted from non-urban to urban uses; 3.4: Residential density; and 3.5: Percentage of medium and high density residential construction).

It is linked to several Water indicators: proportion of stormwater recycled; quality of stormwater discharged; investment in stormwater technology as a proportion of total stormwater expenditure.

It is also linked to several 'Inland Water' indicators, including 2.2 (swimming days lost); 3.6 (pollution point sources), and 3.1 (Guideline Trigger Levels Reached).

Indicator 2.8: Type of Contaminants in stormwater discharges

Description

This indicator is used to identify and monitor the quality of contaminated stormwater entering waterways. As stormwater runs over a variety of surfaces, it may collect a variety of constituents which may degrade receiving waters. These include: excessive nutrients, heavy metals, faecal bacteria, pesticides, non-reactive sediments and turbidity, oil and greases, and litter (such as cans, bottles and plastic bags) (Department of Environment and Land Management, 1993).

Rationale

The impact of stormwater discharges on the receiving environment is related to the extent, level, nature and intensity of urban and industrial development. The quality of stormwater is highly variable, and under the worst conditions, may be similar to raw sewage, particularly after the first flush in low rainfall areas (Gutteridge, Haskins and Davey, 1981; Clark, 1992; Pugh and McIntosh, 1991). The potentially adverse health impacts associated with pathogens and toxicants found in stormwaters result in stormwater quality issues being of particular concern within human settlements.

Analysis and interpretation

Stormwater contaminants may be grouped into five broad classes: pathogens, toxicants, nutrients, litter and suspended solids (Melbourne Water, 1993). This indicator represents a pressure indicator that monitors the quality of receiving waters over time. It may also be used to gauge the effectiveness of various mechanisms in controlling pollution, such as gross pollutant traps, litter booms, oil/grit separators, litter and sediment traps and flow controls (Thomas *et al.*, 1997).

Toxicants are substances containing certain concentrations of poison, such as petroleum products, industry by-products, biocides (pesticides and herbicides), some household chemicals; mercury, copper and crude oil (which occur naturally in the environment). Common toxicants in stormwater runoff include oil and petrol, treated pine, paints and primers, solvents, spray can propellant, rust, garden pesticides and fertilisers, and anti-freeze.

Pathogens are microscopic organisms and include viruses, bacteria, fungi and parasites. They can cause disease in plants and animals, including humans (eg. hepatitis and gastroenteritis). Beach closures often follow heavy rain, due to high levels of E-coli in stormwater discharges to oceans.

Nutrients in stormwater runoff may come from fertilisers, leaf litter, decomposing lawn clippings, detergents from car washing, engine oils, eroding surfaces and pet faeces.

Typical litter in stormwater includes plastic bags, plastic sheeting and film, plastic take-away food containers, paper items (particularly free-distribution and junk mail), glass and cans. Suspended solids in water include fine particles of: soil from erosion, especially clays; dirt from streets, households and buildings; airborne particulate matter; organic matter from plants and animals (including sewage); and bacteria and other micro-organisms. Suspended solids are often generated at land development and road construction sites; building sites; market gardens; sand stockpiles, sand mining and sand transport areas; unstable mining sites, road shoulders; and drains.

Monitoring design and strategy

Occurrence of E-coli is relatively easy to detect and count, and can be used as an indicator for pathogen levels. Total phosphorous and nitrogen levels will provide measures of nutrients in waterways.

Toxicants, heavy metals, oil and grease, volume of litter, and suspended solids should also be recorded. Stormwater disposal data should be available from the water utilities responsible for stormwater.

Reporting scale

This indicator should be reported annually. The unit of measure should be in mg/L for most contaminants (eg. heavy metals, oil, grease, nitrogen, phosphate). Litter would be recorded by number of items. Litter should be broken down into its constituent components (eg. plastic, bottles, cans, etc.).

Output

Results should be presented on a state/territory and national drainage division level.

Data sources

Stormwater contaminant inventories have been reported in Melbourne Water (1993) and Thomas *et al.* (1997). Surveys need to be conducted annually.

State water authorities, stormwater research agencies, industrial stormwater treatment plant and disposal operators, Water Services Association of Australia, Australian Bureau of Statistics would be suitable authorities to hold contaminant records.

Links to other indicators

This indicator links to 2.7 (Volume of stormwater discharged to receiving waters); 2.9 (Proportion of stormwater recycled); 2.12 (Investment in stormwater technology/conservation as a percent of total stormwater expenditure); percent of BOD discharged to coastal and fresh water bodies; Percent of TSS discharged to coastal and fresh water bodies. It is also linked to Inland Waters indicators on Nutrient loads in inland, marine and groundwater bodies.

Indicator 2.9: Stormwater recycled

Description

Depending on the level of treatment, however, stormwater (like wastewater) may be reclaimed for a range of purposes including: agriculture; aquaculture; tree growing; recreation; environment; and industry uses. This Indicator records the amount of stormwater recycled as a proportion of total urban stormwater collection.

Rationale

Most indicators of water quality and quantity focus on water consumption and wastewater disposal and reuse. However stormwater represents a large component of the discharge to ocean and inland environments.
A range of constituents of stormwater exist which may degrade receiving waters. These include: excessive nutrients; heavy metals; faecal bacteria; pesticides; non-reactive sediments and turbidity, oils and grease, and litter (such as cans, bottles and plastic bags) (Department of Environment and Land Management, 1993). In Australia, for example, there is increasing evidence of the negative environmental impacts of stormwater discharges (Thomas *et al.* 1997).

Analysis and interpretation

'Stormwater' includes all surface runoff and infiltration within an urban area, including both dry-weather flows and flood discharges. It also includes overflows from sanitary sewers or combined sewer overflow systems (Thomas *et al*., 1997).

The discharge of treated stormwater to receiving waters represents a *pressure* indicator, which will continue to rise, in line with increasing population. This indicator will therefore not only monitor any increase in total stormwater volumes over time, but will also help identify society willingness to reduce these volumes, through re-use. It would be expected that as environmental considerations are realised, stormwater recycling will increase.

Monitoring design and strategy

Stormwater collection should be available from water utilities responsible for stormwater collection, treatment and disposal. Private utilities involved in stormwater recycling will also need to be monitored.

Reporting scale

This indicator should be recorded annually. The unit of measure should be in gigalitres per annum and recorded on a state-wide, national, and drainage division level.

Output

Volumetric results should be in table form, on a state/territory, national and drainage division basis. Graphical representation (such as a bar-chart) should depict the proportion of stormwater recycled per year.

Data source

State water authorities; private stormwater treatment plant operators; Water Services Association of Australia; Australian Bureau of Statistics.

Links to other indicators

Links exist with Indicator 2.12 (Investment in wastewater and stormwater technology as a proportion of total water utilities' expenditure).

Indicator 2.10: Wastewater re-used by type of application

Description

This Indicator reports on the volume and percentage of wastewater re-used by type of application.
Applications comprise: direct potable; indirect potable; non-potable urban residential; non potable urban municipal; agriculture; aquaculture; tree growing; recreation; environment; and industry. Definition and examples of each application is discussed in NHMRC, ARMCANZ and ANZECC (1996).

Rationale

Wastewater re-use may result from treatment of effluent either prior to it reaching the wastewater treatment plant or after. Private or small public industry strategies that produce reclaimed water for re-use within the economy, and reduce wastewater flows to the treatment plant include: detention storage, sewer mining and local re-use; greywater re-use; and sewer infiltration/flow reduction. Strategies to re-use wastewater after treatment at the plant include: wetland establishment; agricultural land irrigation; woodlot establishment; non-potable urban re-use and potable re-use; aquifer storage and recovery; and industrial uses for reclaimed water. In Australia, the proportion of wastewater reclaimed and used is small. However, by monitoring re-use applications throughout Australia, it will be possible to identify areas for future investment and management, which will help facilitate and promote the use of reclaimed water.

> *'An awareness of the role that water plays in the natural ecosystem has led to support for water for the environment. Where reclaimed water can be substituted for abstractions of water from the environment, protection of the natural ecosystems may be able to be achieved.'* (NHMRC, ARMCANZ and ANZECC, 1996, p.2)

Analysis and interpretation

This indicator will provide a breakdown on the volume of wastewater re-use by application. It would be expected that as environmental resources become constrained due to expected increases in population over time, re-use would become more widespread. Re-use represents a response to concerns for maintaining environmental integrity.

Monitoring design and strategy

Monitoring information on re-use strategies and pilot studies administered at the water utility level (for example by ACTEW) would be easier to collect than re-use applications undertaken on a smaller (for example, block size) scale. However, many water utilities and wastewater authorities have information on existing re-use applications.

Reporting scale

Due to the large number of re-use applications required for monitoring, reporting should be undertaken at the State/Territory level.

Output

Table will identify total re-use and its breakdown by application. Graphic representation (such as pie-charts) will also be useful for percentage applications.

Data source

Wastewater re-use data are available from state water authorities; private wastewater treatment plants; Water Services Association of Australia and the Australian Bureau of Statistics. Information on users of wastewater (eg. industry) are available from the water retail utilities, although some data may be confidential. This can be overcome by use of total re-use volumes.

Links to other indicators

Linkages exist with Indicators 2.4 (Volume and percentage of sewage disposed to oceans, inland waters, land and re-used), 2.5 (Volume and percentage of wastewater discharged by domestic, industrial, other), 2.6 (Percentage and number of municipal population serviced by treated wastewater to various levels), 2.9 (Proportion of stormwater recycled), and 2.12 (Investment in wastewater and stormwater technology as a proportion of total water utilities' expenditure).

INDICATOR 2.11: RESIDENTIAL WATER CONSUMPTION UNDER FIXED VERSUS FLEXIBLE WATER PRICING REGIME

Description

This Indicator records both the volume and cost of residential water consumption under a fixed or variable pricing regime, according to the water pricing structure in each state. This is done at the state/territory, household, and per capita level.

Rationale

If changes to water pricing structures induce more water conservation practices, then areas which currently operate under a fixed-price regime may benefit from changing to a flexible pricing structure. The result will be a decrease in demand for our limited resources. Alternatively, if the changes to price are ineffective at changing water demand, then it will be important to examine why. For example, is the price of water currently set too low? are people already operating at a necessity level? etc.

Analysis and interpretation

Under a flexible water pricing regime, total annual water consumption may decline, if households are expected to pay a higher per unit cost for water as their water consumption levels increases. This is in contrast to a fixed rate system, where the per unit cost for water would by constant, regardless of usage.

Monitoring design and strategy

As some States and Territories within Australia have recently converted from a fixed to variable water pricing regime for domestic water consumption, it would be necessary to also record previous years' consumption patterns, to allow for recent trends in consumption. Records of total water consumption, water consumption per household, and number of occupants per household will need to be identified, in order to assess both total, per person and per household consumption. Whether a fixed or flexible pricing regime exists in each state will need to be identified.

Reporting scale

Results should be presented for all urban centres in the settlement hierarchy (UH). Results should also be summarised at a state/territory and national basis.

Total residential sector water consumption for each urban settlement and state/territory should be reported in Ml/year. Total and average annual water consumption per household, and total and average annual water consumption per person should be measured in litres per household or per person (respectively).

Information should be reported twice yearly (summer and winter with corresponding rainfall figures). Assuming information is available for past practices, this database should date back to 1995.

Output

Results should be tabulated, based on the information identified in the Reporting Scale above.

Data source

State water authorities; Water Services Association of Australia; Australian Bureau of Statistics.

Links to other indicators

Linkages exist with Indicator 2.2 (Municipal daily and annual household water consumption), Indicator 2.3 (Total annual water usage by sector), Inland Waters Indicator 4.7 (water pricing).

Indicator 2.12: Investment Ratio in wastewater and stormwater technology/conservation Practices

Description

This Indicator represents expenditure by water utilities (both private and public), on technology, research, development and implementation for wastewater or stormwater treatment collection or disposal practices (including re-use) that are more environmentally friendly than conventional (current) practices. It also records expenditure by other private industries and other public sectors for the purposes mentioned above.

Rationale

Disposal of treated wastewater and stormwater to natural environments is of growing concern within Australia. The need to ensure a high quality of treated water being disposed of to natural environments, to improve collection and transport of effluent so that leakage is minimised, and to develop re-use technologies to reduce total discharge volumes, is increasing. This indicator will identify private and public commitment to improving disposal of wastewaters to natural environments. As the volume of wastewater for disposal increases in line with population increases over time, investments in stormwater and wastewater will become increasingly necessary.

The capacity of different infrastructure treatment options has potentially significant implications for greenhouse gas emission levels. Consequently it is important that information on anaerobic/aerobic options be collected, including information on the capture and re-use of methane as a resource to decrease operating costs for some facilities or at least to flare the methane to reduce greenhouse impacts. The Commonwealth released a waste management workbook on methane capture and use in late 1997.

Analysis and interpretation

The indicator will identify the investments into *wastewater* management as a proportion of total water utilities' annual operating expenditure. It will also record differences in expenditure between water utility and non-water utility sectors, and between private and public sectors. The indicator will also identify the investments into *stormwater* management as a proportion of total water utilities' annual operating expenditure, and will record differences in expenditure between water utility and non-water utility sectors, and between private and public sectors.

Monitoring design and strategy

Information will be required from the state/territory water utilities, wastewater treatment plants; and private and public sector involved in wastewater and stormwater investment and management. Information will also need to be collected from those utilities engaging only in conventional wastewater and stormwater practices, so that these results may be compared to *total* expenditure on wastewater and stormwater.

Reporting scale

The reporting scale should be at the State/Territory and national levels. Such an indicator may be presented in terms of both total cost, and cost as a proportion of the total expenditure of sewage treatment, or of stormwater disposed.

Output

Results should be tabulated with the following information:

- Total investment in wastewater technology/conservation practices ($m/year)—by public and private sector.
- Total expenditure on wastewater practices ($m/year)—by public and private sector.
- Investment in wastewater technology/conservation practices as a proportion of total water expenditure on wastewater—by public and private sector.
- Total investment in stormwater technology/conservation practices ($m/year)—by public and private sector.
- Total expenditure on stormwater practices ($m/year)—by public and private sector.
- Investment in stormwater technology/conservation practices as a proportion of total water expenditure on stormwater—by public and private sector.

Data source

Although perhaps more difficult to obtain, state water authorities; private wastewater treatment plants; Water Services Association of Australia; Australian Bureau of Statistics and research organisations (including CSIRO, CRCs) could provide information on wastewater and stormwater conservation expenditure. This could be available from the water supply and treatment industries directly.

Links to other indicators

Linkages exist with Indicators 2.4 (Volume and percentage of sewage disposed to oceans, inland waters, land and re-used), 2.5 (Volume and percentage of wastewater discharged by domestic, industrial, other), 2.6 (Percentage and number of municipal population serviced by treated wastewater to various levels), 2.9 (Proportion of stormwater recycled), and 2.11 (Proportion of wastewater re-used before/after reaching treatment plant).

Indicator 2.13: Community drinking water violations

Description

This indicator provides a measure of the proportion of the Australian population that has access to drinking water systems conforming to Australian Drinking Water Guidelines (NHMRC, 1994). In line with a similar indicator developed by US EPA (1996), public water systems are defined here as systems that provide piped water for human consumption to at least 15 service connections or serve an average of at least 25 people for at least 60 days each year. Non-community water systems, such as workplaces, schools and restaurants, are excluded from this indicator series.

This is covered under Fairweather and Napier's (1998) Inland Water Indicator 2.1: 'Human Criteria exceedances' which report on the percentage exceedances of water quality guidelines for a suite of bacterial and chemical water quality parameters for human health and recreation per drainage division.

Rationale

The quality of tap water throughout Australia is of a high standard when compared to other parts of the world (ABS, 1996). However, in some remote areas and rural settlements, water supplied to consumers may fail to meet Australian Drinking Water Guidelines and WHO drinking water quality standards. This may be due to economic impediments (ie. high cost of treatment), variability in the source water quality, and a lack of appropriate monitoring and treatment. Storage reservoirs may also develop water quality problems of thermal stratification, turbidity, salinity and blue-green algae, all of which would require treatment prior to distribution (ABS, 1996). In addition, expected future increases in pressure on water resources from urban expansion, recreation, agriculture and forest development may also reduce the standards of Australia's water resources. This may result in the need for additional expenditure in water treatment and monitoring; or a lowering of drinking quality guidelines.

Urban Design

Indicator 3.1:	Stock of Heritage and Cultural Assets
Indicator 3.2:	Amount of Land Converted from Non-urban to Urban Uses
Indicator 3.3:	Public Urban Green Space per Capita
Indicator 3.4:	Residential Density
Indicator 3.5:	Percentage of Medium and High Density Residential Construction
Indicator 3.6:	Index of Industrial Concentration
Indicator 3.7:	Percentage of Mixed Land Use Ratio
Indicator 3.8:	Percentage of Home-Based Workers Ratio
Indicator 3.9:	Number of Physical Assaults in Public Places
Indicator 3.10:	Number of House Burglaries
Indicator 3.11:	Indices of Urban Socio-economic Inequality
Indicator 3.12:	Indices of Socio-Spatial Segregation

The indicators of urban design cover land use, heritage, industrial structure, safety and crime; and economic and spatial inequality. The *heritage* indicator is the stock of heritage and cultural assets. *Land use* indicators include urban conversion, green space, mixed use, medium/high density dwelling construction, and population density. These relate to issues of urban consolidation, increasing densities and reducing motor car use. *Industrial* indicators include home-based workers, who generally use less transport, and industrial concentration, which measures the extent to which a community is dependent on just a few major industries. *Crime* issues are taken as physical assaults and house burglaries, which are crimes likely to affect a significant proportion of the population at one time or another. Debate exists as to the role of the physical setting and detailed design in addressing these matters. *Inequality* indicators relate to the extent to which social groups are spatially confined to particular locations within human settlements and the implications for well-being if a range of public and private goods and services are likewise spatially skewed.

Indicator 3.1: Stock of heritage and cultural assets

Description

Number of artefacts of historic, architectural or cultural significance, expressed by type: buildings, streetscape, public art, public spaces, other.

Rationale

The quantity, quality and accessibility of heritage and cultural assets influence perceived quality of life and sense of well-being. In this sense, the city is 'an open air museum'. Cities or human settlements which have a substantial and varied stock of such assets tend to also have well utilised, highly valued and safe public spaces, with a high degree of visual orientation for residents and visitors. A rich urban public realm supports local communal interaction, diverse lifestyles and pedestrianisation.

Analysis and interpretation

The assets covered by this indicator are highly differentiated by type and significance for different groups. Some assets—like central public spaces or town squares—are significant for and valued by a diverse range of people. Other assets—like particular sites or buildings—may have significance for a specific ethnic, religious or, even, age group.

Monitoring design and strategy

Monitoring should be carried out at national, state, individual metropolitan and individual smaller urban centre or township scales, based on Australian Bureau of Statistics (ABS) Statistical Local Areas (SLAs). Individual artefacts should be geocoded utilising a standard GIS. Monitoring should occur every 2 to 3 years so that trends can be established.

Reporting scale

Reporting should occur across the full urban hierarchy (UH) and where possible at local government level.

Outputs

A table which presents numbers of artefacts by type (see Description) and settlement type (see Reporting Scale). Maps which show location and density of artefacts, overall and by type.

Data sources

The Heritage Commission (national); State heritage registers; relevant State government agencies such as the Historic Buildings Register (Victoria) and Historic Houses Trust (NSW); State Chapters of the National Trust; professional associations—Royal Australian Institute of Architects and Royal Australian Planning Institute. Considerable effort will be required to develop consistent data sets, integrating data available from these diverse sources (see Natural and Cultural Heritage indicator set proposed by Pearson *et al.*, 1998).

Linkages

Indicator 3.9: urban centres with well preserved historic and cultural artefacts and precincts generally have safer public places due to the significant numbers of pedestrians in and near those areas. See also, Natural and Cultural Heritage indicators.

Indicator 3.2: Amount of land converted from non-urban to urban uses

Description

Total area (hectares) of land previously in rural or non-urban usage converted to urban uses—residential, commercial, industrial, public spaces—per year.

Rationale

Excessive loss of land previously in non-urban uses can reduce the accessible flow of rural commodities to urban centres, as well as threatening water sources and quality, natural habitats, recreational and environmental assets, and increasing the likelihood of land degradation and pollution. A high land conversion rate is often associated with significant extensive population growth and a highly rate of new household formation on the urban fringe. Loss of agricultural land at the edges of expanding urban centres results in longer transport distances for food, and hence, more energy consumed, including for refrigeration.

Analysis and interpretation

Non urban land may be identified and later rezoned for urban use years before development—eg. as a new residential estate—actually occurs. This indicator should, ideally, monitor actual development at the point in time at which conversion to a new urban land use occurs.

Monitoring design and strategy

This indicator should be monitored annually across the full urban hierarchy (UH).

Reporting scale

As for the previous section; local government areas (LG) aggregated to each scale (UH).

Outputs

A table presenting area of land conversion for each settlement category. Maps depicting the rate and location of development over time can be generated in order to monitor outcomes temporally and spatially as an input into policies to control future patterns and pace of land development.

Data sources

Relevant information on urban land development are collected by each local government authority and relevant public utilities, including electricity, gas, railways, roads and water authorities. This data will need to be collected, interpreted on a consistent basis, and compared with land use records held by the appropriate State Government planning and land agencies. The accuracy of collected data can be checked at, say five yearly periods, against areal photographic and/or remote sensing data.

Linkages

See Indicators 3.7, 6.3 and 6.4; high rates of dwelling construction, especially on greenfield sites, results in high rates of land conversion. There are also strong links to Land Indicators 2.2, 2.3 and 2.7 (see Hamblin, 1998).

Indicator 3.3: Public urban green space per capita

Description

Area (hectares) of publicly owned and/or accessible urban land devoted to parks, gardens, recreation and other open spaces, divided by total resident population.

Rationale

The amount, location and quality of green space in urban centres influences the health of residents and visitors, through contributing to air quality, passive and active recreation, and habitat preservation. Access to such spaces reduces the need to travel further in search of these assets, and contributes to the control of greenhouse gas emissions.

Analysis and interpretation

Land counted as urban green space is publicly accessible land used by people on foot or bicycle. It excludes road space and other open spaces not accessible for regular human use or contemplation.

Monitoring design and strategy

This indicator should be monitored across the full urban hierarchy (UH), every 2 to 3 years.

Reporting scale

As for previous section.

Outputs

A table presenting areas of urban green space for each human settlement category.

Data sources

Relevant data at the local scale is recorded on local government and State Planning agency land use data bases (maps). Figures at state and national levels are calculated by aggregating data at lower scales. The resulting data base can be checked against periodic aerial photographic and remote sensing data.

Linkages

Indicators 3.2 and 3.4; High rates of land consumption and conversion reduce available urban green space. Indicator 2.11; urban green spaces can contribute to stormwater recycling.

Indicator 3.4: Residential density

Description

Area of land (hectares) within urban centres designated 'residential land use' divided by total population resident in those centres.

Rationale

High per capita land consumption places pressures on local environments through encroachment on non-urban land uses, recreational resources, and water catchments. A high land consumption rate places pressure on natural habitats and threatens biodiversity, while encouraging outward urban expansion at low density, high energy patterns of urban development.

Analysis and interpretation

This indicator is determined for each designated urban centre to include the total land area within each centre, based on appropriate ABS boundaries, and the total (permanent) resident population in each centre. As there are a range of measures for assessing residential density, the reader is referred to Cardew (1996) for a comparative evaluation with examples.

Monitoring design and strategy

This indicator should be in major urban centres (MU) and municipal level (LG), every 2 to 3 years (including census years).

Reporting scale

As for previous section.

Outputs

A table presenting urban land in residential use per capita for each settlement (urban centre) type.

Data sources

Areal data is collected by State planning agencies and local government. Population numbers are to be taken from the Census and ABS population projections (between Censuses).

Linkages

This indicator should be coupled with Indicator 4.3 which provides a different but related perspective. Also, see Indicators 3.7 and 3.3 (linkages); and Indicators 6.1 and 6.5; low floor area per person and a large range of lot sizes is usually associated with high residential density. Links to Land Indicator 2.7.

Indicator 3.5: Percentage of medium and high density residential construction

Description

Percentage of new dwelling construction *in other than* the fully detached house category.

Rationale

Australia has, by world standards, a very low density housing stock, with about 80 percent of dwellings as fully detached houses. During the 1990s some changes are noticeable, especially in Sydney, where, in the three years to March 1997, about 60 percent of new dwellings constructed were multi-unit. Higher than 'normal' dwelling densities tend to reduce land consumption (except to the extent that dwelling type influences household structure and type), energy demands, waste outputs and greenhouse gas emissions. Higher densities reduce the dependence of residents on cars and increase the feasibility of public transport services.

Analysis and interpretation

This measure provides a general indicator of urban form only. Considerable debate is occurring in urban planning circles as to the precise links between dwelling density, population density, energy usage and the locational dimension of denser urban development. The critical impacts (ie. potential beneficial environmental effects) of increasing densities will be felt in the outer suburbs and fringe areas of the large cities, not in the inner areas of those cities, where limited scope exists for significantly more dense *populations,* or in smaller centres.

Monitoring design and strategy

This indicator should be monitored annually in major urban centres (MU).

Reporting scale

As for previous section.

Outputs

A table presenting the percentage of new residential construction at medium/high density scales, for each settlement type.

Data sources

ABS *Building Activity,* Australia (cat. no. 8752.0) provides data (on a quarterly basis) for the number of dwelling units completed, by (fully detached) 'houses' and 'other residential', for each State and Territory. This data would need to be disaggregated to the selected scales.

Linkages

See indicators 3.4 and 3.7 (linkages); and Indicators 6.5, 4.3 and 1.3. Links also to Land Indicator 2.7.

Indicator 3.6: Index of industrial concentration

Description

The degree of industrial concentration or diversity in the local economy, expressed as the percentage of the workforce employed in the five largest industries in that centre.

Rationale

A diversified industrial structure places a national or local economy in a less vulnerable position relative to shifts in demand, population, technologies and public policies, than is the case where investment and employment are concentrated in a few key industries. In the latter situation, the economy is subject to large swings in levels of economic activity, both on the up-side and down-side, over relatively short time periods. Local decline in highly specialised economies, once commenced, can be self-perpetuating, reinforced by downward economic multiplier and inter-industry linkage effects. A high degree of economic instability and uncertainty militate against the accumulation of basic economic infrastructure and social capital, necessary to maintain sustainable life-styles but necessarily fixed in space and therefore vulnerable to devaluation. Alternatively, a diversified local industry structure is a necessary (but not sufficient) condition for agglomeration economies and sustainable patterns of specialisation which deliver economies of scale.

Local regions that are vulnerable to economic decline are poorly placed to monitor, conserve and enhance local environmental quality. Environmental concerns, in such situations, are likely to be overtaken—in public policy setting and broader community awareness—by an overwhelmingly short term focus on the requirements of economic development.

Analysis and interpretation

This indicator provides a current picture or snapshot view to economic agents and policy makers with respect to future economic risks. As a trend the indicator provides information on whether these risks are, in general, increasing or decreasing through time, therefore informing appropriate responses or interventions. For example, growing industrial concentration in a given urban centre may stimulate coordinated efforts by government, industry associations and community groups in the region to attract a range of new economic activities.

This indicator, when compared to other environmental indicators, allows consideration of explicit trade-offs between economic and environmental outcomes to be drawn and evaluated.

Monitoring design and strategy

Monitoring should be carried out at national, state, individual metropolitan and individual smaller urban centre scales based on ABS Census and Industry Register (continuous surveys), utilising the 2-digit ANZSIC system of industry classification. Some development work will need to be carried out to ensure that the Industry Register surveys deliver data adequate for snapshot and trend monitoring at appropriate scales. Monitoring should occur at 2 to 3 year intervals.

Reporting scale

Reporting should occur across the full urban hierarchy (UH).

Outputs

A table which presents the percentage of the workforce employed in the five largest industries by settlement type.

Data sources

ABS population and housing censuses; Industry Register. Relevant data is already being collected nationally.

Linkages

Indicator 0.3; a high level of global economic dependency together with a high degree of industrial concentration can render a settlement highly vulnerable to shifts in macro-economic conditions and international trade movements with prospective long run environmental impacts (eg. Queenstown, Port Pirie, parts of Newcastle, Whyalla, single industry mining towns, etc).

Indicator 3.7: Percentage of mixed land use

Description

Percentage of precincts or neighbourhoods in urban centres which support mixed land uses.

Rationale

Areas with a mix of housing, local employment and retailing, and a range of recreational resources provide opportunities for travel on foot or by bicycle, reducing total energy demands and waste outputs.

Such areas also increase the employment, leisure and cultural opportunities of 'the transport poor', especially the frail and elderly, the otherwise physically disabled, and young children. Mixed land use areas tend to support viable, visible and safe public places. The benefits of mixing land uses are, however, dependent on preventing negative 'spill-over effects'; ie. the juxtaposition of antagonistic land uses.

Analysis and interpretation

Land use mixes can be monitored in a number of ways and at a number of scales, with choices here influenced by data availability and the need to maintain a degree of consistency through time. The basic urban land use categories proposed here are broad: housing (single dwellings); housing (multiple dwellings); commercial; industrial; open space. The basic scale unit proposed is the local government area, in order to be able to draw on existing data held by State and local planning authorities. More detailed and meaningful smaller area spatial units could be developed along the lines pioneered by the 'Urban Villages Project', carried out by the Victorian Department of Infrastructure and associated State Government agencies, or by developing GIS based data sources augmented through remote sensing techniques. In the absence of these more sophisticated sources, LGA units are recommended. An LGA is designated as 'mixed use' if no one land use category accounts for more than 60 percent of total area (minus streets) of the LGA, and total residential uses do not exceed 80 percent of the total area.

Monitoring design and strategy

Monitoring should be carried out in major urban centres (MU) and their sub-regions; at 2 to 3 year intervals.

Reporting scale

As for previous section.

Outputs

A table which presents the percentage of land in 'mixed use' areas (as defined) for each settlement type (scale).

Data sources

Detailed land use planning maps are held and regularly updated by each State and local government planning authority. Increasingly, these data sources are being supplemented by more detailed surveys of actual uses and changes in use.

Linkages

This indicator links to 3.2, 3.4 and 3.5. Together these indicators reflect the spatial form of urban settlements and the multiple environmental impacts implied; refer to indicators 1.3, 4.1, 4.2, 4.3 and 4.13.

Indicator 3.8: Percentage of home based workers

Description

Percentage of the total workforce who work at or from home.

Rationale

Home-based workers spend less time and resources on travelling to and from work. Although they may make more shorter and multiple trips, it will tend to be outside peak times and routes, reducing pollution and congestion, and investment required for new transport infrastructure to deal with otherwise increasing peak demands. Home-based employment also tends to increase employment opportunities and choice of residential location, especially for people who are unable or unwilling to travel far to seek work—eg. those who are caring for young children or frail aged relatives—or who wish to locate in smaller centres in the ex-urban regions of large cities. However, some home-based workers may be effectively trapped in such occupations through lack of alternatives and may suffer exploitative or unsafe and unregulated working conditions.

Analysis and interpretation

Home-based work covers a large range of situations with respect to type of work, length of working day, system of remuneration, degree of interaction with fellow workers, and proportion of working time spent at home as opposed to in a conventional workplace. It is proposed here that home-based workers be defined as those people who work at least 20 percent of their time or 8 hours per week (whichever is greater) at home.

Monitoring design and strategy

Monitoring should occur across the full urban hierarchy (UH); at 1 to 2 year intervals.

Reporting scale

As for previous section.

Outputs

A table presenting the percentage of home workers (as defined) by settlement type.

Data sources

Existing surveys and sources of home-based workers are partial and inconsistent. The main basic source is ABS *The Labour Force*, Australia (Cat. No. 6203.0) which includes information on people who usually work more hours per week at home than elsewhere, down to and including individual capital cities. Further data could be gathered through adding appropriate questions to the ABS Population Survey Monitor, for the same quarter each year. Special arrangements would need to be made to achieve appropriate sample sizes and composition for the 'individual metropolitan', 'small city' and 'all other urban centres' categories.

Linkages

Indicator 0.4: a significant proportion of information workers are actually or potentially home-based.

Indicator 3.9: Number of physical assaults in public places

Description

Total number of assaults outside home and workplace, by age group and gender of victim.

Rationale

Violence in public places reduces the actual and perceived safety of residents and visitors, and reduces the level, diversity and quality of social interaction, local community cohesion and economic opportunities (eg.

for local traders and service providers). Lack of perceived safety can limit mobility and reduce overall quality of life and health, as well as the opportunities for employment, open air exercise and recreation, while encouraging defensive expenditures on personal safety and building security.

Safe public places encourage greater and more varied use, increasing the market and, hence, economic feasibility of providing and enhancing such facilities. Greater use and market reach, in turn, underpins the continued resourcing of these facilities, reinforcing the beneficial effects of environmental health and well being.

Recent research in this area (Oc and Tiesdell, 1997) argues that cities (and their centres in particular) need to be perceived as safer places before it will become feasible for them to function as places of economic, recreational and cultural activities for all. Solutions advanced to enhance safety in urban settings revolve around better design, surveillance and rule-making.

Analysis and interpretation

This indicator includes all recorded instances of violence against individuals in the public sphere. Most violence, especially against women, occurs in the home, much of which is unrecorded. The reporting rate on assaults of various types in public places, however, is much higher, giving confidence that the official crime statistics on which this indicator is based will capture most of the relevant instances. Assaults counted are to be grouped according to accepted categories in the official statistical series to reflect the range of assaults and level of harm inflicted.

Monitoring design and strategy

Monitoring should occur annually across the full urban hierarchy (UH). Where possible, individual assault events are to be geo-coded utilising a standard GIS.

Reporting scale

As for previous section.

Outputs

A table presenting the number of assaults by type for each gender and age category for each settlement type. Maps recording the relative locational incidence of each category of assault.

Data sources

ABS *National Crime Statistics* (Cat. No. 4510.0) provides uniform crime statistics on offences reported to police, including assaults. These data measure the number of victims for each offence category not breaches of the criminal law. Further refinement with respect to the sub-categories of assault and incidence at the lower spatial scales is required, supplemented by crime statistics collected by each State and Territory Justice Department.

Linkages

See Indicators 3.1, 3.11, 3.12 and 5.3; crime rates are correlated with severity of social and economic inequality.

Indicator 3.10: Number of house burglaries

Description

Total number of dwelling burglaries (break-ins), by gender and age of victim.

Rationale

Perceived safety and well-being is related to the sense of security people experience in their homes. Forced break-ins where property is stolen, destroyed or even disturbed create anxiety and a feeling of lack of control over one's immediate living environment. The fear of such activities can reduce quality of life, impact negatively on health and create financial pressures through the need to expend resources on securing the home.

Existing housing research (eg. Saunders, 1990) strongly suggests that perceived security and control over the home impacts significantly on the capacity of residents to engage in a wide range of economic and social activities, including those which impinge on healthy lifestyles.

Analysis and interpretation

The indicator includes all house break-ins and attempted break-ins, since attempts are as significant as actual crimes in influencing perceived safety and security. Social research suggests that elderly residents and women are particularly vulnerable to the impacts of this form of crime.

Monitoring design and strategy

Monitoring should occur annually across the full urban hierarchy (UH). Where possible, individual events are to be geo-coded using a standard GIS.

Reporting scale

As for previous section and at municipal (LG) level.

Outputs

A table presenting number of burglaries (break-ins) for each gender and age category, for each settlement type. Maps geo-coding the relative locational incidence of break-ins.

Data sources

ABS *National crime statistics* (cat. no. 4510.0); ABS *Crime and Safety, Australia* (cat. no. 4509.0).

Linkages

Together with indicator 3.9, this indicator provides a picture of the safety and perceived security of urban residents.

Indicator 3.11: Indices of urban socio-economic inequality

Description

A set of (a) Gini coefficients and (b) indices of dissimilarity for household income for each human settlement category; plus indices on non-English speaking background; unemployment status and welfare dependency.

(1) For Household income

$$G_i = \left(\sum_{i=1}^{n} X_i.Y_{i+1}\right) - \left(\sum_{i=1}^{n} X_{i+1}.Y_i\right)$$

where G_i = Gini coefficient

X_i = cumulative percentage distribution of households for given human settlement category

Y_i = cumulative percentage distribution of income for same settlement category

n = number of income class units

and

$$I_D = 1/2 \sum_{i=1}^{n} |X_i - Y_i|$$

where I_D = index of dissimilarity

X_i = percentage of population (or household) in a given income class for a given human settlement category.

Y_i = percentage of population (or household) in same income class for Australia as a whole

(2) For 'non-English speaking background': percentage of resident population with a language other than English as first language

(3) For 'welfare dependency': percentage of population 15 years and over receiving Department of Social Security benefits.

Rationale

High levels of socio-economic inequality tend to be reflected and reinforced, on the ground, by the operation of urban property markets. For example, inequalities in income and wealth are expressed spatially through segregation of income groups across the city ie. by the creation of rich and poor suburbs. The provision and quality of basic services like health and education also tends to be unevenly articulated between areas, reflecting the differential economic and political power of residents. Extreme urban inequality can result in adverse environmental factors by relatively disadvantaged groups—eg. inability to afford energy efficient appliances and fully insulated housing, or to changeover old cars running on leaded petrol. Inequalities in effective access to education are passed on through generations, reducing the overall economic growth capacity of society, due to insufficient investment in human capital.

Analysis and interpretation

The Gini coefficient and index of dissimilarity are conventional measures of inequality. The Gini coefficient is a summary measure of inequality of income and other socio-economic and demographic variables that is widely used in many countries. It is based on data that is already available in countries like Australia, facilitating international comparisons. The proposed index of dissimilarity compares the distribution of household income in each selected sub-national human settlement type with the distribution of household income for Australia as a whole. The summary figure represents the proportion of the population who would have to move within a given urban centre to result in the same end distribution of income in that centre, as for Australia as a whole. All variables here—income, language, and welfare dependency—are interrelated parts of the complex overall structure inequality in Australia.

Monitoring design and strategy

This indicator should be monitored annually across the urban hierarchy.

Reporting scale

As for previous section.

Outputs

A table presenting, for each human settlement type:

(a) Gini coefficient and index of dissimilarity for household income,

(b) percentage of non-English speaking population,

(c) unemployment rate, and

(d) percentage of people 15 years and over who receive Department of Social Security benefits.

Data sources

All relevant data is currently collected by ABS (eg. Income Distribution, cat. no. 6523.0; Labour Statistics, Australia, cat. no. 6101.0; Estimated Resident Population by Country of Birth, Age and Sex, Australia, cat. no. 3221.0) and the Department of Social Security. Each Census year, the indicator outputs based on the normal annual data sources are to be complemented by (and compared with) a set based on the Census (ie. for those variables included in the Census).

Linkages

Together with Indicator 3.12, this indicator provides an overview of extant patterns of socio-economic inequality and segregation, at selected spatial scales in Australia. See also Indicator 5.3 and Indicator 0.2.

INDICATOR 3.12: INDICES OF SOCIO-SPATIAL SEGREGATION

Description

A set of indices of dissimilarity for household income distributed across each selected human settlement category:

(1) For Household income

$$I_D = 1/2 \sum_{i=1}^{n} |X_i - Y_i|$$

where the variables are as for Indicator 3.11, with the exception of: X_i, which is the percentage of population (households) in the given variable (ie. income) class in a given district (eg. ABS Statistical Local Area) of the urban centre in question, and ; Y_i, which is the percentage of that population in the same variable class for *that* urban centre as a whole.

A separate index of dissimilarity is calculated for household income, percentage non-English speaking population, unemployment rate, and welfare dependency, for each human settlement category.

Rationale

This indicator provides a more *direct* picture of the *spatial* pattern of inequality within or across each urban centre, and complements the indices included in Indicator 3.11.

Variations in residential environmental quality and amenity are obvious along the continuum of suburbs in Australia's cities, ranked on the basis of income or socio-economic status. What must be avoided is a threshold (termed 'tipping point') being reached where disinvestment in an area reaches such proportions that it attains the 'status' of a ghetto, with the full array of attendant social, economic and environmental problems. To the extent that relative poverty and disadvantage constrains the capacity of people to benefit from, and contribute to, healthy local environments, this indicator will assist policy makers to identify areas and groups at risk, and target appropriate policies.

Analysis and interpretation

This indicator discloses the percentage of the population who would have to move within the selected urban centre to ensure that the variable in question, say unemployment, is uniform throughout that centre. A high score for a given urban centre implies that households are unequally distributed over space with respect to that variable, increasing the likelihood that households are spatially segregated. Direct comparisons between centres are also facilitated. A centre with a high score on this indicator, relative to another centre, has a more intense level of spatial inequality with respect to the variable in question (eg. income, unemployment).

Monitoring design and strategy

As for Indicator 3.11.

Reporting scale

As for Indicator 3.11.

Data sources

As for Indicator 3.11.

Outputs

A table presenting, for each human settlement type, indices for dissimilarity for household income, percentage non-English speaking population, unemployment rate, and percentage of people 15 years and over in receipt of benefits from the Department of Social Security.

Transport and accessibility

Indicator 4.1:	Access to Public Transport Stops
Indicator 4.2:	Car Ownership
Indicator 4.3	Perceived Residential Density
Indicator 4.4:	Driving Licence Holders by Age and Sex
Indicator 4.5:	CBD Parking Supply and Charges
Indicator 4.6:	Fuel Pricing and Taxing
Indicator 4.7:	Average Speed by Mode and Distance
Indicator 4.8:	Mode Choice by Trip Purpose by Area
Indicator 4.9:	Total Time and Distance Travelled
Indicator 4.10:	Perceived Daytime Density
Indicator 4.11:	Economic Costs of Road Accidents
Indicator 4.12:	Fuel Consumption per Transport Output
Indicator 4.13:	Costs of Congestion

Linkages

This indicator complements Indicators 3.11 and 5.3 in identifying the spatial dimension of inequality. Transport is a major environmental concern, being strongly related to congestion, atmospheric pollution, and fuel use, and the search for improved methods of operating and organising transport systems is a major area of environmental and economic policy.

The thirteen indicators chosen deal with overall transport issues such as fuel pricing, fuel consumption, congestion costs and modal choice, motor vehicle operation issues such as car ownership, driving licences, time and distance travelled, traffic speed, parking, and road accidents; access to public transport; and land use issues such as weighted day and evening population densities.

Indicator 4.1: Access to public transport stops

Description

A quantification of the frequency distribution of straight-line distances between each point in an urban area and the nearest public transport station/stop. This distribution would be developed for each mode of public transport in a city, and would be aggregated to a commonly-used boundary (such as a Census Collectors Districts (CCD) or Statistical Local Area (SLA) as defined by the ABS.

Rationale

The extent to which public transport is used in a city will depend on the level of service provided on the service (such as frequency, comfort, etc.) as well as the ease with which the public transport service can be accessed by the potential population of users.

Analysis and interpretation

Many studies have set pre-defined thresholds for access distances to public transport stops (such as the percentage of households which lie within 400 metres of a bus stop). The frequency distribution of access distances gives a more generally applicable measure of public transport access. By calculating the access measures as a function of x-y coordinates within an urban area, this can then be used to calculate access to public transport stops from any specified land-use, such as access to/from residences, access to/from workplaces etc. Most GIS packages now include algorithms (eg. buffering) which can rapidly calculate this indicator over a city or region.

Monitoring design and strategy

This measure is a description of the physical system which should not change markedly in a short period of time. Therefore, there is no need for continuous updating of the measure. Rather, it can be used mainly to contrast accessibility to public transport in different cities and in different parts of a city. The measure could be updated annually to reflect changes in public transport systems and population distributions, and recalculated at 5-yearly intervals to coincide with the ABS Census.

Reporting scale

Major Urban Centres (MU) (with some prospect for reporting on sub-metropolitan regions).

Outputs

Frequency distribution of access distances to the nearest stop by various types of public transport stops, depending on city (eg. train, tram, bus for Melbourne, train, bus and ferry for Sydney) by geographic area (eg. SLA). Inclusion of *service frequency* could be a useful supplement to the measurement of station/stop accessibility. Overall journey times (including access, egress and waiting times) would need to be calculated for specific combinations of origin and destination at various times of day for all modes in order to obtain valid comparisons. While such a measure is technically possible, and probably the best measure of levels of service, it would entail significant work to undertake these calculations for all metropolitan areas.

Data sources

GIS public transport route maps and ABS Census data.

Linkages

Mode choice (4.8).

Indicator 4.2: Car ownership

Description

Cars garaged at households per household, per person and per licensed driver aggregated to a commonly-used boundary (such as a Census Collectors District (CCD) or SLA) as defined by the ABS. Company cars garaged at home should be separately identified.

Rationale

Higher levels of car ownership are generally associated with lower levels of public transport use, and vice versa. As car ownership levels increase over time, the demand for public transport falls, thereby putting greater pressure on the provision of public transport services only for those who do not have access to a car.

Analysis and interpretation

Many previous measures of car ownership have concentrated on cars per household. While this is useful in some studies, it masks the effect of household size variations across different regions. Therefore cars per person is a better measure. Even this measure, however, ignores the effect of household composition differences between regions. Areas with high numbers of children would have lower numbers of cars per person than areas with low numbers of children. Therefore, cars per licensed driver (or person of licencable age) is a better measure of true car ownership.

Monitoring design and strategy

Cars per household and cars per person can be directly calculated from ABS census data on a 5-yearly basis. Cars per licensed driver requires the estimation of licensed drivers from other sources, such as driver registration records or from continuous household-based travel surveys such as the Victorian Activity & Travel Survey and the Sydney Travel Survey.

Reporting scale

Urban Hierarchy (UH).

Outputs

Thematic maps of car ownership for regions within metropolitan areas, and tables of car ownership for metropolitan areas and regional cities.

Data sources

ABS Census data, driver registration records, household travel survey data.

Linkages

Mode choice (4.8); Driving Licence Holders (4.4).

Indicator 4.3: Perceived residential density

Description

The average residential density, as experienced by residents, across a region.

Rationale

Higher residential densities are more conducive to the provision of high capacity public transport services, with lower environmental costs per unit of transport output.

Analysis and interpretation

Existing measures of residential density (refer to Indicator 3.4) are plagued by the problem of defining an appropriate geographic area over which to calculate the density. This is because they use an 'area-weighted' calculation method to obtain the average density (ie. the average density is calculated by taking a weighted summation of the density in each sub-area, such as a Census Collectors District (CCD), using the area of the sub-area as the weight for that sub-area). By using a 'population-weighted' calculation, the arbitrariness of the definition of the study area is removed from the calculation, since superfluous areas (with little population) do not make much contribution to the overall calculation. The 'population-weighted' calculation also provides the answer that would have been obtained if each resident had been asked to state the residential density at which they lived. Thus the 'population-weighted' residential density is also the 'perceived ' residential density. The 'population weighted' residential density would need to be calculated for a standardised sub-area size in order to obtain comparable results in different cities.

Levels of congestion, air quality and greenhouse gas emissions can also be linked to parking availability and relative levels of fees and charges in terms of incentives /disincentives for environmentally sound behaviour/ practices (see also 4.6).

Monitoring design and strategy

Residential densities can easily be calculated for all Australian cities from the 5-yearly ABS Census. The calculation of the perceived residential densities simply requires that the population of a sub-area be used as the weighting factor in the average density calculation, rather than the area of the sub-area.

Reporting scale

Major Urban Centres (MU).

Outputs

GIS thematic maps of residential density within a city, cumulative frequency graphs of residential density, and a 'population-weighted' residential density for each city.

Data sources

ABS Census data

Linkages

Access to public transport stops (4.1); Car ownership (4.2); Mode choice by Trip Purpose by Area (4.8); Residential density (3.4).

Indicator 4.4: Driving licence holders by age and sex

Description

The proportion of people who hold driver's licences as a function of age and sex.

Rationale

People without driver's licences are more likely to be users of public transport and the non-motorised modes of transport (ie, walking and cycling). Therefore a good pointer to the likely use of these modes is by monitoring changes in licence holding across the population. This indicator is just as important as car ownership in determining levels of individual mobility (and hence environmental impact), and will become of greater importance in the future as more older people have driving licenses.

Analysis and interpretation

The current major users of public transport are the young, the old and those without licences. Future demographic changes point to less young people and more old people. However, the old people of the future are much more likely to have driver's licences, because they are the middle-aged people of the present who already have driver's licences. Therefore, future prospects for the usage of public transport may not be as good as might be inferred from simple demographic projections.

Monitoring design and strategy

Licence holding can be obtained from various sources, such as driver registration records or from continuous household-based travel surveys such as the Victorian Activity & Travel Survey and the Sydney Travel Survey.

Reporting scale

Urban Hierarchy (UH).

Outputs

Tables of licence holding for metropolitan areas and regional cities.

Data sources

Driver registration records, household travel survey data.

Linkages

Mode choice by Trip Purpose by Area (4.8); Car ownership (4.2).

Indicator 4.5: Central business district parking supply and charges

Description

A count of the number of parking spaces of different types (on-street, private off-street, public off-street) and the schedule of parking charges as a function of duration of stay for paid parking spaces.

Rationale

The amount of trips going to a Central Business District (CBD) area, and the mode split for those trips, will depend strongly on the ease with which parking can be obtained in the CBD area. Where parking is plentiful and cheap, one can expect a high proportion of trips by car (and vice versa).

Analysis and interpretation

The supply and charges for CBD parking needs to be interpreted in the context of the amount of public transport serving the CBD area. Where public transport services are good, one might expect that higher parking charges could be tolerated since there is a readily available alternative mode of transport.

Monitoring design and strategy

Parking supply and especially parking charges can vary relatively quickly. Therefore the monitoring process needs to be continuous. It is likely that data will need to be obtained from local government authorities and from the parking industry.

Reporting scale

Major Urban Centres (MU).

Outputs

GIS maps for each city showing the geographic distribution of parking supply. Tables showing the number of parking spaces of each type in each city. Graphs showing the schedules of parking charges as a function of duration of stay for each city.

Data sources

Local government authorities and the parking industry in each city.

Linkages

Differences in modal usage (Indicator 4.8) for trips to the CBD will be related to parking supply and charges.

Indicator 4.6: Fuel pricing and taxing

Description

Average prices for different types of fuel (petrol, diesel, Liquid Petroleum Gas (LPG) in metropolitan areas and regional cities. The proportion of these prices which are government taxes of various types.

Rationale

One factor influencing transport decisions by private vehicle is the price of fuel. Government can influence these decisions by imposing a range of taxes to the import price.

Analysis and interpretation

While the price of fuel can affect transport decisions, it is a relatively weak instrument for demand management since many drivers do not fully perceive the cost of their decisions. In addition, while government imposes a range of taxes on fuel, these taxes are generally for revenue raising purpose and not for demand management purposes. Nonetheless, monitoring of fuel prices can give one indication of the price of inputs to transport.

Monitoring design and strategy

Fuel prices can vary markedly within a metropolitan area, both over space and over time. Therefore, the average price will need to be a time/space weighted measure. Already various government and commercial organisations monitor the price of fuel on a daily basis, and efforts should be made to tap into these sources before considering establishment of a separate monitoring process.

Reporting scale

Urban Hierarchy (UH).

Outputs

GIS maps and graphs of average fuel price in a region (such as a Statistical Local Area (SLA)) at monthly intervals.

Data sources

Existing commercial and government monitors of fuel price are preferred; failing that, a weekly spot check of fuel prices at a random sample of outlets within each area.

Linkages

Fuel prices may affect the total amount of distance travelled (Indicator 4.9) and the total fuel consumption (Indicator 4.1).

Indicator 4.7: Average speed by mode and distance

Description

The average speed of travel by various modes of transport (Car, public transport, walking cycling) as a function of the distance of the trip undertaken.

Rationale

Travel time for trips is a primary determinant of the means of transport chosen for a trip. It is also a major input into the economic evaluation of transport improvements, and a fundamental indication of the quality of service provided by each mode.

Analysis and interpretation

The average speed for a trip should reflect the total door-to-door travel time for the trip and not just the running speed on various sections of that trip. The results of the analysis can be expressed either as the average speed as a function of the trip length or the total travel time as a function of the trip length.

Monitoring design and strategy

Motoring organisations and traffic authorities in various cities carry out periodic surveys of travel time, but these are usually restricted to travel times or speeds along particular sections of road. Similarly, public transport organisations only record travel times for travel on their specific mode of public transport.
A better source of data is from household-based travel surveys which record details of the full trips undertaken by respondents. Fortunately, several cities (Melbourne, Sydney and soon Brisbane) are now undertaking, or planning to undertake, continuous surveys of travel behaviour, which will allow regular monitoring of trip travel times and speeds.

Reporting scale

Major Urban Centres (MU).

Outputs

Graphs of travel time and/or speed as a function of trip distance for various modes of transport used within the city.

Data sources

Household travel survey data. These data are held by the relevant State Departments of Transport (or equivalent).

Linkages

Average speeds of travel may affect modal choice (Indicator 4.8) and fuel consumption (Indicator 4.12).

Indicator 4.8: Mode choice by trip purpose by area

Description

The modes of transport used for trips of different purposes (work and non-work) to different areas of the region (Central Business District (CBD) and non-CBD). Mode usage should be measured in terms of trips, travel time and travel distance by each of the modes.

Rationale

A fundamental indicator of the usage of transport in a region is the mix of modes used for travel. The mode choice influences the environmental implications of travel, as well as reflecting the degree of flexibility available to travellers within the area.

Analysis and interpretation

The choice of mode will be affected by the purpose of the trip being made and the place to, and from, which the trip is being made. A basis division of trip purpose is trips to work and trips for non-work purposes (finer divisions can be made, but may not be supportable by all available data sets). The choice of mode will also be affected by the origin and/or destination of the trip, with trips to the CBD likely to have higher usage of public transport than trips to other areas.

Monitoring design and strategy

While some information is available from the 5-yearly ABS Census (in the form of the Journey-to-Work tables), this data source will not be sufficient to cover all the dimensions of this indicator. Better sources will be the continuous surveys of travel behaviour taking place in several Australian cities, supplemented by the less frequent surveys of travel behaviour taking place in other Australian cities.

Reporting scale

Major Urban Centres (MU).

Outputs

Tables of mode usage (trips, travel time and travel distance) by trip purpose, trip origin and trip destination for each of the capital cities.

Data sources

Household travel survey data.

Linkages

Mode choice will have linkages to most of the other indicators of transport and accessibility.

Indicator 4.9: Total time and distance travelled

Description

The total time and the total distance travelled on an average day, stratified by residential area and by age and sex of the traveller.

Rationale

The total time and distance travelled is an overall measure of the total transport task in a region. The total travel time is a social measure of the allocation of time to the travel task, while travel distance is an input to the calculation of resource usage and environmental consequences of travel.

Analysis and interpretation

There is a prevailing theory about 'travel time budgets' that people reallocate their activities and locations in response to changes in the transport system such that they continue to spend, on average, about 70 minutes per day travelling. This figure has been observed in numerous international studies. If this is true, then improvements to the transport system may simply mean that people travel further within the same time budget. Monitoring of total travel time and total travel distance will provide information to ascertain whether the travel time budget theory applies in Australian cities.

Monitoring design and strategy

The level of detail needed for calculation of this indicator can only be obtained from household-based travel surveys conducted in the capital cities. Estimation of these figures should take place on an annual basis for those cities conducting continuous travel surveys, and on a periodic basis for those cities conducting less frequent travel surveys.

Reporting scale

Major Urban Centres (MU).

Outputs

Means and frequency distributions of daily travel times and distances by area of residence (eg. Standard Local Area (SLA)) and by demographic group (age and sex) for each of the capital cities.

Data sources

Household travel survey data.

Linkages

Mode choice (4.8); Fuel consumption (4.12); Total energy use (1.1); Percentage of home-based workers (3.8); Exposure to traffic noise (9.1).

Indicator 4.10: Perceived daytime density

Description

The average daytime population density, as experienced by people within each area, across a region.

Rationale

Higher daytime population densities are more conducive to the provision of high capacity public transport services, with lower environmental costs per unit of transport output.

Analysis and interpretation

The residential density calculated in Indicator 4.3 only describes the density of people when they are at home (eg. when they are asleep). A complementary measure is the density of the population when they are awake and going about their everyday business, which may not be in their residential area. Daytime population densities capture the location of the population during the course of the day. As with the calculation of perceived residential densities, the calculation of perceived daytime densities will also use a 'population-weighted' approach to remove the effect of the arbitrary definition of study area boundaries.

Monitoring design and strategy

Daytime population densities are ideally calculated from household-based travel surveys, whereby trips away from the household for all purposes can be included. Daytime population densities can also be estimated for all Australian cities from the 5-yearly ABS Census, by concentrating on the journeys away from the residential area for work purposes. The calculation of the perceived daytime densities simply requires that the population of a sub-area be used as the weighting factor in the average density calculation, rather than the area of the sub-area.

Reporting scale

Major Urban Centres (MU).

Outputs

GIS thematic maps of daytime density within a city, cumulative frequency graphs of daytime density, and a 'population-weighted' daytime density for each city.

Data sources

Household-based travel surveys and ABS Census data.

Linkages

Perceived residential density (4.3); Access to public transport stops (4.1); Mode choice (4.8); Residential density (3.4); Percentage of mixed land use (3.7).

Indicator 4.11: Economic costs of road accidents

Description

The economic costs of road transport accidents of various severities (fatalities, serious injury, minor injury and property damage only).

Rationale

Road accidents constitute major social and economic costs which are paid for the benefits obtained from the mobility which is made possible by the road system.

Analysis and interpretation

The numbers of road accidents of various types are recorded and released by police and road authorities in the various states on a regular basis. These accidents of different types can be weighted by the economic costs attributed to each accident, as reported by the Federal office of Road Safety, to give a total economic cost of those accidents. If desired, these accidents can be stratified by age and sex to provide a demographic breakdown on the incidence of road accident costs. The accident numbers can also be related to the total distance travelled (calculated as Indicator 4.9) to derive indices of risk for each of the demographic groups.

Monitoring design and strategy

Accident numbers are available on a relatively continuous basis from police and road authorities. therefore, any frequency of reporting is possible.

Reporting scale

Major Urban Centres (MU), State.

Outputs

Tables of accident numbers, accident costs and levels of risk for each severity of accident for each State and metropolitan area.

Data sources

Police and/or Road Authority accident data files, accident costs from Federal Office of Road Safety, distances travelled from Indicator 4.9.

Linkages

Total time and distance travelled (Indicator 4.9), and driving licence holders by age and sex (Indicator 4.4).

Indicator 4.12: Fuel consumption per transport output

Description

A measure of fuel consumption per unit of transport output, measured in megajoules per passenger-km, for each of the major modes.

Rationale

Resource usage, air pollution and greenhouse gas production are highly correlated with the energy consumption of a mode. To control for differences in capacity utilisation of the modes, the energy consumption is measured per unit of output, measured in terms of passenger-kilometres.

Analysis and interpretation

Energy consumed while the modes are being used is relatively easy to measure, based on total kilometres travelled and the unit rates of energy consumption. However, a full picture of energy consumption must also include the energy used in the life-cycle of production of the vehicles and the infrastructure needed for the vehicles. Such 'grey energy' has been estimated to be as high as 35 percent of the energy used in the operation of private cars.

Monitoring design and strategy

Energy consumption rates during operation may be obtained from a variety of industry studies, including the ABS Survey of Motor Vehicle Usage. More extensive and original research will be needed to fully account for the 'grey energy' consumed in the production of vehicles and infrastructure.

Reporting scale

Major Urban Centres (MU), State.

Outputs

Tables of energy consumption in production and operation per unit of transport output by mode of transport.

Data sources

ABS Survey of Motor Vehicle Usage, household travel survey data, published studies and original research on 'grey energy' involved in the production of vehicles and infrastructure.

Linkages

Total distance travelled (Indicator 4.9), speed of travel (Indicator 4.7); mode choice (4.8): total energy use (1.1). Link to pollution indicators in Atmosphere report (Manton and Jasper, 1998).

Indicator 4.13: Costs of congestion

Description

The time penalties imposed on society by way of congestion in the metropolitan areas.

Rationale

Traffic congestion is a major waster of the scarce time resource in major cities. Unlike other resources, time, once used, cannot be recovered. Congestion is an inefficient way of regulating traffic. Efforts to encourage the substitution of other means of regulation (such as road pricing to reflect the time and environmental costs of congestion) will be stimulated by knowing the magnitude of the costs of congestion in Australian cities.

Analysis and interpretation

The extent of congestion costs in urban areas can be estimated using either a network modelling approach or through direct estimation from household travel surveys. The former approach has been used by the Bureau of Transport and Communications Economics, while the latter approach has been used by the Transport Research Centre.

Monitoring design and strategy

If the costs of congestion are estimated directly from household travel survey data, then it can be monitored on an annual basis for those cities conducting continuous travel surveys, and on a periodic basis for those cities conducting less frequent travel surveys.

Reporting scale

Major Urban Centres (MU).

Outputs

GIS thematic maps of congestion costs by region within each metropolitan area, and tables of total congestion costs for each metropolitan area.

Data sources

Household travel survey data.

Linkages

Average speed by mode and distance (4.7); and the total time and distance travelled (Indicator 4.9).

Population

Indicator 5.1:	Population and Household Growth Rates
Indicator 5.2:	Households in Poverty
Indicator 5.3:	Unemployment Rates
Indicator 5.4:	Visitor Numbers

Population data are required for most planning deliberations on sustainability and the environment. Four indicators have been chosen which deal with specific demographic questions such as growth rate by category and visitors, including reasons for visiting. Two other livability indicators have been included, which reflect on the viability and quality of life of communities. These are the poverty and unemployment rates.

As well as these key indicators, there are a number of other widely available data which would normally be included in any SoE report. Some of these data are not strictly indicators, in that they cannot be directly affected by policy, and are more denominators for other indicators or represent the sizes of jurisdictions. Others are basic information regarding demographic structure which may be valuable in determining demands for different kinds of services. There are a large number of demographic variables which might be considered, but some of the most important of these for environmental considerations are:

- *Population.* The absolute level of population is the most common base against which other data are compared. Per-capita expressions of resource use are very commonly employed for all kinds of sustainability issues.
- *Households.* The number of households is a primary measure of impact relating to those things which are housing-specific; particularly, land use and infrastructure connections.
- *Average household size* is a useful demographic indicator which can be calculated from the preceding two numbers.
- *Urbanisation levels and city rank size.* The distribution of population in settlements of different size is a key concern, particularly where the distribution is changing or moving to new areas.
- *Coastal population* is another important population distribution indicator given the particular environmental vulnerability of coastal areas. It may be calculated as proportion of population in coastal SLAs. Like all population distribution figures, it changes only very slowly. Impact of coastal population growth on environment can be assessed via index comparisons (viz. population vs. water).
- *Age of population*. Proportion of population under 18 and over 65, in different areas; giving an idea of demand for different services. Projections of these.
- *Household type*. Expressed as: families with children and more than one adult, single parent families, families with adults only, and single persons.

Indicator 5.1: Population and household growth rate

Description

The absolute growth and percentage growth rates of population and households.

Rationale

Growth of population is the major indicator of increased human impact on the environment and of growing resource use. Growth of households measure demand for new housing and associated inputs such as land and infrastructure. The consequences of population growth or decline depend upon the location and size of the settlement. For example, coastal ecosystems are particularly fragile, and growth in coastal regions may require more careful management than elsewhere. Large cities may be better able than small settlements to sustain falls in population without endangering the capacity to respond effectively to local environmental concerns. Changes in number of households are as significant as shifts in population, because of the effect on demand for land and other resources (ANZECC 1998).

The associated objective is to limit population increase to the carrying capacity of environment; or to the rate at which infrastructure and environmental control can reasonably be applied. A further rationale is to optimise the use of existing infrastructure.

Analysis and interpretation

As discussed earlier, population levels and growth rates have major impacts upon the environment, and the concentration of population in human settlements provides considerable challenges to local carrying capacities. The rate of population growth is likely to have differential effects according to the existing size of the settlement and to its location. Growth rates can be much more rapid in newly developing areas with limited populations, and will have an accordingly greater effect on the environment which, up till this time, may have been largely unaffected by human activity. Conversely, the capacity of small settlements with declining populations to respond effectively to local environmental concerns may be limited. Areas such as coastal regions may be more severely affected by population growth, since coastal ecosystems are particularly fragile.

Population growth rates should be disaggregated as: natural increase, net internal migration, and immigration, since each of these have different effects on local population dynamics.

The rate of household change needs to be considered separately, since the growth of households has particular effects on the demand for land, housing and other resources.

Reporting scale

Urban settlements rank size groups. Should also be reported for coastal areas versus inland (by partitioning SLAs according to whether they share a boundary with the coast (see Hamilton and Cocks, 1996)).

Outputs

Maps, tables, pie/bar charts.

Data sources

ABS Population Census.

Linkages

Has linkages to many indicators, more specifically internal migration (0.1), energy use (1.1), completions (6.3), water usage (2.4), solid waste (10.1).

Indicator 5.2: Households in poverty

Description

Percent of households below the Henderson poverty line, by family type.

Rationale

The level of poverty measures the most economically vulnerable groups and those in need. The reduction of poverty is an essential part of sustainable development, which includes quality of life and distributional issues as well as those relating purely to the physical environment.

High levels of poverty can also have a very significant effect on the physical environment, as is evident in 'slum' areas and in the informal settlements of the developing world. Those with inadequate incomes or housing may be forced to resort to informal methods of waste disposal and to the direct extraction of resources such as wood for heating and cooking. Poor households may also not be able to afford 'clean' technology or repairs to housing, services and vehicles, which can result in poor indoor air quality, health problems, and a greater rate of pollution and environmental degradation. A high concentration of poor households will also reduce the capacity of communities to respond to environmental problems, due to an inadequate financial base.

Analysis and interpretation

This indicator relates to identifying concentrations of vulnerable groups and need for support programmes. It will also assist in identifying areas where local capacity for response to environmental problems may be low, and where certain kinds of damage to the environment due to informal practices may be more evident. The appropriate responses to environmental problems may be quite different in poorer areas than in more affluent ones.

Poverty has a different incidence among different family types, with the highest frequencies now being among low income families with children, particularly single parents.

There have been extended arguments as to whether the Henderson poverty line is the most appropriate measure of poverty or poor quality of life (see King 1994). However, it remains the most commonly used measure and the only one that is collected regularly for different locations and family types. The use of this indicator relates to identifying concentration of vulnerable groups and need for support programs.

Reporting scale

Only available at Capital city/Rest of State level.

Outputs

Tables, charts.

Data sources

Melbourne Institute.

Linkages

Unemployment (5.3), homelessness (6.6), social stress measures, eg. assaults (3.9), burglaries (3.10), mental illness (8.10), hospitalisation (8.17), indices of inequality (3.11, 3.12), mobile buildings (7.10) and consumption of various resources.

Indicator 5.3: Unemployment rates

Description

Long term unemployed by sex (proportion unemployed for more than six months)

Rationale

Unemployment is a major social concern with implication across a wide range of governmental and environmental program areas. As with poverty, this indicator shows social disadvantage, and more particularly will distinguish those areas in economic decline or with a high transient population. In the former case, this may be associated with a run-down built environment with limited capacity for environmental improvement, while in the latter case there may be particular environmental impacts due to informal living practices or the inadequacy of infrastructure and facilities to cope with a transient population. There may also be health impacts associated specifically with high unemployment levels and the lack of regular incomes.

Analysis and interpretation

High unemployment means that few jobs are available for those who wish to work. The indicator identifies need for employment programmes, concentration of vulnerable groups, areas in economic downturn or with high transient populations, and associated environmental and health concerns.

Some care should be taken to distinguish between declining areas with falling populations which may have lost their economic base and which have associated problems of a degrading built environment and facilities; and other areas with growing populations which attract the unemployed and others on fixed incomes because of low living costs and a pleasant environment, but which may be vulnerable to population intrusions. The kinds of environmental concerns and the responses to be employed will be quite different in each type of location.

Data on unemployment at the small area level are readily available, but different unemployment series are collected by ABS and (formerly) by the CES, which can cause confusion.

Unemployment rates only measure those seeking work, and not 'hidden unemployment' of those who have given up seeking work, for whom the environmental concerns may be very similar. An alternative measure is the labour force participation rate.

Reporting scale

Small area labour statistics are available, but capital city/rest of state, or urban settlement rank size category, may be sufficient.

Outputs

Tables, charts, maps.

Data sources

ABS.

Linkages

Poverty (5.2), homelessness (6.6); others as for poverty.

Indicator 5.4: Visitor numbers

Description

Annual numbers and peak numbers of visitors, by reason for coming and/or by type of visitor (international tourist, interstate tourist, intrastate, business traveller, family visit, etc).

Rationale

Where visitors are coming to and why they are coming is of major concern with respect to impact on the environment and the peak use of facilities.

Analysis and interpretation

Visitors make use of facilities and impact on the local environment, sometimes more than regular residents. Local infrastructure must support not just permanent population, but peak loads including visitors. Tourism in particular is both a major economic justification for environmental protection, in that many tourists seek areas of natural beauty, but also a source of pressure on the environment, in that tourism which is not properly regulated an cause damage to these areas through litter, human intrusion into wilderness areas, and pressure on local resources. This indicator assists in monitoring pressure on environment; identifying the need for special facilities or programs.

Reporting scale

Major cities, areas receiving tourists or summer visitors by Statistical region or Statistical Local Areas.

Output

Table or map showing number of visitors to the most affected areas.

Data sources

Data are available regarding international visitors from Dept of Immigration. ABS conducts regular surveys.

Linkages

Population growth (5.1), water quality (2.3, 2.6, etc.), noise (9.1, 9.6), waste (10.1, 10.4) indicators; also to Estuaries and the Sea Indicator 7.7 (Ward *et al.*, 1998).

Housing

Indicator 6.1:	Floor Area per Person
Indicator 6.2:	House Price to Income Ratio
Indicator 6.3:	New Dwellings Completed
Indicator 6.4:	Dwellings Constructed on Greenfield Sites
Indicator 6.5:	Ranges of Lot Size
Indicator 6.6:	Homelessness
Indicator 6.7:	Building Materials Used in Housing/Embodied Energy
Indicator 6.8:	Operating Energy Efficiency

The major concerns with housing involve the consumption of resources such as energy, materials, and land; and livability or access concerns. The selected housing indicators include resource supply measures: dwellings completed, materials used, energy efficiency, lot size, dwellings on new sites as opposed to infill or redevelopment; and consumption and access measures such as house size, house costs, and homelessness.

As with population, some housing data are more in the nature of background information or key drivers than policy-responsive indicators. It may be desirable to include these in a SoE report as they are readily available. They include:

- *Housing tenure.* Information on home ownership, private rental and public housing are measures of the success of ownership policies and the need to provide public housing or rent allowances.
- *Type of dwelling.* Proportion of low-density, medium density and high density dwellings, providing a picture of urban form and the use of more land-intensive housing types.
- *Average age of dwellings.* Measure of quality of stock and need for upgrading (though sometimes good-quality older dwellings suited for renovation are more in demand than newer ones).

Indicator 6.1: Floor area per person

Description

Total housing floor area, including covered verandah areas, etc, divided by resident population.

Rationale

This indicator is a major international measure of housing consumption, crowding and the quality of life (Flood, 1995, 1997). It is a simple measure of the space available to each individual, which, if inadequate, may have deleterious effects on health, living standards, and indoor air quality, while if excessive, may represent an unnecessary use of land, resources, energy and infrastructure.

Analysis and interpretation

Increasing floor area correlates very strongly with increasing income. At approximately 55 square metres of housing per person, Australia is one of the best housed nations in the world (UNCHS, 1995; Flood, 1997). However, despite its equable climate, it is also a relatively high consumer of energy per person for space heating and cooling.

The steady move to single person and smaller households will also increase space used per person (since each dwelling needs bathroom, kitchen, etc.).

Floor area is only collected for new dwellings, and the series is not complete. Data from ABS (Adelaide) over the decade since 1985 suggest an average increase in floor area for new housing of $20m^2$ (Newton, 1997). Rooms per dwelling is collected in the census and other surveys, and this can either be converted to floor space estimates, or used as a surrogate measure. World Bank/UNCHS (1993) estimated this indicator as 65 m^2 per person in Melbourne which is among the highest values in the world.

This indicator is typical of many indicators in the social arena in that it may be interpreted either positively or negatively depending on the perspective of the observer. For some, plenty of space is a sign of affluence, comfort and a high quality of life, whereas others may see it as wasteful and an excessive use of materials, energy and land. For example, while increased floor area is desirable from a personal perspective in that it reduces crowding, there may be a trade off against certain environmental costs such as energy use for space heating, or land consumption. This sort of trade off between environmental and consumption objectives is usual in achieving a balanced approach to urban development.

Reporting scale

Capital city/rest of state.

Output

Table.

Data sources

Census; survey (viz. ABS analysis of local government approvals data for new construction).

Linkages

Domestic energy use (1.4), land converted (3.2), residential density (3.4).

INDICATOR 6.2: HOUSE PRICE-TO-INCOME RATIO

Description

Median house price divided by median household income.

Rationale

This indicator is the major international measure of affordability. When high, is a sign that housing markets are not working properly. It is important to examine the trade-off between housing affordability and urban consolidation, as Troy (1996) has pointed out.

Analysis and interpretation

House price to income is low in places where housing is affordable; where markets work effectively and there is no excess demand for land due to planning or building restrictions. Typical ranges for Australia are 2.5 to 3.5, but in places such as Japan where there are heavy land use controls, the ratio may be over 12.

House prices are lower in rural areas, and are typically 30 percent higher in Sydney that other capital cities. Inner city prices in particular have risen very sharply under pressure from gentrification, the trend to smaller two income families, and consolidation measures, and this may be of concern for accessibility of lower income residents.

House price data are not routinely collected on a national basis. Estimates are made for capital cities by the Real Estate Institute of Australia (REIA). In States where Valuer-General data are published, detailed prices down to suburban level are available annually.

Reporting scale

Capital city/rest of state.

Output

Table, possible gradient charts of house prices for major cities.

Data sources

REIA, Valuer-general.

Linkages

Residential density (3.4), land converted (3.2), completions (6.3), various amenity measures.

Other indicators in common use are distributional ones, such as the National Housing Strategy housing stress indicator (proportion of income units in bottom 40 percent of incomes paying more than 30 percent of income for housing).

INDICATOR 6.3: NEW DWELLINGS COMPLETED

Description

Numbers of completions of new dwellings, by type of dwelling (detached/medium/high density). Can be calculated as percentage of housing stock.

Rationale

Numbers of dwellings constructed is both a response to housing shortages, and a pressure on resources, such as land, infrastructure, materials and energy.

Analysis and interpretation

Completions of new dwellings is also a major economic indicator.

Reporting scale

Largest cities, urban centre rank sizes.

Output

Table.

Data source

ABS.

Linkages

House prices (6.2), use of resources including land (3.2), water (2.1), waste (10.2, 10.4), building materials (6.7).

Indicator 6.4: Dwellings constructed on greenfield sites

Description

Proportion of new dwelling units constructed on previously unoccupied land.

Rationale

Ideally, rather than the continued expansion of cities which consumes land and other resources and which encourages petroleum usage, it would be better, where possible, to make use of existing serviced land and redevelop it to more valuable purposes. Objectives are: reduced consumption of land, and better use of existing urban land. Data on this indicator would be required if Australia was to follow the UK policy in requiring a 50:50 ratio of new house construction on greenfield vs. previously built sites.

Analysis and interpretation

Increasing infill development has been a feature of housing activity in recent years. This is partly due to higher residential demand for inner locations, partly due to reduced planning restrictions, and partly to the improved economics of redeveloping inner industrial areas to other uses and relocating industry in cheaper suburban zones. The indicator is likely to be useful in monitoring success of consolidation strategies.

Problems in interpretation and collection

These data are not collected at present. First estimates could be made by comparing completions in urban fringe SLAs with inner SLAs.

There will also be some problem in defining exactly what is a greenfields area, as some urban fringe areas already contain existing housing at low density.

Reporting scale

Capital city/rest of state

Output

Table.

Data source

Cadastral registers, land banks; local government development approvals registers.

Linkages

Completions (6.3), land converted (3.2), green space (3.3), mixed land use (3.7), lot size (6.5), servicing by waste water (2.10), water usage (2.4), waste (10.1, 10.4).

Indicator 6.5: Ranges of lot size

Description

Distribution of lot sizes eg 250-350 sq m, 350-500 sq m, 500-1000 sq m, >1000 sq m.

Rationale

Large blocks of land may not be the most efficient use of urban space. Many lots are now of smaller size than in the past, and this development should be monitored. By giving a distribution of lot sizes as well as just the average (which is partially implied by density calculations—see Indicator 3.4), it would show quite clearly the move towards consolidation, which would only be partially shown by densities which tend to change slowly.

Analysis and interpretation

Smaller blocks can be interpreted either as an improvement in consolidation, or a reduction in consumption corresponding to lower quality of life.

Data on lot sizes are not available nationally, and may have to be obtained from cadastral registers.

Multi-unit dwelling blocks may need to be excluded, or can be included by dividing the number of units by block size.

Reporting scale

Capital city/rest of state; or by urban centre rank sizes.

Output

Table.

Data sources

Cadastral registers, land banks

Linkages

Floor area per person (6.1), land converted (3.2), mixed land use (3.7).

Indicator 6.6: Homelessness

Description

Numbers of homeless persons, by sex, and age group.

Rationale

Homelessness is the extreme expression of poor housing, in that homeless persons have no fixed or formal abode and are usually dependent on charitable bodies for assistance and accommodation. Homelessness is largely a measure of poor quality of life, but as with other forms of poverty, homelessness will have a significant effect on the physical environment. This is particularly true of the small group who 'sleep rough' on any given night, who must resort to wholly informal means of living, waste disposal, etc., and may suffer from health problems due to exposure.

Analysis and interpretation

Homelessness is actually a population issue rather than a housing issue, since it is not the lack of housing which is the problem but the lack of access to housing, which is closely related to poverty.

Homelessness is very difficult to define, as Neil (1993) has pointed out, since most 'homeless' people have access to some form of accommodation. The strong definition of homelessness is those sleeping 'rough' or in hostels on any given night, but the numbers of these are quite few. Weaker definitions include those in any form of temporary accommodation or accommodation deemed inadequate. The stronger definition of homelessness is the most common.

Attempts to collect homelessness figures have only been done sporadically, because of the difficulties of defining and locating the homeless. The use to which such an indicator could be put relates to identifying need for temporary shelters, and programs for the homeless.

Reporting scale

Major cities.

Output

Table of homeless numbers for major cities, possible estimate for rest of country.

Data sources

Occasional ABS surveys; direct estimates (paying attention to definition).

Linkages

Poverty (5.2), unemployment (5.3), otherwise as for poverty.

Indicator 6.7: Building materials used in housing/embodied energy

Description

Total building materials of different types used in new housing and major renovations: bricks, concrete , steel, timber, other metals, fossil fuel etc; together with embodied energy equivalents.

Rationale

While most building materials are common and not likely to become scarce, energy usage in buildings can be very substantial. Embodied energy can be equal to a number of years energy in-use. The major objective is reduction in the use of energy and scarce materials.

Analysis and interpretation

Energy and CO_2 equivalents for various materials are commonly available. The subject has been extensively studied by CSIRO and other researchers (Tucker *et al.*, 1998) and is associated with a software package to aid calculations.

Figures on total usage of various materials are available, but not specifically those restricted to residential use. Input-output tables provide guidance.

Reporting scale

Capital city/rest of state, or national figures.

Output

Table.

Data sources

ABS Building materials, Input-output tables, CSIRO data.

Linkages

Energy efficiency ratings, energy use.

INDICATOR 6.8: OPERATING ENERGY EFFICIENCY

Description

Average energy efficiency ratings for dwellings, as defined by various regulations in all States.

Rationale

Efficient use of energy is a major environmental objective, and the household sector is a major user (Newton *et al*., 1997). In 1995-96 the residential sector consumed 360 PJ of energy. This represents about 11 percent of Australia's total secondary energy use. Energy use in residences is dominated by space heating and cooling and water heating.

Analysis and interpretation

Energy use in dwellings may be reduced by the use of insulation, by passive means such as siting, or through heat sinks, efficient appliances, co-generation and other means. The Nationwide Home Energy Rating Scheme (NatHERS) is a joint Commonwealth, State and Territory Government initiative to improve the energy efficiency of houses throughout Australia. States are introducing a 'star' rating system to measure the success of different dwellings in meeting locally defined energy standards. In some States this will be compulsory for all new dwellings, and legislation is currently under preparation. This scheme is likely to be extended to commercial and industrial buildings according to the Prime Minister's Greenhouse Statement of November 1997.

Consistent rating is not widely practised, and benchmarking needs to be established.

Patterns of energy use tend to vary according to climate: in cooler areas, heating is the main concern, while in warmer areas, ventilation and air conditioning efficiency may be more significant. Different States have adopted different standards, in line with climatic conditions.

Reporting scale

Capital city/rest of state.

Output

Table.

Data sources

State energy or housing ministries.

Linkages

Floor area per person (6.1), domestic energy use (1.4), materials used in construction (6.7).

Indoor air quality

Indicator 7.1:	Occupant Satisfaction with Commercial Indoor Air Quality
Indicator 7.2:	Mechanical Ventilation Rate of Commercial Buildings
Indicator 7.3:	Thermal Comfort in Commercial Buildings
Indicator 7.4:	Air Infiltration Rates of New Housing
Indicator 7.5:	Proportion of Population Sensitive to Pollutants
Indicator 7.6:	Proportion of Adult Smokers with Children
Indicator 7.7.	Proportion of Commercial and Recreational Buildings with Smoking Prohibition
Indicator 7.8:	Quantity of Asbestos Products Removed from Workplaces
Indicator 7.9:	Number of Unflued Gas Heaters in Residences and Schools
Indicator 7.10:	Number of People Housed in Mobile Buildings
Indicator 7.11:	Proportion of Residences with High House Dust Mite Allergen
Indicator 7.12:	Incidence of Legionnaires' Disease
Indicator 7.13:	Production of Low-VOC Emission Building Products
Indicator 7.14:	Exposure to Indoor Air (Time spent in City Traffic)

There is a limited amount of information available on indoor air quality; data have not been collected over a long time period or in a systematic manner. This limits the extent to which potential indicators can be utilised. There is a critical need for the condition of indoor air quality in Australia to be recorded systematically, given that, on average, 95 percent of people's time is spent indoors (Newton, 1997, p.12). Australia is lagging behind other developed countries in this regard.

In general, the selected indicators are occupant- or building-related factors that are known to influence pollutant levels in buildings, rather than the pollutant levels themselves. Ideally, it would be desirable to sample buildings for concentrations of pollutants such as formaldehyde and nitrogen dioxide as discussed in Brown and Robinson (1997) and listed in Table 3.3, but in the short-term, practicalities suggest the substitution of surrogate indicators such as 7.10 and 7.9. Furthermore, these indicators are appropriate in the context of Human Settlement reporting. Ultimately, both types of indicators are essential (ie. national measures of concentrations of critical indoor air pollutants in specific built environments known to be associated with pollutant sources, and national measures of population or housing characteristics associated with known sources of indoor air pollutants). Indoor air pollutant concentrations will be important Atmospheric Indicators (see Manton and Jasper, 1998) when assessing the impact of air pollution on the population, whether this be in outdoor, transit or indoor air. The population spends different amounts of time in these environments, with a heavy bias to the indoor environment. Since most indoor air pollutants are influenced by the nature of indoor materials and activities, rather than the quality of outdoor air, indoor air pollution must be considered as a separate entity when considering total exposures to air pollutants. Characteristics of population and housing (Human Settlement Indicators) will be important in considering the proportion of the population exposed and the impact of such exposure, or they may act as surrogate measures of pollutant levels. Clear links between these two types of Indicators will exist for some pollutants but not others.

Indicator 7.1: Occupant satisfaction with commercial indoor air quality

This indicator relates to occupants of commercial buildings such as offices.

Description

Proportion of occupants in a multi-State survey of offices who experience air to be stuffy or to cause drowsiness, headache, dry or irritated nose or throat, blocked or stuffy nose.

Rationale

This indicator provides a measure of the effects of poor indoor air quality on building occupants on a national scale.

Analysis and interpretation

Incidences of these effects in up to 30 percent of occupants may be typical of the general population since the health effects are non-specific and have many possible causes. Incidences above 30 percent would be considered poor.

Monitoring design and strategy

National surveys of Commonwealth government office workers were carried out by the Commonwealth Public Service Union (CPSU) until 1992 and found high complaint rates (48–72 percent). These findings were used to establish new awards through the Industrial Relations Committee (IRC) (eg. access to records, training) and the CPSU does not intend to repeat the survey.

The Australian Bureau of Statistics (ABS) gathers statistics on national health in the National Health Survey on a 5 yearly basis. The focus is on experience in the preceding 2 weeks (eg. respiratory illnesses such as common cold and asthma, headache, allergy, dizziness) and long-term conditions. 'Accidents' (which includes incidents and exposures resulting in illness or injury) are surveyed, including those that are work-related. The Survey is not designed to gather information relative to air quality in offices but the latter may be easily incorporated into future surveys using a recently published 'standard' questionnaire from the UK Royal Society of Health (Raw 1995).

Reporting scale

Major Urban Centres (MU).

Outputs

Table of incidences of major indoor air quality symptoms.

Data sources

Need to be developed eg. by ABS as part of the National Health Survey.

Links to other indicators

This indicator will be linked, to varying degrees to Condition indicators based on pollutant levels in buildings and to Pressure indicators on mechanical ventilation rates.

Indicator 7.2: Mechanical ventilation rate of commercial buildings

Description

Fresh air intake rate of commercial buildings relative to requirements of the Building Code of Australia (1996).

Rationale

Mechanical ventilation rates are required to comply with AS 1668.2 'Mechanical ventilation for acceptable indoor air quality' to ensure removal of occupant odours, but there is no post-construction system to ensure continued compliance. Low ventilation rates may significantly deteriorate indoor air quality.

Analysis and interpretation

Mechanical ventilation rates vary as AS 1668.2 is revised; in the 1980's much lower rates were specified than are accepted in the current Standard. Building operators may reduce rates for energy conservation. Ventilation systems may become faulty. The performance of a random sample of buildings relative to current Standards will indicate the impacts of these factors.

Monitoring design and strategy

No systematic evaluation of this measure has occurred but surveys in Melbourne and Perth have found that 82 percent of commercial buildings (predominantly low-rise) failed to meet current Standards. Melbourne's survey was performed by Melbourne University's Department of Architecture and Building and involved student assessment of several hundred buildings. National surveys could be established by a cooperative action of Universities in each capital; the surveys should be repeated on a 3-yearly basis.

Reporting scale

Major Urban Centres (MU).

Outputs

Table of proportion of unacceptable buildings, based on state and national level.

Data sources

No data sources exist. See 'Monitoring design and strategy'.

Links to other indicators

This indicator and Indicator 7.1 will provide an overview of air quality performance in commercial buildings.

INDICATOR 7.3: THERMAL COMFORT IN COMMERCIAL BUILDINGS

Description

An index of thermal comfort in commercial buildings, based on physical measurement of temperature, relative humidity, radiant heat and air velocity.

Rationale

Occupants of commercial buildings seldom have control of physical conditions affecting their thermal comfort and complaints of poor thermal comfort (too hot, too cold, draughts) are not uncommon. Physical measurement of factors affecting thermal comfort will provide an objective assessment.

Monitoring design and strategy

'Heat stress' is measured in industrial environments according to the Wet Bulb Globe Temperature (WBGT) Index, calculated from:

Outdoors with solar load

WBGT = 0.7 NWB + 0.2 GT + 0.1 DB

Indoors or outdoors with no solar load

WBGT = 0.7 NWB + 0.3 GT

where

NWB = natural wet bulb temperature

DB = dry bulb temperature

GT = globe temperature (black body temperature)

Permissible WBGT indices are available for various work environments (eg. light work—standing performing light hand or arm work—could be applicable to office work).

WBGT index measurements in commercial buildings would require a survey of a representative, random sample of the population. Large differences according to State and season are expected and would need to be considered in the survey. The survey should be repeated on a 3-yearly basis.

Reporting scale

Major Urban Centres (MU).

Outputs

Table of WBGT indices (mean and distribution).

Data sources

No data sources exist. A survey would need to be designed and carried out to measure this indicator.

Links to other indicators

This indicator is strongly linked to Indicator 7.1 which would determine occupant satisfaction with the thermal environment by questionnaire.

INDICATOR 7.4: AIR INFILTRATION RATES OF NEW HOUSING

Description

Air exchange rate of housing by natural infiltration when doors and windows are closed.

Rationale

Housing in Australia has not had a requirement for fixed ventilation (eg. by wall vents) since the early 1980s because infiltration rates at that time were considered to provide adequate minimum ventilation. However new housing is now constructed with less air leakage and infiltration rates may be lower than required for acceptable indoor air quality.

Housing construction practice in recent years is believed to have led to 'tight' envelopes with low levels of air infiltration. Largely, this has been an energy conservation measure although changes in building practice (continuous flooring, different types of windows, elimination of wall vents) have also had an influence. Australian housing is rarely ventilated mechanically and relies on openable windows for fresh air supply. Historically, ventilation was provided by air infiltration through fixed vents and envelope leakage when windows were closed; nowadays there may be little air supply to buildings when windows are closed (eg. for security or noise) and minimum air supply levels necessary for acceptable indoor air environments may not be achieved. Overseas surveys of office occupants have identified a significant and common degree of dissatisfaction with these indoor environments, and very limited study in Australia suggests a similar experience. Apart from health factors, this is estimated to cause a significant economic burden due to lost productivity. This burden needs to be systematically measured and monitored as an Indicator of general improvements to Indoor Air Quality.

Analysis and interpretation

Low infiltration rates will cause pollutant accumulation in closed housing (eg. for security or under adverse weather). A minimum ventilation rate of 0.5 air changes per hour is required in some countries to prevent poor indoor air quality (and higher rates may be necessary if strong pollutant sources cannot be avoided). A minimum infiltration rate at this level is assumed to fulfil the same function.

Monitoring design and strategy

A random sample of new housing from each State should be assessed using tracer gas decay procedures (no Australian Standard exists but well-characterised Standards are available overseas). The infiltration rate of any house will vary over time according to ambient wind speed and indoor/outdoor temperature differentials. Models exist to compensate these effects and to allow an estimate of infiltration rate under defined conditions (eg. winter in southern States, summer in northern).

Reporting scale

Urban Hierarchy (UH).

Outputs

Median and range of infiltration rates and proportion of housing below 0.5 air changes per hour under defined conditions relevant to climatic zone.

Data sources

State authorities (eg. Energy Victoria) have made these measurements in the past. Infiltration rate estimates are used in NatHERS scheme although measurements are not ongoing. National coordination of effort is required for this indicator.

Links to other indicators

This is linked to all pollutant source indicators since pollutant accumulation will be more severe under low infiltration conditions.

Indicator 7.5: Proportion of population sensitive to pollutants

Description

Proportion of population who are more sensitive to pollutant exposure due to age (<5 years of age, >65 years of age), defined medical conditions (asthma, allergy) or undefined medical condition (multiple chemical sensitivity (MCS)).

Rationale

These population sectors will be at greatest risk from pollutant exposures. By law, building owners and occupiers owe them a greater duty of care.

Analysis and interpretation

These sectors will constitute a moderate proportion of the population with the need for access to a large proportion of buildings. Some (eg. asthma sufferers) are believed to be increasing in their proportions, possibly because of pollutant levels, while others (>65 yo) are increasing with societal changes.

Monitoring design and strategy

Australian Bureau of Statistics (ABS) National Health Survey and Census will provide data on much of these sectors. MCS data is not readily available since this condition lacks a medical definition for its diagnosis and statistics on incidence are not gathered. Many MCS sufferers are members of two national community groups (Australian Chemical Trauma Alliance, Allergy Association) who may provide data.

Reporting scale

Urban Hierarchy (UH).

Outputs

Proportion of population within each sector.

Data sources

ABS, ACTA (Australian Chemical Trauma Alliance), AA (Allergy Association).

Links to other indicators

This indicator is linked to all pollutant source indicators since these population sectors may be more sensitive to these pollutants.

Indicator 7.6: Proportion of adult smokers with children

Description

Proportion of adult population (aged 18-34) who smoke and have young (<14 years old) children.

Rationale

Adults who smoke are likely to expose young children to environmental tobacco smoke (ETS) in indoor air and adversely affect child health.

Analysis and interpretation

A high proportion of adults in the child rearing stage of the family life cycle continue to smoke tobacco. They also represent the population sector most likely to reside with young children. Since young children suffer from impaired lung development and increased respiratory illness from ETS exposure, this indicator will be a measure of potential exposure to ETS at a critical stage of life.

Monitoring design and strategy

Australian Bureau of Statistics (ABS) National Health Survey—Health Risk Factors, Australia (Publication 4380.0) provides a breakdown of smokers by sex and age (18+) for the year 1989–90. More recent information is unavailable. The Australian Institute of Health and Welfare (Australian Health Indicators No. 4 June 1995) lists the percentage of adults 18–34 years who smoke (31 percent).

Reporting scale

Urban Hierarchy (UH).

Outputs

Proportion of smokers aged 18–34 with children.

Data sources

ABS.

Links to other indicators

Expected to link with environmental health indicators.

Indicator 7.7: Proportion of commercial and recreational buildings with smoking prohibition

Description

Proportion of commercial (office, retail etc) and recreational (hotels, restaurants, clubs etc) buildings which apply a smoking prohibition policy to indoor spaces.

Rational

A smoking prohibition policy is the most effective means to eliminate environmental tobacco smoke from indoor air.

Analysis and interpretation

While a large proportion of commercial buildings in Australia have instigated a smoking prohibition policy, this is not the case for recreational buildings. In both types of buildings, many occupants can be involuntarily exposed to environmental tobacco smoke. This indicator will demonstrate the relative performances between these classes of buildings, as well as the performance compared to other countries where smoking prohibition is less accepted.

Monitoring design and strategy

This data may be available from anti-smoking organisations (eg. Action on Smoking & Health (ASH, Aust.) Ltd, Sydney) or may have to be gathered by independent survey. The latter should survey a representative portion of the buildings according to the number of each building type (eg. office, retail, hotels, restaurants, clubs) or the number of occupants of such buildings. Since some office buildings may have multiple tenants with different policies (and yet share the same ventilation system), a building-specific focus (rather than business-specific) is required.

Reporting scale

Urban Hierarchy (UH).

Outputs

Proportions of commercial and recreational buildings that apply a smoking prohibition policy to indoor spaces.

Data sources

ASH (above), ABS.

Links to other indicators

Expected to link with environmental health indicators.

Indicator 7.8: Quantity of asbestos products removed from workplaces

Description

Mass of asbestos products removed from workplaces.

Rationale

Removal of asbestos from buildings has become a common response to managing asbestos problems. Research has not found this to be beneficial to indoor air quality and it may be detrimental (but still very low in risk) in many instances due to difficulties in dust containment and residual contamination. However asbestos removal activities are likely to continue for the next 10–20 years in response to public and commercial (eg. property transactions) fears of this hazards.

Analysis and interpretation

Quantities of asbestos removed from buildings will be a response indicator of occupant perceptions of asbestos hazards, government codes and regulations and commercial pressures. It will also assist in longer term planning of this activity. In the longer term this indicator is problematic since a decline in asbestos removal may simply mean that the job has been done.

Monitoring design and strategy

Asbestos removal from workplaces can be carried out only by licensed contractors. (Removal of products from dwellings is not generally licensed). It is a prescribed waste and requires certification when it is transported from the removal site and disposed to an approved landfill. This information is recorded on databases in some States, although recording practices may differ eg. in some cases, products are categorised (eg. Asbestos Cement (AC) sheet, lagging, blue asbestos) while in others only a total is recorded. It is desirable that AC sheet and other products are specified separately due to the low friability of the former.

Reporting scale

Major Urban Centres (MU).

Outputs

Mass of asbestos products removed annually from workplaces as either AC sheet products or 'other' asbestos products.

Data sources

Some State EPAs record licensed quantities of asbestos transported and disposed on databases that are accessible under Freedom of Information (FOI) (eg. Victoria, NSW).

Links to other indicators

Nil.

Indicator 7.9: Number of unflued gas heaters in residences and schools

Description

Number of unflued (unvented) gas heaters used in residences and schools.

Rationale

Unflued gas heaters are a significant source of nitrogen dioxide (and other pollutants) exposure in indoor air and have been widely used in Australia. They have been implicated as a cause of childhood respiratory illnesses.

Analysis and interpretation

The number of unflued gas heaters is used as a surrogate for the number of buildings with high nitrogen dioxide exposure levels. Exposure levels will vary greatly with the type of heater (eg. capacity, classification as low emission), installation requirements (some States require fixed wall vents to also be installed), building air tightness and heater use patterns. However, in general, it is assumed that exposure levels in these buildings will be significantly greater than those in other buildings.

Monitoring design and strategy

No definitive source of this information is available. However the ABS Housing Survey 1994 recorded that 1.92 million dwellings used natural gas heating and 212,000 bottled gas heating. This use varied with State and Territory eg. '000 households:

	NSW	Vic	Qld	SA	WA	Tas	NT	ACT
Bottled	101	43	21	21	19	9	2	1
Natural	319	1100	13	168	177	0.3	0.3	47

However, there is some information available that allows estimates to be made:

(a) unflued heaters have been prevented from use in suburban Melbourne

(b) unflued heaters have been widely used in Sydney (eg. one estimate was 20 percent of dwellings)

(c) bottled gas heaters are generally unflued

(d) survey information from SA shows that one-quarter of natural gas heaters are unflued.

Using these factors, the following estimates are made for unflued heaters in Australia:

Further surveys of heater types in each State should permit a more reliable estimate of this indicator.

Reporting scale

Urban Hierarchy (UH).

Outputs

Number of buildings with unflued gas heaters; reported every 3–5 years.

Data sources

Development of ABS Housing survey to distinguish flued from unflued heaters would supply data.

Linkages

Use of these heaters in buildings with low air infiltration rates (Indicator 7.4) will be a critical factor to the level of exposure to nitrogen dioxide.

'000 households

	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	Total
Bottled	101	43	21	21	19	9	2	1	608
Natural	300	–	–	40	40	<1	<1	10	

Indicator 7.10: Number of people housed in mobile buildings

Description

Number of people who live in mobile residences (eg. caravans, mobile homes).

Rationale

Mobile buildings have been found to have high and persistent indoor air concentrations of formaldehyde, an irritant gas which is also classified as a probable human carcinogen. This results from the high usage of reconstituted wood products (which use formaldehyde-based resins) and restricted ventilation in such buildings. Other organic pollutants may also occur at elevated levels in these buildings.

Analysis and interpretation

This measure is used as a surrogate indicator for high levels of exposure to formaldehyde gas. Manufacturers are now making lower emitting products, but exposures in this class of building may still remain high because of low ventilation rates.

Monitoring design and strategy

The number of people housed in these buildings needs to be determined for each State and Territory since formaldehyde emissions will vary with climate; higher emissions are known to occur in hotter and more humid conditions.

Reporting scale

UH.

Outputs

Number of people housed in mobile buildings; recorded every 3–5 years.

Data sources

The ABS Census records the number of people living in 'caravans, cabins or houseboats' (eg. 161,420 in last Census).

Linkages

Will be related to (low) air infiltration rate (Indicator 7.4) of these buildings.

Indicator 7.11: Proportion of residences with high house dust mite allergen

Description

Samples of housing are surveyed for house dust mite allergen levels in carpet and bedding, and the proportion exceeding acceptable exposure guidelines is determined.

Rationale

Australian housing has been found to exhibit one of the highest house dust mite allergen levels in the world. This is because housing is located predominantly in temperate, coastal climates conducive to mite proliferation. Some research has implicated exposure to the allergen as a cause of childhood asthma and an influence on its severity. It has been clearly shown that a high proportion of asthma sufferers (~80 percent) are allergic to the allergen. Other effects are eczema and allergic rhinitis (nasal inflammation).

Analysis and interpretation

Medical researchers around Australia have adopted semi-standard procedures for sampling and analysis of house dust mite allergen in carpet and bedding. WHO guidelines for allergen levels in fine dust from these surfaces are: >2 mg Der p 1/g dust ~ risk of sensitisation and >10 mg Der p 1/g dust ~ risk of severe asthma attack. Allergen levels in a large proportion of coastal residences exceed these levels, while such levels are rare in central Australia due to the low humidity climate.

Monitoring design and strategy

Samples of residences (greater than 2 years old, with fitted carpets) would be monitored on a 3-yearly basis. Four dust samples should be taken from each building (eg. 2 floor samples, 2 bedding samples) and averaged. Allergen levels have been found to be highest in autumn and sampling should be carried out in this season only.

Reporting scale

Urban Hierachy, C.

Outputs

Proportions of samples exceeding WHO guidelines.

Data sources

Medical researchers in several States gather this type of information as part of health-environment studies, particularly in relation to asthma. These are unlikely to use randomly selected buildings. The data for this indicator may have to be gathered specifically for this measure, using local researchers competent in sampling and analysis procedures on a fee-for-service basis (it is estimated that it will cost approximately $150 to gather and analyse four dust samples from each building).

Linkages

This indicator, together with Indicator 7.5 (proportion of population sensitive to pollutants), provides the best information on a population sector and a pollutant of specific concern to this sector.

Indicator 7.12: Incidence of Legionnaires' disease

Description

Number of notifications of Legionnaires' disease per 100,000 population.

Rationale

Legionnaires' disease is notifiable in all States and Territories and is a severe disease with high fatality. Since it arises mainly from drift of contaminated water mists from external cooling towers into nearby building ventilation inlets, human settlement factors (eg. building density) may be significant to its incidence. Codes for its control exist but their impact on incidence is presently unknown.

Analysis and interpretation

Annual incidence rates vary by State with lowest values occurring in the colder climates (ACT, Tasmania). Annual incidence rates by State will show whether control of cooling tower water is effective in disease prevention and whether climatic factors are significant.

Monitoring design and strategy

Notifications are gathered by the National Notificable Diseases Surveillance System—Communicable Diseases Network (Australia and New Zealand).

Reporting scale

By State and Territory (data already reported in this format).

Outputs

Annual number of notifications of Legionnaires' disease per 100,000 population for each State or Territory.

Data sources

See Above.

Links to other indicators

This indicator may be linked to other indicators related to population density.

Indicator 7.13: Production of low-VOC emission building products

Description

Production of low-Volatile Organic Compound (VOC) emission building products as a proportion of total production.

Rationale

VOC concentrations have been found to be elevated in new buildings for several months after construction and have been implicated in occupant illness. Manufacturers (particularly those overseas) are developing 'low' emission products to counter this effect.

Analysis and interpretation

A range of definitions of 'low' emission are possible and standard procedures by which the emissions can be measured and classified need to be developed in Australia (an application for standards is pending with Australian Standards).

Monitoring design and strategy

ABS gathers information on production quantities of materials and would need to instigate new procedures to identify 'low' emission components.

Reporting scale

Sectoral.

Outputs

Proportion ($/$) of low emission products manufactured according to product types of greatest VOC emissions eg. paints, adhesives, sealants, reconstituted wood panels.

Data sources

Need to be developed by ABS.

Linkages

This indicator, together with Indicator 7.1 (occupant satisfaction with commercial indoor air quality), provides the best information on a population sector and pollutant sources of concern to this sector.

Indicator 7.14: Exposure to indoor air (time spent in city traffic)

Description

Amount of time spent travelling in city traffic

Rationale

Recent studies (Newton, 1997) have revealed that the Australian population, on average, spends 95 percent of its time indoors (5 percent of this is in transport of one form or another, where research indicates heightened exposure to air pollution). Pollutant measurements within automobile environments have shown that high exposures to benzene and other toxic VOCs occur depending on traffic density and vehicle characteristics. 10-60 percent of daily exposure to these pollutants can occur in this environment.

Analysis and interpretation

This Indicator needs to consider both the average time spent in traffic by urban populations and the variation according to an individual's occupation (eg. professional drivers c.f. office worker) or age (eg. young student c.f. adult) and susceptibility (eg. asthma sufferers). Traffic density will be a critical influence on pollutant exposure by this route and may have to be factored in using Indicator 4.10 Perceived Daytime (Population) Density. No specific criteria are recommended other than the minimisation of time spent in city traffic.

Monitoring design and strategy

The Transport Research Centre at the Royal Melbourne Institute of Technology (RMIT) gathers survey information on time-activity patterns of urban populations that could act as a data source for this Indicator. This data may have to be refined on the basis of specific occupations, pollutant susceptibility or traffic density, as described above.

Reporting scale

Major Urban Centres (MU).

Outputs

Average (and distribution) of time spent in 'heavy' city traffic for total population, professional drivers and asthmatics.

Data sources

The Transport Research Centre at RMIT.

Links to other indicators

This indicator is linked to Indicator 4.9 (Total Time and Distance Travelled) and Indicator 4.10 (Perceived Daytime Density) and Road Traffic Density (Indicator 9.6), some Environmental Health Indicators and indicators of urban pollution from the Atmosphere working group.

The indicators for environmental health are drawn from both indicators recommended in this report, and from indicators recommended in the other reports of this series. Here, they are presented together with a discussion of their importance as indicators of environmental health. Several additional indicators, not listed elsewhere, are also recommended.

Environmental health

Indicators for environmental health:

Indicator 8.1: Bacterial Contamination of Food or Water in the Environment

Indicator 8.2: Incidence of Vector-borne Diseases

Indicator 8.3: Exposure to Hazardous Chemicals and Wastes

Indicator 8.4: Passive Smoking

Indicator 8.5: Health Literacy and Coping Skills

Indicator 8.6: Depression and Related Disorders

Indicator 8.7: Melanoma of the Skin

Indicator 8.8: Cause Specific Mortality Rates for Different Settlement Types

Indicator 8.9: Mortality Among Indigenous Australians

Indicator 8.10: GP Consultations

Indicator 8.11: Hospital Separations, All Causes

Indicator 8.12: Health Services Expenditure

Indicators recommended elsewhere, but also relevant to environmental health:

Proportion of Settlements Served by Treated Water (Indicator 2.1, this report)

Human Criteria Exceedances (Inland Waters Indicator 2.1)

Swimming Days Lost (Inland Waters Indicator 2.2)

Guideline Trigger Levels Reached (Inland Waters Indicator 3.1)

Population Serviced by Treated Wastewater (Indicator 2.6, this report)

Seafood Quality (Estuaries and the Sea Indicator 4.4)

Change in Status of Highly Contaminated Sites per Catchment (Land Indicator 3.6)

Rate of Violations in Residue Levels (Metals and Organics) in Harvested Rural Produce and Foodstuffs (Land Indicator 6.7)

Indicators of Indoor Air Quality (7.6, 7.9, 7.10, 7.11, 7.13, 7.14, this report)

Ultra-violet (UV) radiation flux at the surface (Atmosphere Indicator 2.3)

Concentration of Carbon Monoxide in Urban Areas (Atmosphere Indicator 3.1)

Concentration of Ozone in Urban Areas (Atmosphere Indicator 3.2)

Concentration of Lead in Urban Areas (Atmosphere Indicator 3.3)

Concentration of Nitrogen Dioxide in Urban Areas (Atmosphere Indicator 3.4)

Concentration of Sulphur Dioxide in Urban Areas (Atmosphere Indicator 3.5)

Concentration of Benzene in Urban Areas (Atmosphere Indicator 3.7)

Toxic dosage of air pollutants (Atmosphere Indicator 3.10)

Concentration of Particles in Urban Areas (Atmosphere Indicator 6.3)

Proportion of Settlements Served by Treated Water (Indicator 2.1, this report)

Human Criteria Exceedances (Inland Waters Indicator 2.1)

Swimming Days Lost (Inland Waters Indicator 2.2)

These three indicators relate to the availability of good quality water for drinking, household use, and recreation. The availability of water free from chemical and bacteriological contamination is essential for good health.

It is important that these indicators be reported separately for settlements of different size and type. In 1996 it was estimated that more than 98 % of water samples in metropolitan areas and about 85 % of samples from non-metropolitan supplies complied with bacteriological guidelines. However, in remote settlements only 43 % of samples complied (Commonwealth of Australia 1996). It is likely that these differences have some bearing on the differences in health status of different types of settlements (see indicator 8.1).

These indicators are linked to indicator 8.2: Disease outbreaks directly attributable to bacteriological contamination of food or water in the environment.

Guideline Trigger Levels Reached (Inland Waters Indicator 3.1)

This indicator describes the chemical and bacteriological characteristics of inland waters, relative to a range of specific environmental values. Amongst these environmental values is use for agriculture. The quality of water used to grow food (including fish, oysters, mussels, etc. in aquaculture) can have important health implications, since poor quality water may lead to biological contamination of foods. Spasmodic outbreaks of food poisoning from contaminated oysters is an example of such an effect.

This indicator is linked to indicator 8.2: Disease outbreaks directly attributable to bacteriological contamination of food or water in the environment.

Seafood Quality (Estuaries and the Sea Indicator 4.4)

Rate of Violations in Residue Levels (Metals and Organics) in Harvested Rural Produce and Foodstuffs (Land Indicator 6.7)

These indicators document the contamination of foods with unacceptable levels of a range of substances that are potentially damaging to human health. These substances are chemical rather than biological, so this indicator is not linked to indicator 8.2.

Municipal Population Serviced by Treated Wastewater (Indicator 2.6, this report)

This indicator relates to the number of households serviced by metropolitan sewage systems. From an ecosystem perspective, this is important to assess the impact of human settlements on receiving waters. From a human health perspective, it an indicator of the adequacy of sanitation in human settlements. Poor sanitation is associated with increases in the incidence of a variety of infectious and parasitic diseases.

Change in Status of Highly Contaminated Sites Per Catchment (Land Indicator 6.3)

This indicator measures both changes in the number of contaminated sites that have been identified and progress toward remediating known contaminated sites.

Contaminated sites generally contain substances such as heavy metals or organic compounds that are potentially damaging to human health. While the number of contaminated sites in Australia is low compared to other developed countries, there may be as many as sixty thousand contaminated sites, and many of these are unknown. Identifying and remediating such sites is an important measure to reduce threats to human health.

Concentration of Carbon Monoxide in Urban Areas (Atmosphere Indicator 3.1)

Concentration of Ozone in Urban Areas (Atmosphere Indicator 3.2)

Concentration of Lead in Urban Areas (Atmosphere Indicator 3.3)

Concentration of Nitrogen Dioxide in Urban Areas (Atmosphere Indicator 3.4)

Concentration of Sulphur Dioxide in Urban Areas (Atmosphere Indicator 3.5)

Concentration of Particles in Urban Areas (Atmosphere Indicator 3.6)

Concentration of Benzene in Urban Areas (Atmosphere Indicator 3.7)

These indicators measure the concentration of a range of air pollutants in urban airsheds. The potential health effects of the pollutants are:

Carbon monoxide: impacts are related to carboxyhaemoglobin, which reduces the carriage of oxygen to organs in the body, in blood. Exposure at low levels can lead to increased occurrence of cardiovascular disease symptoms.

Nitrogen dioxide: health effects include decreases in lung function, increased susceptibility to respiratory infection and aggravation of existing respiratory and cardiovascular disease. Exacerbation of asthma is also associated with exposure to nitrogen dioxide. Increases in daily mortality have been shown to be associated with ambient concentrations of nitrogen dioxide. It can also exacerbate the effects of other pollutants such as ozone and sulphur dioxide.

Sulphur dioxide: health effects are associated with respiratory disease and asthma. Increases in daily mortality have been associated with exposure to sulfur dioxide. Asthmatics are a particularly susceptible group.

Lead: major health effect of lead exposure is on the central nervous system, as demonstrated by decreased IQ with increased blood levels. Children exposed to lead are especially at risk.

Ozone: health effects of ozone vary from minor changes in lung function to aggravation of existing respiratory and cardiovascular disease which may lead to an increase in hospital admissions for these conditions. Increases in daily mortality have also been associated with exposure to ozone.

Particles: main health impacts which have been associated with particles are increases in daily mortality. Aggravation of existing respiratory and cardiovascular disease (including asthma) leading to increased hospital admissions and medication use has also been associated with exposure to particles, even at low levels.

Benzene: The concentration of benzene has been included as a surrogate for the presence of a range of air toxics—volatile organic compounds present in the atmosphere in low concentrations. The health implications of air toxics are not yet well understood.

Indoor air pollution also has health effects (see the indoor air quality section of this report), although it has received less attention than the effects of outdoor air pollution. The suite of indoor air quality indicators is not included here, since direct measurements of the concentration of pollutants in indoor air are yet not available. The relationship between the indicators and potential health effects is thus further removed than is the case for outdoor air quality indicators. However, the indicator 'toxic dosage of air pollutants' covers the effects of indoor air pollution.

Toxic dosage of air pollutants

This indicator describes the overall health risk due to exposure to a range of pollutants in both ambient (outdoor) and indoor air.

At this stage, there is no agreed methodology to measure toxic dosage (also known as 'personal exposure') for large populations. The toxic dosage for each individual is a function of the concentration of pollutants in each air environment and the amount of time spent in that environment. Since the range and concentration of pollutants in indoor and outdoor air varies significantly (see the indoor air quality section of this report, as well as Newton, 1997) and given the large spatial variation in the concentration of some outdoor air pollutants, estimating toxic dosage is likely to be difficult. A further issue is the possible synergistic effects of exposure to a range of pollutants.

Ultra-violet (UV) radiation flux at the surface (Atmosphere Indicators 2.3)

The health effects of exposure to UV radiation include damage to the eyes, suppressed immunity, and increased likelihood of skin cancers (Commonwealth of Australia 1996). Australia has the highest incidence (and death rate) of melanoma in the world. Exposure to ultraviolet radiation is a major risk factor for the development of this type of cancer. It should be noted, however, that there can be a lag of many years between exposure to ultraviolet radiation and the onset of melanoma. Further, trends in melanoma incidence are likely to be more strongly correlated with changed patterns of behaviour than with changes in the flux of UV radiation at the surface.

Indicator 8.1: Bacteriological contamination of food or water in the environment

Description

The number of outbreaks of food poisoning or other diseases where the cause can be directly attributed to contamination of food or water in the environment (as opposed to food handling). The number of people affected by such outbreaks.

Rationale

This indicator is a direct measure of an impact of the environment on human health.

Analysis and interpretation

An increase in the number of incidents may indicate that the food supply is being increasingly contaminated 'at source'. However, care should be taken to ensure that any trend is not due to increased (or decreased) diligence in investigating the causes of disease outbreaks. Trends in this indicator should be checked against trends in the indicator 'guideline trigger levels reached'.

Monitoring design and strategy

State and Territory Health Departments keep records of such incidents, and these are analysed by the Communicable Diseases Network of Australia and New Zealand. Consolidated national records and analysis are available from in the publication 'Communicable Diseases Intelligence' (Commonwealth Department of Health and Family Services). It is important that the incident be recorded against the place where contamination occurred rather than where the outbreak took place.

Reporting scale

Reporting on the national scale should be adequate. Reporting on a catchment scale may also be useful if there is a large increase in incidents, since this would help to relate trends in water quality to trends in disease incidents.

Outputs

- Maps showing the locations of the sources of disease outbreaks, and tables showing the number of people affected.
- A chart showing trends (if any) in the number of outbreaks and people affected over time.

Data sources

Communicable Diseases Intelligence (Commonwealth Department of Health and Family Services). Data are also available from the Communicable Diseases Network of Australia and New Zealand.

Indicator 8.2: Incidence of vector-borne diseases

Description

The number of new cases of vector borne diseases reported each year, together with the area within which the diseases were contracted. (Excluding cases contracted outside Australia.)

Rationale

A number of diseases are transmitted by vectors (principally mosquitos). Diseases that are problems or potential problems in Australia include Ross River Fever, Dengue Fever, Barmah Forest Virus and Japanese Encephalitis. Of these, the most common in Australia is Ross River Fever, with 5,428 cases reported in 1993 and 3,974 in 1994. The number of cases of such diseases, and the area in which they can be contracted, is related to the distribution and abundance of disease-bearing vectors. This, in turn, can be affected by the extent and condition of vector habitats and breeding areas (eg wetlands), and control measures.

Any changes in climate due to the enhanced greenhouse effect are likely to change the distribution and abundance of vectors.

While this indicator is not, strictly speaking, a function of human settlements, it is a significant environmental health issue.

Analysis and interpretation

Changes in the number of new cases of vector borne diseases may be due to:

- changes in the distribution or abundance of vectors,

- increasing numbers of residents or visitors to affected areas, or
- changes in the precautions taken against infection (clothing, insect repellent, nets, etc).

Care must be taken to disentangle these possible causes.

Changes in the affected area (corresponding to changes in the distribution of vectors) is environmentally significant.

Monitoring design and strategy

The major vector-borne diseases are notifiable, and records of new cases and the area where the disease was contracted are kept by State Health Departments.

Reporting scale

Reporting should be on the national scale. Annual data are available.

Outputs

Charts showing a time series of the number of people affected by each disease and maps showing the affected areas. Any change in the affected areas should be highlighted.

Data sources

Communicable Diseases Intelligence (Commonwealth Department of Family Services), and Australian Institute of Health and Welfare.

Indicator 8.3: Exposure to hazardous chemicals and wastes

Description

Percentage of the population located in close proximity to industrial sites containing hazardous wastes or chemicals.

Rationale

The physical juxtaposition of industrial and residential land uses in urban areas presents a health risk to population, living close to sites where dangerous chemicals and/or wastes are stored, manufactured or used. Existing zoning schemes do not necessarily provide adequate buffering in the case of a major event (explosion, fire, etc.).

Analysis and interpretation

GIS buffering techniques can be employed to overlay populations considered 'at risk' by virtue of their proximity to nominated hazardous sites.

Monitoring design and strategy

Baseline analysis undertaken in major metropolitan areas and monitored every five years for change.

Reporting scale

Major Urban Centres (MU).

Output

Metropolitan level indicator relating percentage of total population exposed. Maps of sub-urban regions which identify at risk neighbourhoods.

Data sources

Metropolitan land use coverages held by State government planning departments and local government planning departments; EPA databases on location of hazardous chemicals and waste.

Links to other indicators

Indicators 10.2, 10.7, 10.8, 10.9.

Indicator 8.4: Passive smoking

Description

Exposure to tobacco smoke.

Rationale

Tobacco smoking is a major health risk factor, responsible for significant mortality, morbidity and poor quality of life. It is known to contribute to a variety of health problems, prominent among which are cardiovascular disease and cancer. Exposure to tobacco smoking is also known to constitute a health risk factor. Children of persons smoking at home are at an increased risk to this type of exposure.

Significant emphasis has been placed upon smoking reduction lately. The message has been well accepted by governments and the society as a whole, but the habit persists in a significantly large proportion of the population to the detriment of the health of their family members.

Analysis and interpretation

A population-based approach to determine variation in degree of exposure to tobacco smoking.

Monitoring design and strategy

Spatio-temporal variation in tobacco smoking prevalence rates as a proxy indicator for exposure to tobacco smoke.

Also, to identify groups among whom the uptake of messages to quit smoking is low as well as to determine reasons for their attitudinal rigidity, through regular surveys. Information on how many people are being exposed to passive smoking also needs to be generated.

Reporting scale

Exposure rate by age group, sex and socio-economic level.

Output

- Contribution of passive smoking to morbidity and health costs.
- Trends in smoking prevalence and attitudes towards smoking.

Data sources

Australian Bureau of Statistics (ABS) National Health Surveys, Population Survey Monitor, State Risk Factor Surveys.

Links to other indicators

Indoor air quality (Indicator 7.6).

INDICATOR 8.5: HEALTH LITERACY AND COPING SKILLS

Description

Proportion of people who can correctly identify actions required in reducing their likelihood of developing ill health.

Rationale

The knowledge of, and ability to gain access to, information for health-related actions is highly important in achieving good health. Obtaining the required knowledge is itself dependent upon levels of literacy in the community. Appropriate utilisation of available health care services is strongly facilitated by this knowledge.

Analysis and interpretation

No information is currently available to measure this indicator as described above, although self-reported information on risk factors and health-related actions obtained during the ABS National Health Surveys and other State-run surveys may act as proxy for this type of information. Appropriate questions may need to be developed and included in various surveys to obtain the relevant information. Literacy levels can also act as a proxy for the indicator.

Monitoring design and strategy

A series of actions need to be identified for inclusion in the set that will be used for scoring this indicator. Time series information is required for regular monitoring. There is some variation noted in health-related actions among various human settlement categories. Any monitoring strategy must attempt to cover this heterogeneity in knowledge of and attitudes towards health-related actions.

Reporting scale

Urban Hierarchy (UH), cross-classified by age and sex.

Output

- An index of ability to gain knowledge for a variety of health-related actions.
- Spatial variation in self-reported health-related actions.

Data sources

New collections; National Health Surveys; State Risk Factor Surveys.

Links to other indicators

GP consultation (8.11); socio-economic status of the population (3.11, 3.1); households in poverty (5.2), etc.

Indicator 8.6: Depression and related disorders

Description

Prevalence of depression and related disorders (1-year prevalence) per 1,000 population

Rationale

Depression has emerged to be one of the major health problems over the past few decades, a source of much personal distress, chronic morbidity and economic cost. In addition to biological determinants, the quality of family and marital relationships and other social support networks also play important roles in the occurrence and outcome of depression-related illness. It is accepted that depression and related disorders (post-partum depression, bipolar disorders, etc.) have a life-time prevalence of 6.3% and a one-year prevalence of 3.7% in Australia, but no reliable source of information is currently available for generating national estimates. Variations in mental health have been documented between urban and remote settlements in Australia (Brealey *et al.*, 1988).

Analysis and interpretation

The 1997 National Survey of Mental Health and Wellbeing provides baseline information on the prevalence of depression in Australia. The Survey also provides the opportunity to look at a range of determinants of depression.

Monitoring design and strategy

In the absence of time series information, it is at present not possible to institute a useful monitoring design and strategy. It is hoped that the 1997 Survey, which will provide information on baselines, will be repeated at a regular interval to generate a useful time series.

Reporting scale

Urban, rural and remote (URR), cross-classified by age and sex.

Output

- Tables of cross-classified prevalence rate.
- Association with various determinants.

Data sources

ABS National Survey of Mental Health and Wellbeing.

Links to other indicators

Hospital separation rate for psychiatric facilities; attitudes to mental disorders; suicide rates; etc.

Indicator 8.7: Melanoma of the skin

Description

Number of new cases of melanoma per 100,000 population (incidence rate)

Rationale

Australia has the highest incidence (and death rate) of melanoma in the world, and it is rising. Exposure to ultraviolet radiation is a major risk factor for this type of skin cancer.

People with fair, sun-sensitive skin are at an increased risk to develop melanoma if exposed to ultraviolet radiation intermittently. Protection against direct sunlight, particularly in lower latitudes, is required to protect against melanoma.

High recreational exposure to sun, leading to frequent sunburns early in life, is common in Australia.

Analysis and interpretation

A large variation is noted in the incidence rate for melanoma among States and Territories, with Queensland showing the highest rate for both sexes. Except in Tasmania, the rates are higher among males than females.

Geographical distribution and population analysis of melanoma cases will allow further insight into this important environmental health issue.

Monitoring design and strategy

Time series analysis of melanoma incidence.

National information is currently available for the years 1983-94. The melanoma death rate also needs to be monitored.

Early removal of lesions leads to improved prognosis. Self-reported information on actions taken for sun protection also needs to be collected regularly.

Reporting scale

Five-yearly pooled information by SLA (UH, C), by age and sex.

Output

- Trend analysis of melanoma incidence and death rates.
- Gaps in self-reported prevalence and cancer registry rates.

Data sources

Australian Institute of Health and Welfare (AIHW) and the Australasian Association of Cancer Registries

Links to other indicators: GP consultations (8.11); hospital separation rates (8.12), etc.

Indicator 8.8: Cause specific mortality rates for different settlement types

Description

Standardised mortality ratios for selected causes of death for different settlement types. Causes of death to include: infectious and parasitic diseases, diabetes mellitus, mental disorders, diseases of the circulatory system, respiratory system diseases, perinatal conditions, and all causes. Settlement types to include: cities, rural towns, remote settlements (indigenous) and remote settlements (other).

Description

There are variations in the mortality rates between settlements of different type, with striking large differences in the rates for remote settlements (indigenous) and other settlement types (Newman *et al.* 1996). These differences are more pronounced for certain causes of mortality than for others, and these are selected for particular attention.

While it is not possible to attribute all of the variations in mortality rates between settlements to environmental differences, it is highly likely that at least some of the variation is due to differences in environmental factors such as the quality of the water supply and sanitation services.

Analysis and interpretation

Variations in mortality must be interpreted with care. Many causes of mortality are subject to multiple causation and confounding factors which make it impossible to directly attribute variations to differences in the environment. Mortality statistics are recorded according the location at which a person dies, which may not correspond to the place where the condition causing death was acquired.

Lack of clean water and sewerage contribute to the relatively high rates of infectious disease, rheumatic heart disease, and respiratory disease in remote indigenous settlements (Newman *et al.* (1996).

Monitoring design and strategy

Relevant statistics are routinely collected and reported by hospitals and health services.

Reporting scale

This indicator should be reported using the full urban hierarchy. Annual data are available and should be used.

Output

The table on page 3-32 of Newman *et al.* (1996) is a suitable form of output. Charts should be used to illustrate any trends in mortality from specific causes.

Data sources

Data are collated by the Australian Institute of Health and Welfare.

Links to other indicators

This indicator is potentially linked to all of the indicators from other reports listed above as relevant to environmental health. The strongest links are likely to be to indicators of water quality.

Indicator 8.9: Mortality among Indigenous Australians

Description

Standardised mortality ratio (SMR) between Indigenous and non-Indigenous Australians for all causes of death.

Rationale

The health of Indigenous Australians is comparatively poor compared to that of non-Indigenous Australians (Newman *et al.*, 1996). Much of this inequality is attributed to the settlement of non-Indigenous population in Australia and the marginalisation of the Indigenous population as a consequence.

Indigenous Australians continue to suffer from health problems introduced by structural maladjustments and locational difficulties. This gap in health status is best captured by an SMR.

Analysis and interpretation

Death rate for all causes together does not constitute a useful indicator of environmental health, in the context of Indigenous health, but the SMR is a useful statistic for summarising the extent of disadvantage in the same setting. It is expected that Indigenous: non-Indigenous SMR can be brought down speedily; hence SMR as a key indicator.

Monitoring design and strategy

Time-series analysis of mortality data (from States and Territories with reliable Indigenous identification on death records).

Rurality and remoteness appear to contribute to heterogeneities in death rates among Indigenous Australians. Any analysis of Indigenous death rate ratio should take into consideration this particular determinant of health status.

Reporting scale

By Urban Hierarchy (UH) and Urban, rural and remote (URR).

Output

- Comparative tables of death rates and ratios.
- Trend comparisons.

Data sources

Australian Institute of Health and Welfare mortality database.

Links to other indicators

Water (2.1, 2.2); Urban design (3.11, 3.12); population (5.2, 5.3); housing (6.6); environmental health (8.2, 8.5, 8.6, 8.7, 8.8, 8.9, 8.10, 8.11, 8.12).

Indicator 8.10: GP Consultations

Description

Average number of visits to general practitioners (GPs) per 1,000 population.

Rationale

Access to, and availability of, general practitioners is the centrepiece of primary health care setting in Australia. Utilisation of this important resource is a useful indicator of both the extent of illness in the community and attitudes towards health-related actions. The indicator also acts as a proxy for the availability of, and access to, medical facilities in human settlements.

Analysis and interpretation

Large differences are noted in GP consultations between males and females, as well as between metropolitan and rural areas. These consultations also indicate the accessibility and availability of services, as well as community attitudes towards seeking help early.

Monitoring design and strategy

Time series information to determine trends in GP consultations; small area variation also needs to be monitored.

On account of universal Medicare subsidy, differences in GP consultations are much less influenced by socio-economic factors. Any variation in the extent of subsidy may influence the use of primary health care services.

Reporting scale

UH, cross-classified by age and sex.

Output

- Tables of cross-classified GP consultation rate.
- Trend analysis and baselines.

Data sources

Medicare statistics (Health Insurance Commission).

Links to other indicators

Spatial distribution of GPs; hospital separation rate; attitudes towards health-related actions; changes in Medicare subsidy; etc.; transport indicators (4.1, 4.2); population (5.2, 5.3).

Indicator 8.11: Hospital separation, all causes

Description

Average number of hospital separations per 1,000 population.

Rationale

Hospital separation rates provide useful measures of community morbidity in combination with General Practice (GP) consultations. Event rather than person based, they also act as indicators of accessibility and availability of secondary health services. Cause-specific rates are helpful in plotting spatio-temporal variation in illness and injury requiring hospitalisation.

Hospital separations also act as a proxy indicator for access to and availability of health care services in various settings, including type of settlement.

Analysis and interpretation

Large differences are noted in hospital separation rates between metropolitan and rural areas. To some extent, the variation reflects the locational distribution of hospital-based facilities and their accessibility. Substitution for other types of health care services, not available in the immediate neighbourhood, also occurs and needs to be carefully analysed.

Monitoring design and strategy

Time series information to determine trends in hospital separations by International Classificaton of Diseases (ICD) groups.

In view of universal Medicare subsidy, differences in hospital separation rates are much less influenced by socio-economic factors. But functional hierarchies associated with inaccessible and remote locations need to be built into analysis and interpretation.

Reporting scale

Urban Hierarchy (UH), cross-classified by age and sex, and adjusted for non-availability of GPs.

Output

- Tables of cross-classified hospital separation rate by major ICD groups.
- Trend analysis of average length of stay (ALOS.)

Data sources

National Hospital Morbidity Database.

Links to other indicators

GP distribution; GP consultation rate; attitudes towards health-related actions; age-standardised death rate; etc.; transport (4.1, 4.2).

Indicator 8.12: Health services expenditure

Description

Average per person expenditure on health services. (The indicator does not cover non-health services-related expenditure for improving or maintaining health and wellbeing of an individual.)

Rationale

A response indicator, health services expenditure per person quantifies the costs incurred by the individual and the community on an annual basis. It also provides some insight into the health services outlay by the community.

Analysis and interpretation

Differences in health services expenditure are noted across communities and locations. These differences reflect both accessibility and availability of health services (including GPs) as well as overall health status of the community. Health services expenditure per person is also linked to several other aspects of individual and community actions that do not strictly fall within the purview of health-services expenses, but impact upon health status strongly.

Monitoring design and strategy

Time series analysis to determine trends in health services expenditure per person. Small area variation, adjusted for structural and locational needs, should also be monitored.

Interpretation of health services expenditure is fraught with difficulties when applied to defined population groups. It could provide a useful indication of relative needs, but may also reveal differences that do not necessarily constitute inequalities or disadvantage.

Reporting scale

UH, cross-classified by age, sex and Indigenous status.

Output

- Tables of cross-classified expenditure by area of expenditure and source of funds.
- Trend analysis.

Data sources

Various.

Links to other indicators

Spatial distribution of GPs; GP consultation rate; hospital separation rate; attitudes towards health-related actions; changes in Medicare subsidy; etc.

Noise

Indicator 9.1:	Exposure to Traffic Noise
Indicator 9.2:	Exposure to Aircraft Noise in Urban Centres
Indicator 9.3:	Exposure to Industrial Noise
Indicator 9.4:	Industrial Noise Injuries
Indicator 9.5:	Cost of Noise Control
Indicator 9.6:	Road Traffic Density
Indicator 9.7:	Air Traffic Density

Noise considerations fit well into the C-P-R model, and noise indicators can be readily catalogued in this way. The seven key indicators selected can be considered as pressures—road and air traffic density; states—exposure to traffic, aircraft and industrial noise, along with industrial noise injuries, and responses—cost of noise control.

Indicator 9.1: Exposure to traffic noise

Description

Population affected by traffic noise: this is a condition indicator, expressed as a percentage of the population subjected to various levels of traffic noise.

Rationale

Road traffic noise is one of the most widespread and growing problems in urban areas. It can be the cause of discomfort, sleep disorders, disruption to normal activities and communication. Essentially, noise becomes a problem when building facades (mostly in residential communities) are exposed to levels that exceed acceptable limits over extended periods of time. While road, motor and other relevant technologies may have improved, data collected over the last few years do not suggest significant improvement to the noise levels. There is anecdotal evidence that while the peak levels may not have increased to any significant extent, the duration of the high levels has lengthened.

Analysis and interpretation

A scale appropriate to report traffic noise level is $L_{Aeq,18h}$. It is noise in the A-weighted decibel scale from varying sources, which, integrated over 18 hours, is equivalent to the sound energy received from a steady source of a given pressure level. For example, $L_{Aeq,18h}$ of 60 dB(A) therefore is equivalent to a steady noise of 60 dB(A) over 18 hours. OECD studies suggest three levels of noise effects, varying from annoyance to constrained behaviour patterns, symptomatic of serious damage caused by noise. The bands are respectively 55-60 dB(A), 60-65 dB(A) and > 65dB(A). These bands are recommended for the indicator.

Monitoring design and strategy

The study requires:

- the selection of a random sample of dwellings in each urban centre;
- consideration of the noise sources for each of these;
- collection of traffic data at the roadways affecting these dwellings; and
- calculation of the noise level.

Reporting scale

Scale effects and population densities affect the noise levels in the community. It is unlikely that noise is a serious problem in remote and rural centres and the recommendation, therefore, is to emphasise urban centres with more than 10,000 population. This represents 86 percent of Australia's population. The objective, therefore, is to develop this indicator for settlements based on a full national urban hierarchy. An appropriate reporting frequency would be every five years.

Output

Tables reporting the percentage of population exposed to each noise level band.

Data sources

Australian Bureau of Statistics, Australian Electoral Offices, State Road Authorities

Links to other indicators

Car ownership (4.2), average speed by mode and distance (4.7), mode choice by trip purpose (4.8), fuel consumption per transport output (4.12), road traffic density (9.6).

Indicator 9.2: Exposure to aircraft noise in urban centres

Description

Population affected by aircraft noise: this is a condition indicator, expressed as a percentage of the population subject to various levels of aircraft noise.

Rationale

The issues of concern with aircraft noise are the number of overflights, the noise level of each event, the intermittent nature of the noise, the cumulative effect of these and the time of occurrence. The method of measurement must therefore take these into account. The main determinants of aircraft noise for people at home are the path, namely the distance to the aircraft, and the transmission loss of the residence. The current Standard requires the long-term average maximum aircraft noise level to be less than 50 dB(A) in resting and sleeping areas and 60 dB(A) in recreational areas. This is higher than the values of 30 dB(A) and 40 dB(A) respectively that the Standard allows for continuous sound. The difference is in recognition of the intermittent nature of the noise.

Analysis and interpretation

Many measures are used to describe aircraft noise, usually related to the maximum A-weighted sound pressure level L_{Amax}. Corresponding time-integrated measures that allow for the variability of noise as the aircraft approaches and recedes from the receiver can be approximated, and special penalties added for night operation. Australia has adopted an energy summation method over 24 hours to determine the suitability of certain zones for residential use. The measure known as the ANEF values (Australian Noise Exposure Forecast) can be projected on a map of the region to define contours of acceptability (ANEF <20), conditional acceptability (ANEF 20–25) or unacceptability (ANEF >25). In the case of Sydney airport, it is estimated that 8000 dwellings are in the ANEF 25-30 range, 4000 in the ANEF 30-40 range and 150 in ANEF >40. It is recommended that these criteria be adopted for reporting the indicator.

Monitoring design and strategy

ANEF data in the form of contours are currently available for major airports from Civil Aviation Authority/Federal Airports Corporation (CAA/FAC) offices. Overlay of population data from the Australian Bureau of Statistics on these is required to calculate the number of people in each noise band.

Reporting scale

Scale effects and population densities affect the noise levels in the community. It is unlikely that noise is a serious problem in remote, rural and smaller urban centres. Therefore, the indicator should emphasise urban centres with more than 100,000 population. This represents 62 percent of Australia's population in 13 centres. An appropriate reporting frequency would be every five years.

Output

For each major airport, ANEF contours and number of residences in each band. Table of the percentage of the population within each band.

Data sources

Australian Bureau of Statistics, Australian Electoral Offices, CAA/FAC

Links to other indicators

Air traffic density (9.7).

Indicator 9.3: Exposure to industrial noise

Description

Population exposed to excessive noise levels in the workplace: this is a condition indicator of noise levels in factories, mines, construction sites and other workplaces.

Rationale

The most common effect of exposure to excessive noise is to cause hearing loss. The loss may be temporary or permanent, depending on the duration of the high levels, the characteristics of the noise and the susceptibility of the individual. There is strong evidence to suggest that the A-weighted sound exposure provides the best cause-effect relationship with hearing loss in noisy environments. Therefore, the equivalent (average) continuous sound pressure level is the most useful tool for dealing with industrial deafness with upper limits placed on that measure. Since a 3dB increase over the average daily limit corresponds to double the energy, half the exposure time to that noise level represents the same total exposure. The National Standard for exposure to noise in the occupational environment defines the criteria for excessive exposure. The criteria are based on an eight-hour equivalent continuous A-weighted sound pressure level ($L_{Aeq,\,8h}$) and a peak noise level which is independent of the exposure time.

Analysis and interpretation

The OH&S Act requires employers to ensure the health, safety and welfare of their employees. This includes the requirements to assess noise levels in the workplace and reduce them if they exceed set limits. The National Standard sets two types of noise exposure limits:

- an average daily limit $L_{Aeq,8h}$ of 85 dB(A)
- an absolute maximum of 140 dB(A)

The consequences of these are requirements to either reduce the noise levels through engineering controls or to reduce the exposure time of the workforce to the noisy environment. A regular survey of the workplace is required by the Victorian WorkCover Authority to determine workers at risk and take remedial action.

Monitoring design and strategy

The Regulation and Code of Practice for Noise, which is administered by the Victorian WorkCover Authority, has well established protocols to assess the risk from noise exposure. It requires that assessments be performed at least every five years (or as soon as practicable after there has been a change in the workplace). Within each industry segment, an evaluation of these noise assessment surveys provides a measure of exposure to excessive noise at the workplace. Where the surveys are not available, and where noise is expected to be a relevant industrial issue, it is the responsibility of the enterprise to carry out the assessment.

Reporting scale

It is unlikely that noise is a serious problem in remote and rural centres except where these may be supporting industries. The reporting scale is therefore sectoral and focuses on industrial centres, with samples on the basis of national industry profiles.

Output

For each industry sector, present a table showing the percentage of the workforce subjected to a noise level exceeding acceptable limits.

Data sources

WorkCover reports, surveys of industry.

Links to other indicators

Industrial Noise Injuries (9.4).

Indicator 9.4: Industrial noise injuries

Description

Number of injury claims and damages relating to noise in the workplace: this is a condition indicator of industrial noise practices in factories, mines, construction sites and other workplaces.

Rationale

The most common effect of exposure to excessive noise is to cause hearing loss. The loss may be temporary or permanent, depending on the duration of the high levels, the characteristics of the noise and the susceptibility of the individual. Other effects of noise exposure may include loss of concentration, lowering of attention and interference with auditory warning signals. Usually, temporary loss of hearing is restored within 24 hours. Permanent losses are irreversible and cannot be corrected by conventional surgery or therapeutic procedures.

The OH&S Act requires employers to ensure the health, safety and welfare of their employees. This includes the requirements to assess noise levels in the workplace and reduce them if they exceed set limits. The National Standard sets two types of noise exposure limits:

- an average daily limit $L_{Aeq,8h}$ of 85 dB(A)
- an absolute maximum of 140 dB(A)

The first criterion $L_{Aeq,8h}$ is a measure of exposure over eight hours, equivalent to a continuous exposure of 85 dB(A). The consequences of these are requirements to either reduce the noise levels through engineering controls or to reduce the exposure time of the workforce to the noisy environment.

Analysis and interpretation

Clearly, industry is responsible for excessive noise levels that may contribute to deafness in the workforce and the consequent costs of compensation. Noise-induced hearing loss has become the most prevalent compensable industrial disease and the costs are substantial.

The variation with time of the number of injuries sustained and their magnitude (as identified by the damages) provides an indication of the magnitude of the problem and the effectiveness of measures to reduce noise in the workplace. Clearly, hidden in the data are the change of attitude to work related deafness, and awareness of the problems and consequences by the employer and the employee.

Monitoring design and strategy

Within each industry segment, evaluate OH&S reports. In many cases, these reports will be available.

Reporting scale

The reporting scale is sectoral and focuses on industry.

Output

For each industry sector, present a table showing the percentage of the workforce reporting noise related injuries.

Data sources

WorkCover.

Links to other indicators

Exposure to Industrial Noise (9.3).

Indicator 9.5: Cost of noise control

Description

Expenditure on noise control measures: this is a condition/response indicator that targets all sections of the economy, including governments, industries and households.

Rationale

Expenditure on noise control and abatement reflects some of the efforts to reduce health pressure on the workforce and to improve the quality of life. However, many of the costs will not be available. Typically, the cost of transport noise on households is traditionally based on the hedonic approach which values the effect of noise on property values. To date there has not been comprehensive research of the economic costs of reducing noise levels in Australian industry. Much of the debate has been carried out using the general perceptions of costs involved and limited knowledge of available solutions to specific problems. The owners of the problems (and WorkCover) would have documented these latter costs. The indicator needs to define the sectors and sub-sectors where data/actions are available and documented. This includes government initiatives.

Analysis and interpretation

The expenses incurred by industry and governments include the costs of surveys, remediation, and prevention. The Regulation and Code of Practice for Noise, which is administered by the Victorian WorkCover Authority, has well established protocols to assess the risks from noise exposure in the workplace. It requires that assessments be performed at least every five years (or as soon as practicable after there has been a change in the workplace). The regulations further require employers to produce a written plan describing the proposed action to control noise and the subsequent implementation.

Monitoring design and strategy

Data on the cost of environmental noise abatement measures was reported by ABS (1995).

Reporting scale

Scale effects and population densities affect the noise levels in the community. It is unlikely that community noise is a serious problem in remote, rural and smaller urban centres. However, remedial action for industrial noise is carried out wherever industry is located. Therefore, the indicator is primarily sectoral, sampled on the basis of industry, housing, and other Australian and New Zealand Standard Industrial Classification (ANZSIC) Divisions.

Output

For each major sector, including governments, present a table showing the costs of noise control.

Data sources

The ABS undertakes surveys of pollution abatement costs by industry. Expenditure by governments is also available from ABS public sector accounts. Commonwealth and State budget papers may also provide data. Where industry receives grants and subsidies from government, these should be counted in the government estimates to avoid double counting.

Links to other indicators

Exposure to traffic noise (9.1), exposure to aircraft noise (9.2), exposure to industrial noise (9.3), industrial noise injuries (9.4).

Indicator 9.6: Road traffic density

Description

Road traffic: with regard to traffic noise, this is a pressure indicator expressed as the proportion of an urban area's main road network experiencing high daily traffic volumes and/or high heavy vehicle component of the traffic stream.

Rationale

Traffic noise is the most serious noise pollution problem affecting residential communities in Australia and considerable funds are expended to improve road conditions and control noise at residential boundaries. Noise at residences due to road traffic generally increases with traffic volumes, vehicle speeds, numbers of heavy vehicles in the traffic stream and proximity to roadways. Weather conditions and local effects of terrain, road surface and nearby traffic control devices can be important. This indicator addresses traffic volume.

Analysis and interpretation

Since traffic noise is greatest alongside the busiest roads, this indicator needs to give an indication of how much of an urban area's road network is likely to be a significant noise problem. Ignoring isolated noise problems on local and minor roads, this indicator should only be concerned with major roads, highways and freeways, such as all roads with annual average daily traffic greater than 10000 vehicles per day—the capacity of a two-lane road with major intersections. Lengths of road sections experiencing daily traffic volumes greater than 10000 vehicles per day would be recorded in increments of 5000 vehicles per day. The proportion of the main road network in each interval would then be determined. Comparing the proportions for different cities or for different years for one city would indicate differences in major traffic loads and hence in noise propensity. Similarly, because of the importance of heavy vehicles to traffic noise generation, the proportion of these vehicles in the traffic stream throughout the major road network needs to be considered.

Monitoring design and strategy

State Road Transport Authorities conduct extensive traffic counting surveys and run advanced traffic planning computer models to estimate traffic volumes in the absence of roadside counts. They maintain databases of traffic volumes for all important roads. Summary indicator statistics can be drawn from these. An annual reporting period would be appropriate.

Reporting scale

Scale effects and population densities affect noise levels in the community. It is unlikely that noise is a serious problem in remote and rural centres and the recommendation, therefore, is to emphasise urban centres with more than 10,000 population. This represents 86 percent of Australia's population. The objective, therefore, is to develop this indicator for settlements based on a national urban hierarchy.

Output

Table showing, for each urban area, the proportion of that area's main road network experiencing daily traffic volumes in excess of say, 15000, 20000, 25000 and 30000 vehicles per day. Table showing, for each urban area, the proportion of that area's main road network experiencing high heavy vehicle flows, say 5-10 percent, 10-15 percent, 15 percent+ of the traffic stream.

Data sources

State Road Transport Authorities.

Links to other indicators

Exposure to traffic noise (9.1); car ownership (4.2); average speed by mode and distance (4.7); mode choice by trip purpose (4.8).

Indicator 9.7: Air traffic density

Description

Air traffic: with regard to air traffic noise, this is a pressure indicator expressed as the total number of commercial aircraft landings per week.

Rationale

Aircraft noise is different from road noise in that the source of noise is elevated and will therefore affect all facades of the building. Furthermore, pressure on land availability, particularly in capital cities, implies that many new residents will inevitably live close to airports. The main noise problems from aircraft occur during take-off and landings and the number of people affected is therefore dependent on the traffic density through the airport, proximity to residences and positioning relative to flight paths. This indicator addresses the traffic density.

Analysis and interpretation

Since penalties are added to the measure of exposure to aircraft noise according to the time of occurrence, the traffic density measure should discriminate between day and night operations.

Monitoring design and strategy

The number of commercial aircraft landings per unit of time is taken as a macro measure of traffic density in cities and a measure of the pressure on most of the population. For many residents, the issue of concern is the high number of overflights and the time of flight. The measure of noise, which therefore takes into account noise levels and time of event occurrence, must include a distribution of (say) landings per unit time over the hours of operation of the airport and differentiate between landings from 7am to 7pm and from 7pm to 7am.

Reporting scale

Scale effects and population densities affect noise levels in the community. It is unlikely that noise is a serious problem in remote, rural and smaller urban centres. Therefore, the indicator should emphasise urban centres with more than 100,000 population. This represents 62 percent of Australia's population, in 13 centres.

Output

Table number of landings:

- from 7am to 7 pm;
- from 7 pm to 7 am.

Data sources

Since landings are taken as a measure of air traffic density in cities, the data, which ultimately will be correlated to noise levels and is related to dwelling density, are available from Civil Aviation Authority Federal Airports Corporation (CAA/FAC) Offices for major airports.

Links to other indicators

Exposure to aircraft noise (9.2).

Waste

Indicator 10.1:	Quantity and Composition of Domestic Solid Waste Generated
Indicator 10.2:	Quantity and Composition of Domestic Solid Waste Disposed to Landfill
Indicator 10.3:	Quantity and Composition of Waste Recovered—Recycling
Indicator 10.4:	Quantity and Composition of Commercial and Industrial Waste Generated
Indicator 10.5:	Quantity of Energy Recovered From Waste
Indicator 10.6:	Proportion of Sludge And Biosolids Re-used
Indicator 10.7:	Quantity, Composition and Source of Hazardous Waste Generated
Indicator 10.8:	Quantity and Composition of Domestic Hazardous Waste Collected
Indicator 10.9:	Amount, characteristics and location of Contaminated Land

In general, three principal waste-outputs are generated as a result of economic activity. These are: domestic waste; commercial and industrial waste; and construction and demolition waste. Waste outputs may also be represented as a resource input, insofar as they can be recycled into alternative energy sources or products. Examples include: converting methane gas at wastewater treatment plants and municipal landfill sites to produce energy or use as a fuel (which also reduces greenhouse gas emissions from these sources); and paper, glass, rubber, aluminium and steel recycling.

The list of indicators tabled represent those that were identified as important representations of waste within human settlements, throughout Australia and internationally. For example, they may be representative of a particular event, show trends over time, give early warning about irreversible trends where possible, or be important to policy decisions and planning.

A range of waste indicators have been excluded from the human settlement waste indicator set. Although they may be important waste indicators in general, they are also linked to other human settlement categories, and are therefore dealt with there. One such example is wastewater (both effluent and industrial or trade waste), which has been assessed in the Water Indicators group.

Indicator 10.1: Quantity and composition of domestic solid waste generated

Description

This indicator identifies the amount and composition of solid domestic waste generated within Australia. Domestic solid waste comprises: organic compostable wastes (food/kitchen wastes, garden/lawn and other putrescibles); other organic wastes (textile, rags, wood rubble, oils, leather), household hazardous wastes (household chemicals, dry cell batteries, paint); paper (newsprint, writing paper, magazines, cardboard, package board) and packaging products (aluminium cans, polyethylene terephthalate (PET) bottles, aluminium and steel cans, liquid paperboard).

Rationale

Waste arising directly from domestic sources accounts for approximately 40 percent of total municipal waste produced in Australia per year. Information provided by monitoring the amount and type of refuse being discarded at the domestic level will provide an indicator of the rate of transformation of primary natural resources for human activities (ABS, 1996). The indicator will show trends over time in household waste composition and volumes, both per capita, and in total, for Australia.

Monitoring the annual changes to the composition of domestic solid waste generated will help direct future research and development and investment into the most needed areas. It is expected that, as populations increase, so too will domestic solid waste generation. By monitoring waste generation on a per capita basis, it will enable waste managers and decision-makers to target high waste-producing locations. Such information is important, for example, when implementing education, demand management or awareness programs/policies.

It is important, not only for this indicator, but other key indicators developed in this study, to identify a uniform classification for data collection. Within the various capital cities and states, for example, the classification used for solid waste data collection differs. Data are collected and reported at a municipal level (in Sydney, Melbourne and Perth), a household level (in Brisbane), a domestic level (in Adelaide, Darwin) or a combination, such as commercial/household (Canberra), or commercial/domestic (Hobart).

Analysis and interpretation

Solid waste arising directly from households are defined here to include: municipal waste collection, special collections for garden and bulky waste, litter and waste taken to civic amenity sites.

Characterising the contributions of different sectors to the waste stream is difficult (ABS, 1996). Currently, solid waste accounts for approx 50 percent of total waste. To determine household solid waste, a range of sampling techniques may be used. Samples may be taken from the waste generator prior to collection by compactor trucks, which would provide detailed composition of individual generators without cross-contamination. Although the direct sampling option is expensive and labour intensive, it may be useful for the verification of other waste sampling methods. Typically, a front end loader mixes a 100kg load taken from a compactor truck at a landfill or transfer station. This amount has been determined to cover a desired confidence level (Moore, Grime and Kung 1993). Using data from the sample, combined with information on collection route and socio-economic factors, waste generation per person or per household for a designated area, can be estimated. Alternatively, incineration sampling requires selected and mixed 100 to 200kg sample from a known route and analysis conducted on the post incineration remains (Moore, Grime and Kung, 1993).

Monitoring design and strategy

Monitoring and data collection will require direct sampling and sorting to be undertaken by various waste facilities. Materials Flux Analysis may also be undertaken, using all available data sources, with data redundancy where possible.

Reporting scale

The spatial scale for data collection will be at the local scale (LG), and geographic extent is national. Waste composition and quantity (tonnes of material type per region per year).

Output

Results of this indicator should be tabulated, and summary statistical data from waste composition incorporated into the Waste Streams Database. Graphs may be used to represent domestic solid waste generated (in kg/person/week).

Data sources

Australia Waste Database, State/Territory Environment Protection Authorities, Australian Bureau of Statistics, local transfer stations, recycling depots.

Links to other indicators

Indicator 10.1 is linked to other Human Settlement waste indicators on domestic wastes: 10.2 (domestic solid waste disposed to landfill), and 10.8 (domestic hazardous waste collected), and other solid waste indicators: 10.4 (commercial and industrial solid waste generated), and 10.3 waste recovered and recycled.

Indicators on quantity and composition of domestic solid waste generated can also be linked to indicators of consumer expenditure per capita and consumption of household waste on a national scale. It can also be used at a state or local regional council level.

Indicator 10.2: Quantities and composition of domestic solid waste disposed to landfill

Description

This indicator identifies the amount and composition of solid domestic waste disposed to landfills within Australia. As discussed above, domestic solid waste includes organic compostable wastes, other organic wastes, household hazardous wastes; paper and packaging products.

Rationale

Disposal of wastes to landfills is the dominant method of disposal in Australia (ABS, 1996). However, landfills occupy large areas of land, usually in close proximity to urban areas. Waste disposal to landfill is often associated with pollution, unpleasant odours, litter, vermin and loss of visual amenity. Leachate emanating form landfill sites may pollute groundwater and add to eutrophication problems in surface water. Decomposing solid waste generates greenhouse gas emissions such as methane and carbon dioxide. Hazardous substances can migrate into surrounding areas and accumulate in the food chain, with catastrophic consequences for local residents and the environment. The cost of landfill in Australia is between $6 - $40 per tonne. By international standards the cost of landfill is relatively cheap and does not currently constitute a scarce resource (Moore and Tu, 1993c).

Quantities of domestic solid waste disposed to landfill provides an indicator of the rate of the transformation of primary natural resources for human activities, through the amount of refuse being discarded (ABS, 1996). The composition of solid waste (building/ construction and commercial/industrial) disposed to landfills provides an opportunity to identify hazardous, toxic or non-degradable wastes which have long term adverse affects on natural resources. Such information is important for determining future research and development directions, investment into waste management, and the focus for environmental education, demand management and awareness programs/policies.

As governments search for new instruments and policies to manage wastes, such as landfill disposal levies (or taxes) designed to reduce the amount of waste being landfilled, the monitoring of waste disposals to landfills will become increasingly important.

Analysis and interpretation

Indicator 10.2 will be developed as a composite indicator that quantifies and characterises domestic solid waste disposed to landfill. Landfill data will be categorised according to content, and will include: inert waste landfill, sanitary landfill and secure landfill.

Monitoring design and strategy

As mentioned previously (refer to Indicator 10.1), characterising the contributions from different economic sectors to the waste stream is difficult (ABS, 1996). Domestic solid waste comprises approximately 50 percent of total waste to landfill.

Waste management to landfills and transfer stations are certified under ISO 9002 for quality management and ISO 14001 for environmental management (Environment Business, 1997). The National Waste Database will record waste disposed to landfill provided by owners or operators for Municipal Authorities, using weighbridges where possible, or estimating throughput by vehicle count applied to average weight of vehicle class.

Reporting scale

The spatial scale for data collection is at the local government level (LG). Indicator results should be reported at the State/Territory and National level.

Output

Results of Indicator 10.2 should be tabulated and divided into the categories: inert waste landfill, sanitary landfill and secure landfill. The amount of solid domestic waste disposed to landfills within Australia to be reported in tonnes (and tonnes per person). The composition of landfill waste to be represented in tonnes, with each component identified in tonnes and as a percentage of total landfill waste.

Data sources

National Waste Minimisation and Recycling Strategy (NWMRS), State/Territory Environmental Protection Authorities, Australian Bureau of Statistics.

Links to other indicators

Indicator 10.2 is linked to other Human Settlement waste indicators on domestic wastes: Indicator 10.1 (domestic solid waste generated); hazardous domestic waste Indicator 10.8 (Quantity and composition of domestic hazardous waste collected); and other solid waste indicators: 10.4 (Quantity and composition of commercial and industrial solid waste generated); and waste recovered 10.3 (Quantity and composition of waste recovered recycling). Links to Nutrient loads in inland, marine and groundwater waterbodies, can also be established. Urban Design Indicator 3.2, Amount of land converted from non-urban to urban uses, and Indicator 3.3, Consumption of public urban greenspace per capita.

INDICATOR 10.3: QUANTITIES AND COMPOSITION OF WASTE RECOVERED RECYCLING

Description

This indicator records quantities and composition of waste recovered from kerbside recycling, Materials Recovery Facility (MRF) recycling and direct recycling arrangement between the generator of waste and the consumer of the material. MRF is a facility for separating collected recyclables into their material types. The National Solid Waste Classification System provides guidelines for categorising material recovered or recycled from municipal (domestic, other domestic, and other council wastes) commercial and industrial as well as building and demolition sources.

Rationale

In 1991, the Australian and New Zealand Environment and Conservation Council (ANZECC) endorsed the National Kerbside Recycling Strategy to assist in reaching waste recycling targets. The aim in this strategy is to divert 50 percent of domestic waste per capita, from landfill through municipal collections by the year 2000. New targets for commercial and industrial processes are to be negotiated between industry groups and ANZECC to assist in achieving overall objectives in addition to kerbside collection. Building and demolition efficiencies to enhance recovery and recycling are also being encouraged. These objectives are consistent with those of the National Solid Waste classification scheme. This indicator will help to monitor the effectiveness of this endorsement.

Recycling plays an important role in solid waste management, and should be encouraged not only to reduce the need to dispose of vast amounts of waste, but also to protect new raw materials from being extracted and used (World Resources Institute *et al.*, 1996).

To decide whether or not waste disposal and recycling matters requires reliable and timely data. Collection and processing of a comprehensive set of this information does not currently exist. The set of waste indicators will help to set out what data collection is required and to benchmark quantity and quality issues. The inclusion of waste indicators in the human settlement arena provides an opportunity to determine the sustainability of human settlements into the future. The sound management of waste disposal and the issue of viable recycling are management issues that require community acceptance. When this is achieved there is then the potential to deal with rigorous economic assessment. Cost benefit analysis provides no social commentary or measure of community acceptability; rather, it provides an economic choice between alternatives. If those alternatives are ill founded, benefits are illusory.

Analysis and interpretation

Indicator 10.3 will be useful in assessing the extent and effectiveness of recycling programs and schemes. For example, it identifies community involvement in waste recycling, by quantifying the extent of ongoing participation in kerbside collection practices.

As discussed previously, according to Environment Business (1997), kerbside collection has been so successful that commodity prices for recycled products have fallen to an economically unsustainable level. This has important implications for changes to policy and management of non-recycled resource inputs. The monitoring of the composition of waste recovered will therefore be important for waste management.

This indicator will also monitor the extent to which waste minimisation is occurring. Waste minimisation indicators help to determine activities that reduce quantity, toxicity and hazardous properties of waste. Natural resources are conserved as usage of raw materials and natural resources is reduced. Toxic materials used in production are also reduced by recycling.

Monitoring design and strategy

Monitoring design will require information to be collected on the amount of waste recovered from kerbside recycling, MRF recycling and direct recycling arrangement between the generator of waste and the consumer of the material. Information will also be collected on the amount of waste recovered that is then recycled. In light of current concerns that recycling may be economically unsustainable, it may be appropriate to record both the proportion (and mass) of waste collected that can be recycled, and the proportion (and mass) of waste collected that actually is recycled. Recycled material should be identified by the following categories: garden refuse; paper and cardboard; PET (plastic soft drink bottles, etc); glass; rubber; aluminium and steel; and liquid paperboard.

Reporting Scale

Data can be collected at the local government, state government and national levels. Indicator results should be reported at the State/Territory and National level.

Output

Results of Indicator 10.3 should be divided into recycle categories and the results tabulated. The Table should show information on the amount of recyclables collected, the amount that may be potentially recycled, and the amount actually recycled. This should be presented at the State/Territory and National levels.

Information needs to be measured in tonnes/annum and tonnes/person/annum (or tonnes/household/annum). Graphs may be used to identify the composition of recyclables by state.

Data sources

National Waste Minimisation and Recycling Strategy (NWMRS), State/Territory Environmental Protection Authorities, Australian Bureau of Statistics, Local recycling depots and transfer stations.

Links to other indicators

Indicator 10.3 is linked to other Human Settlement waste indicators on domestic wastes: Indicator 10.1 (Quantity and composition of domestic solid waste generated); and 10.2 (Quantities and composition of domestic solid waste disposed to landfill).

Indicator 10.4: Quantity and composition of commercial and industrial waste generated

Description

This indicator identifies the quantity and composition of commercial and industrial waste generated within Australia. Commercial waste refers to waste generated from premises used for the purpose of a trade or business or purposes of sport, recreation or entertainment. Industrial waste, is waste from any factory or premises used for the provision of transport services to the public by air, land or water; the supply of gas, water, electricity or sewerage services to the public; or the provision of postal or telecommunication services to the public (UK Department of the Environment, n.d.).

Rationale

The composition of commercial and industrial waste is diverse and changing, due to the decline in traditional heavy manufacturing industries such as steel-making and shipbuilding, and the expansion of the electronics sector. Similarly, the changes in the size, structure and working practices of the tertiary or service industries are changing the nature and importance of commercial wastes (UK Department of the Environment, n.d.). Commercial and industrial wastes are varied in composition and toxicity.

Commercial and industrial sources form a significant component of the total waste stream, and with changes continuing to occur in the composition of this stream, it is important that trends in the amount of waste arising from these sectors are monitored continually.

As discussed previously, (Indicator 10.3), new targets for commercial and industrial processes are to be negotiated between industry groups and ANZECC to assist in achieving overall objectives in addition to kerbside collection. This indicator will help to monitor the effectiveness of this endorsement.

Analysis and interpretation

This indicator will identify who the major industrial and commercial waste generators are, and the changes in waste volumes over time. By identifying the quantity, composition and industry/commercial sector responsible for waste generation, it may be possible to relate this information to causative factors, monitor targets of different waste types and set benchmarks. This will assist in the development of quantitative data and an index for an industry/commercial group to aim for.

Monitoring design and strategy

Waste generation, from the commercial and industrial sectors, may be monitored by the Australian Standard Industrial Classification (ASIC) major industry division. This includes: agriculture, forestry, fishing and hunting; mining and manufacturing; electricity, gas and water; construction; wholesale and retail trade; transport and storage; communication; finance, property and business; public administration and defence; community services; recreation, personal and other services (Moore, Tu and Kung, 1993b).

Reporting scale

The quantity and composition of commercial and industrial waste generated within Australia should be reported at a state/territory and National level, at the state capital (and large city) level and selected communities within the urban hierarchy. Waste volumes need to be reported for the various groups within the commercial and industrial sectors (such as manufacturing, retail, electricity) and in total. The composition of commercial and industrial wastes (such as contaminated land, fuels, paints) must also be identified and estimated. Statistics should be reported on an annual basis.

Output

Graphs and tables should be used to represent: commercial and industrial waste composition; and commercial and industrial waste generation by type of enterprise/business.

Summary statistical data from waste composition studies should be incorporated into the Waste Streams Database.

Data sources

State/Territory Environmental Protection Authorities, Australian Bureau of Statistics, National Pollution Inventory.

Links to other indicators

This indicator is also linked to several Water Indicators for Human Settlements, including:

Indicator 10.1 (Quantity and composition of domestic solid waste generated), 10.5 (Quantity of energy recovered from waste), 10.7 (Quantity and composition of hazardous waste generated), and 10.9 (Amount, characteristic and location of contaminated land).

INDICATOR 10.5: QUANTITY OF ENERGY RECOVERED FROM WASTE

Description

This indicator identifies the quantity of energy recovered from waste within Australia. Types of energy that may be recovered include: harvesting methane from the decomposition of organic matter from landfills and biosolid or sludge digestion; the combustion of non-biologically active sludge wastes, bagasse, straw, wood, paper and waste tyres.

Rationale

Energy recovered from landfill gas is one of the most promising renewable energy technologies in countries such as the UK, and has been commercially demonstrated in many countries (Meadows and Maunder, 1995). According to the US Department of Energy (1996), the recovery of methane created in municipal solid waste landfills has local and global environmental and economic benefits. By acting as a substitute for fossil fuels, energy recovered from waste reduces the pressure on environmental resources. In 1991, the Australian Bureau of Statistics (1996) reported 330,000 metric tonnes of renewable energy recovered from solid waste.

Domestic solid waste and similar wastes collected by local authorities have a high calorific value and are a valuable source of energy. Where the cost of recycling is prohibitive, energy recovery from waste may be a viable alternative (UK Indicator of Sustainable Development, n.d.). A target set to recover this resource is required.

The importance of this indicator is evident. 'Incineration of waste has a number of environmental advantages: it reduces emissions of methane which is a potent greenhouse gas, it reduces by up to 90 percent, the volume of waste which then has to be disposed of, and it converts waste into material which is less biologically active and poses fewer potential risks for the environment. Using the gas produced in landfill sites reduces greenhouse gas emissions, reduces local risks of explosion' (UK Department of the Environment, 1996. p. 1).

Analysis and interpretation

Indicator 10.5 will be developed as a composite indicator that quantifies and characterises energy recovery from waste. Energy produced will be categorised according to the waste source. The result of this would reflect the move towards re-use and waste minimisation.

It is expected that energy recovered from waste would increase, not only in line with population growth, but also as a consequence of increased education standards, environmental sustainability objectives, international obligations to meet greenhouse gas emission targets, and improvements in technology.

Monitoring design and strategy

By identifying the contents of landfill, it is possible to determine the methane generating potential. Alternatively, potentials may be estimated using monitoring stations/wells within the landfills. In the case of municipal combustion, for example, energy recovery rates can be determined by material dry weight.

The amount of energy recovered from waste (categorised by waste source) may be recorded as an annual total, and as a proportion of total waste energy produced, and as a proportion of total energy (renewable and non-renewable).

Reporting scale

Data should be collected at the municipal level (LG). Results should be reported annually, based on the method suggested in the monitoring design and strategy (above). Reporting should be collated to the state/territory and national level, and at the capital (and large city) level.

Output

Data could be tabulated based on the reporting scale above.

Data sources

Municipal council, State/Territory Environment Protection Authorities, National Waste Database, Australian Bureau of Statistics, State/Territory energy utilities.

Links to other indicators

Indicator 10.5 is linked to other Human Settlement Waste Indicator 10.2 (Quantity and composition of domestic solid waste disposed to landfill); Micro-level Indicator 0.5: (Renewable energy) Energy Indicator 1.1: (Total energy use).

Indicator 10.6: Proportion of sludge and biosolids re-used

Description

This indicator identifies the proportion of sludge and biosolids re-used within Australia. Sludge is the solid material remaining after sewerage treatment facilities process wastewater from domestic and industrial sources. Sludge contains organic matter and nutrients derived primarily from domestic wastewater, as well as heavy metals and organic contaminants discharged from industry (Lue-Hing *et al.*, 1996). Biosolids are the organic component of sludge.

Sludge use may be for the following purposes: land application including agricultural and land reclamation; disposal to landfill; and thermal processing. Land application is the largest beneficial use of sludge and biosolids. In NSW liquid digested biosolids and dewatered cake is typically provided free to farmers. Composting of biosolids and mixing with soil is becoming more common in urban landscaping (Samuel, 1996). Nutrients found in sludge reduce the need for commercial fertilises and can reduce fertiliser costs significantly. Landfill of biosolids is practised by many local council operators and is mostly categorised as waste. There is no incineration of sludge currently undertaken in NSW (Samuel, 1996). Further, it is unclear whether any sludge is disposed of by this method in Australia.

Rationale

Demand for more highly treated wastewater for re-use or release into the environment will inevitably result in an increase in the quantity of sludge and biosolids produced. However, there are concerns that the application of sludge to land will result in an increase in pathogenic bacteria, viruses, parasites, chemicals and metals in the food chain, and in surface and groundwater. Sewage treatment plants have little control over incoming wastewater; and technology used to clean this wastewater does not have the flexibility to vary treatment processes according to waste streams. Sludge quality is therefore dependent on the state of incoming wastewater. In terms of public acceptance, re-use is guided by cultural experience and concern over health consequences.

As the population increases so too does the production of sludge and biosolids; and as in the wastewater treatment levels increase, so too will the generation of these wastes. Consequently, it is important that the proportion of sludge and biosolids re-used (and distributed to land, landfill, and thermal processing) is monitored.

Analysis and interpretation

Results of Indicator 10.6 will need to be analysed in line with Environmental Management Guidelines for the use and disposal of biosolid products.

Changes in sludge and biosolid re-use will need to be evaluated, to determine whether increases in sludge re-use are the result of an easing of environmental, health or social barriers.

Monitoring design and strategy

A benchmark for assessing the potential for sludge re-use involves classifying the concentration of contaminants within sludge and biosolids (based on a contaminant acceptance concentration threshold). Biosolid products are given a contaminant grade and a stabilisation grade which determines what land application is acceptable, while determining what restrictions if any are necessary after application.

Changes in sludge re-use to the various uses (land, landfill, thermal processing) should be monitored annually.

Reporting scale

Biosolid and sludge reuse should be collected at the local government level (LG). Indicator results to be reported at the State/Territory and National level. This indicator should also be reported at the capital (and large city) level.

Output

Results of Indicator 10.6 should be tabulated and divided into the three sludge and biosolid re-use categories: land, landfill and thermal processing. These components should be identified in tonnes and as a percentage of total sludge and biosolid volumes.

Data sources

Data sources include biosolid producers, Industry groups, State Environment Protection Authorities, Wastewater treatment plants.

Links to other indicators

This indicator is also linked to several Water Indicators for Human Settlements, including:

Indicator 2.4 (Volume and percent of sewage disposed to oceans, inland waters, land and re-used); Indicator 2.5 (Volume and percent of wastewater discharged by domestic, industrial and other sectors); Indicator 2.6 (percent and number of municipal population serviced by treated wastewater—to primary, secondary, tertiary and nil treatment levels); Indicator 2.10 (Volume and percent of wastewater re-used by type of application) and Indicator 2.12 (Investment in wastewater and stormwater technology as a proportion of total water expenditure).

Indicator 10.7: Quantity, composition and source of hazardous waste generated

Description

This indicator identifies the quantity and composition of hazardous waste generated within Australia. They may be solid, liquid and gaseous in nature and comprises both domestic and industrial hazardous waste.

Hazardous wastes usually have one or more of the following characteristics: they are corrosive, flammable, reactive (can cause an explosion or produce deadly vapours), and toxic in that they are poisonous to humans and animals. Intractable waste is also a subset of the hazardous waste. Examples of domestic hazardous waste include household cleaners, solvents and paint, motor vehicle lubricants and fuel, batteries, prescription drugs, garden chemicals and fertilisers, pesticides and pool chemicals (Moore and Tu, 1993). A common industrial hazardous waste is contaminated soils.

Rationale

Industry has a responsibility to ensure that both the quantity and hazardous nature of its waste is reduced. This may require innovative production methods, such as the introduction of clean production, recycling and re-use. The storage, transport, treatment and disposal of hazardous waste is controlled by legislation (see for example, Waste Disposal Act). Recording the volume, nature and source of hazardous wastes is important in helping to protect the environment from long-term contamination. It also allows the identification of sectors which are large generators of hazardous wastes. This will aid in the identification of sectors which require the future establishment of programs and practices for waste monitoring and control.

Analysis and interpretation

Comparisons between countries are sometimes made using the relationship between GDP and total hazardous waste generation. This is too general, as it does not provide detailed comparisons between regions and cities. Indices that will deliver the necessary detail, include environmental quality indices and hazardous waste indices (Moore and Tu, 1993).

By identifying the quantity, composition and source of hazardous waste generated, it may be possible to relate this information to causative factors, monitor targets of different waste types and set benchmarks, and develop quantitative data and an index for an industry group to aim for. An environmental quality index function would allow individual facilities to determine the mix of reduction to comply with hazardous waste minimisation and recycling objectives. The consultative process between all stakeholders needed to arrive at mutually acceptable compliance levels is seen as more favourable than fixed reduction targets. (Moore and Tu, 1993)

Monitoring design and strategy

Using a four digit code, as defined by the Australian and New Zealand Standard Identification Classification (ANZSIC), a data aggregate of industry type may be used when identifying the quantity of each waste type per unit of goods produced (Moore and Tu, 1993).

Waste generation, from the industry level, may be monitored by the Australian Standard Industrial Classification (ASIC) major industry division. This includes: agriculture, forestry, fishing and hunting; mining, manufacturing; electricity, gas and water; construction; wholesale and retail trade; transport and storage; communication; finance, property and business; public administration and defence; community services; recreation, personal and other services; and unknown (Moore, Tu and Kung 1993b). Industries in Sydney, Victoria and South Australia use the annual quantity of each waste type per production employee in each ASIC industry group. This method has difficulty accounting for increased productivity, and movement of employees through privatisation outside waste generating ASIC industry groups. Use of production employees only may overcome this difficulty.

Monitoring of hazardous waste generation will only cover waste sent from licensed generators for off-site disposal, due to the lack of information that exists on off-site and on-site hazardous waste recovery or recycling. Hazardous Waste Indices, which include taking an annual quantity of each hazardous waste type per head of population, is limited to waste types such as oils, oily water and grease trap waste. Hazardous waste is generally related to industrial activity and therefore indirectly related to population.

Reporting scale

Data could be collected using the ANZSIC code of: generator, waste type and quantity, month generated, treatment type provided and region generated; and would be transferred monthly to a regional database. This indicator would need to be monitored annually and across the urban hierarchy of settlements.

Output

Reporting can be undertaken based on the categories outlined in reporting scale (above). Hazardous solid, liquid and gas wastes could be reported at the ASIC major industry level, and per household at the state/territory and national level. This indicator should also be reported at the capital (and large city) level.

Reports on the generation of waste types in each region on a routine basis, with special client focussed reports generated when necessary.

Data sources

National Pollution Inventory.

Links to other indicators

Linkages exist with Human Settlement Waste Indicator 10.8 (Quantity and composition of domestic hazardous waste collected).

Indicator 10.8: Quantity and composition of domestic hazardous waste collected

Description

This indicator identifies the quantity and composition of domestic hazardous waste generated within Australia. Here, Domestic hazardous wastes represent the residues of potentially harmful substances used in the home. They include those not allowed to be disposed of to sewers or municipal solid waste landfills; and usually have one or more of the following characteristics: they are corrosive, flammable, reactive (can cause an explosion or produce deadly vapours), and toxic (in that they are poisonous to humans and animals).

Examples of domestic hazardous waste include: household cleaners, solvents and paint, motor vehicle lubricants and fuel, batteries, prescription drugs, garden chemicals and fertilisers, pesticides, and pool chemicals (Moore and Tu, 1993).

Rationale

Regulations that control the disposal of hazardous waste are absent or difficult to enforce at the household level. Yet the effects of domestic hazardous wastes on the environment can be dramatic. Burial of hazardous waste can contaminate soil and groundwater. Disposal to sewerage or septic systems may corrode, clog or overburden the system. Burning may distribute the hazardous material over a larger area.

In absence of regulations, and with domestic hazardous wastes likely to increase in tandem with population, it is important that their volume and composition is monitored carefully.

Analysis and interpretation

By identifying the quantity and composition of domestic hazardous waste generated, it may be possible to set realistic municipal targets and develop strategies for hazardous waste management at the household level. The result of this would be the encouragement of recycling, re-use and hazardous waste minimisation.

Monitoring design and strategy

The annual quantity of each hazardous waste type (such as oils, oily water and grease trap waste) may be recorded as an annual total, and as a quantity per head of population per annum. This would enable the assessment of not only changes in total domestic hazardous wastes over time (which would be likely to increase due to population increases), but per capita waste generated.

Reporting scale

Data collected on waste type and quantity, month generated, treatment type provided and region generated, would be transferred monthly to a regional database.

This indicator would need to be monitored annually, with reporting carried out at the state/territory and national level, and at the capital (and large city) level.

Output

Data could be tabulated based on the reporting scale above.

Data sources

National Pollutant Inventory (NPI), State EPA's, Australian Bureau of Statistics, National Waste Database.

Links to other indicators

Linkages exist with Human Settlement Waste Indicator 10.7 (Quantity, composition and source of hazardous waste generated).

Indicator 10.9: Amount, characteristics and location of contaminated land

Description

This indicator identifies the amount, characteristics and location of contaminated land within Australia.

Contamination of land has mostly occurred due to poor chemical storage, waste containment and disposal practices. Through urban spread, land previously used for industrial and agricultural is now being used as residential land. Complex mixtures of contaminants occur (Moore and Tu, 1993b), and can be contaminated by the following methods: toxic chemical releases, oil and chemical spills, hazardous waste accidents through handling or transport, waste unaccounted for in disposal processes, nuclear waste as a product of fusion, fission, refinement, processing, permanent or temporary storing or testing of radioactive materials.

Rationale

Contaminated land is a serious human settlement and environmental issue. Land contamination can be defined as land where hazardous substances occur at concentrations which are likely to cause immediate or long term hazard to human health and the environment. Past indiscriminate dumping has not accounted for intergenerational equity when assessing the cost of losing the productive capacity or amenity of the dump site. Focus is changing from landfill sites as better planning and monitoring is implemented, to contaminated sites in inner-urban areas that are redeveloped from industrial to residential. Potential health impacts increase with time exposed to contaminants. A detailed inventory of contaminated land is currently not available in all states. Indicator 10.9, therefore, would help identify and monitor these sites within Australia and remove some of the gaps in this important data-base.

The most common beneficial use made of reclaimed contaminated land is that of creating open spaces for public use. If contaminated lands are to be put to alternative uses, and are likely to located in urban (and recreational) environments, then it is important that they are monitored carefully.

Analysis and interpretation

Indicator 10.9 will be useful in assessing the extent and effectiveness of waste management and clean-up programs. It will also have important implications for any changes to policy and management of contaminated land that may arise in the future (for example: the enforcement of minimum health standards before redevelopment can occur on contaminated land; and identifying responsibility for recovering the costs of clean-up or remediation). The monitoring of contaminated land sites will therefore be important for waste management.

This indicator will also monitor the extent to which waste minimisation is occurring. An increase in contaminated land (beyond that expected due to increases in population), means that waste minimisation policies and practices are ineffective. By identifying the characteristics of contaminated land, it will be possible to target appropriate waste generators.

Monitoring design and strategy

A range of monitoring designs and strategies exist. For site-specific contaminated land sites, methods such as groundwater monitoring of underground petrol storage tanks at service stations; periodic sampling and industrial site inspections and analysis of outputs and production processes may be required. Such monitoring would provide information on the source, type and amount of contaminants within human settlements and the natural environment.

Reporting scale

Data should be collected for the amount, characteristics (waste constituents), cause (landfill site, accidental spillage, industrial site, agricultural site);

location and size of contaminated land throughout Australia. This indicator would need to be monitored annually, with reporting carried out at the state/territory and national level.

Output

A detailed inventory would need to be produced of past and current landfill sites, accidental spillage sites, industrial, commercial and domestic sites. Data should be tabulated based on the reporting scale above.

Data sources

State EPA's, CEPA's contaminated site management framework

Links to other indicators

Linkages exist with Human Settlement Waste Indicator: 10.2 (Quantity and composition of domestic solid waste disposed to landfill), 10.4 (Quantity and composition of commercial and industrial solid waste generated), 10.6 (Quantity of sludge and biosolids reused), 10.7 (Quantity and composition of hazardous waste generated), 10.8 (Quantity and composition of domestic hazardous waste collected) and 10.9 (Amount, characteristic and location of contaminated land). In addition, links exist with Urban Design Indicator 3.2: Amount of land converted from non-urban to urban uses and; Housing Indicator 6.4: Dwellings constructed on greenfield sites.

Recommendations for Research

Towards higher level indicator-based models of the built environment and human settlements

In the context of the knowledge pyramid (Figure 5.1), the set of indicators as developed in this report represent a half-way house. Each step of the pyramid represents a value-added step, typically characterised by a higher-level conceptualisation of a particular domain area. Within SoE reporting, a P-S-R framework (with additives such as sustainability goals and sectoral representation) has encouraged cause-effect thinking between sets of indicators, albeit in a relatively low level fashion.

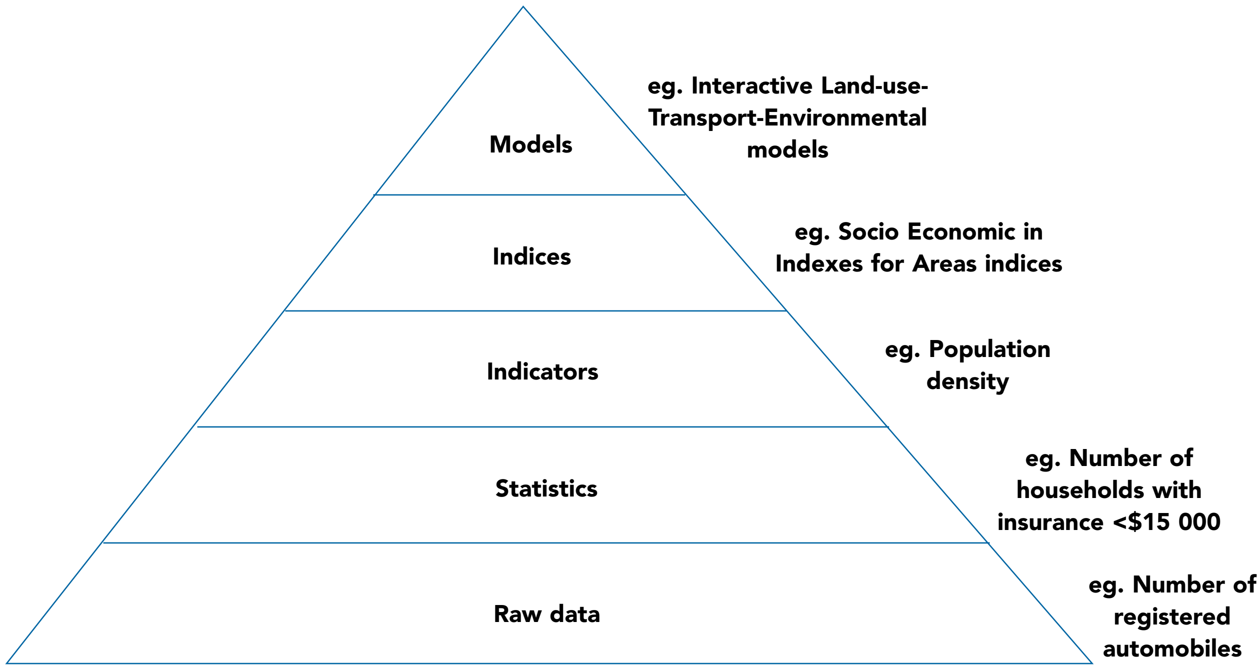


Figure 5.1: The knowledge pyramid.
Source: Adapted from *World Resources Institute (1996).*

Composite indicators. One logical progression is towards composite indicators (eg. SEIFA indices used in Newman *et al.*, 1996). The former has attracted its share of supporters who appreciate the gestalt effect that surround measures such as the Consumer Price Index (CPI), Gross Domestic Product (GDP), Genuine Progress Indicator (GPI), etc. There are, however, some detractors who find difficulty in identifying which variables in a composite index are specifically implicated in a positive or negative shift in the index's trajectory; i.e., which particular 'levers' to pull to try to re-direct the path of development for a particular aspect of the environment, economy or society.

Internet-html-systems dynamics model 'construction'. One of the criticisms that can be levelled at indicator reports in general is their production of a seemingly unconnected set of indicators as ends in themselves rather than stepping stones to a more fundamental understanding of a particular domain area.

There are a bundle of technologies that now provide a platform for making a step-function improvement in this regard. Key among them are the Web-based technologies that provide a capability of linking documents through hypertext. If we conceive of an indicator (*viz. Occupant Satisfaction With Commercial Indoor Environments*) as a single *document* where links to other indicators (documents) are also embedded—as in this study—then it will be possible to establish html (*hypertext macro language*) connections to all cross-specified indicators. This will facilitate the creation of a *model* comprising all inter-linked indicators triggered from a 'hit' on any initiating indicator.

The resultant model of linked indicators constitutes the precursor to possible *systems dynamics* modelling (Newton and Taylor, 1985) and scenario analysis. Clearly there are a range of competing models capable of application in their original modes or with modification to the issue of environmental performance of human settlements. Each have their relative strengths and weaknesses (eg. the Metabolism Model deals very well with flows—that is its great strength—but not well with endowments (good and bad), and is primarily designed for finite systems and thus does not deal well with impacts on surrounding areas, as does, for example, the Ecological Footprint Model; (Yencken, 1998). In the context of human settlements there is also the conceptual challenge involving the combination of biophysical and ecological indicators with those related to human activity and well-being.

Integrated multi-factor modelling of the built environment. SoE Reporting, as it currently stands, does not possess the capability of examining *what if?* types of questions or exploring *probable futures* or *alternative scenarios* (although goal-based indicators attempt to establish elements of a *desirable future* and possibly a target date for achieving particular outcomes).

To achieve outcomes in this area requires the development of *integrated models* which link key indicators located in different domain areas. *Integrated landuse-transport-environment models* (Hayashi and Roy, 1996) are illustrative of what is required. Such models give us the prospect of exploring how future settlements might be designed in order to minimise resource inputs and waste outputs while maximising livability. Perspectives are both analytical and prescriptive. The *analytical* focus is on the ways in which resource inputs of various kinds are 'processed' by human settlements to produce both livable outcomes for the inhabitants and waste outputs. Selected indicators must be able to capture the processes of transformation at each critical stage. However, there is also a *normative* imperative driving the urban metabolism approach—viz. the aim to increase the productivity of resource use (and efficiency of transformations) to increase livability outcomes and reduce both resource use and waste flows.

To illustrate what is possible, reference can be made to research undertaken for the Inquiry into Air Quality in Australia (Newton, 1997) which sought, among other things, to explore the nexus between *energy use* ('Resource Input'), *air quality* ('Waste Output') and *urban form* ('Settlement Dynamics'). Given that there are several archetypal urban forms—dispersed, compact, multi-nodal/edge, corridor—the key question is whether one or more are demonstrably superior in terms of the criteria air pollutants such as NO_x, SO_2, CO, VOCs, ozone and particles, as well as other key dimensions of human settlement sustainability, such as energy consumption and greenhouse gas emission.

The modelling indicated that there was significant scope to improve the environmental performance of cities and identified strategies that could be devised to re-shape cities for a more sustainable future.

An alternative perspective which also stresses the need for an integrated, multi-factor approach to the analysis of urban systems (and their sustainability) is what has recently been termed the multi-modal system of indicators (Lombardi, 1998; Brandon *et al.*, 1997). It recognises fifteen key dimensions (numerical, spatial, kinematics, physical, biological, sensitive, analytic, historical, lingual, social economic, aesthetic, juridicial (jurisdictions or judges), ethical and credal) each of which has associated with it, a set of urban factors (indicators). For example, for the numerical dimension it is possible to attach indicators related to population, resource endowment, etc.; for the spatial dimension – layout, shape, density, proximity, etc.

It provides a framework for accommodating both quantitative and qualitative indicators as well as a decision support matrix (15 x 15 with nested expansion for indicators) where relevant data and linkages can be explicitly 'mapped', where gaps and limitations in scientific knowledge become evident and where focus shifts from a set of indicators related to a description of the environment to one of urban (total system) sustainability.

Environment economics. A further area for attention, according to Bennett (1998) is the manner in which indicators address (or fail to address) the interaction of the physical environment with human society. At issue is how society allocates its scarce resources amongst all the competing uses/users. The environment comprises many of those resources, and it is scarce because of the competing demands people place on it. People want the environment to perform an ever-growing range of tasks, ranging from a waste sink to a place of beauty for rest and meditation. The environment is hence a valuable asset to society and one that must be carefully managed. The economics perspective is therefore relevant in the consideration of state of the environment indicators because of the role economic analysis can play in the determination of appropriate environmental management. It seeks to link physical science with public policy as it relates to the environment.

In this context, a primary weakness of 'condition' or 'state' indicators of the type listed in this report is that they focus almost entirely on the physical state of the environment. They do not address the relevance of that physical state to the community. The condition of the current state of the environment is judged by analysts ('experts') as to whether or not it is problematic. What is missing is a consideration of the values that the community has for the various environmental issues considered. They do not breach the gap between the physical science and the social sciences that encompass the policy debate. Policy is necessarily about trade-offs between competing interests. What is important, therefore, in the consideration of policy matters is the relative importance of the competing interests. This amounts to a comparison between the values that the community holds for the alternative options. The values that the community holds for the changes in the physical condition of the environment that are addressed by the indicators are not addressed by this report—although they have been assembled for selected environmental themes (see, for example, ANOP, 1993) elsewhere, albeit not as tradeoffs.

The focus on physical rather than value indicators has a further ramification. Questions regarding the environment are rarely uni-dimensional. Usually, people have to consider a trade-off between the environment and other values they want to pursue. For example, people may not like noise, but they are willing to put up with it because the noise is associated with a place of residence that is close to their place of work, shops or public transport. Similarly, congested roads may be regarded by people as a cost they are willing to bear in order to enjoy other benefits of an urban lifestyle.

Tradeoffs notwithstanding, there is, however, the need for environmental assessment to continually strive towards a point where scientifically well-grounded goals and standards are a common feature of each key environmental indicator.

The 'response' indicators are very much focused on interventionist response by governments. This focus is understandable, given that the indicators are designed to provide information to governments for the formulation of policy. However, as well as ignoring potential responses to environmental problems that may be inherent in the natural system, indicators also ignore the potential for 'self-correction' mechanisms within the community. Most notable of these are economic adjustments. For instance, the price mechanism will automatically reflect a growing scarcity of environmental assets, and this will trigger responses from both buyers and sellers. The problem with this type of response is that it is frequently confounded in the case of environmental assets because they are often 'unowned' resources. It is in such circumstance of 'market failure' that governments have a rationale for intervention. This does not necessarily mean that intervention must take place: intervention can create benefits as well as costs. Both sides of the intervention coin must be carefully considered. Yet indicators as currently constructed do not confront this issue. There is a need for response indicators to relate not just to the benefits of intervention (eg. to indicate the lack of green space in cities) but also to note the costs of the intervention (eg. what would be given up if more green space was created). If the overriding purpose of indicators is to provide better information for the development of policy, then without some focus on the goals of policy indicators are in danger of simply being an academic exercise without linkage to policy.

Domain areas

Urban design

> *'Finally, the verdict is in. Urban Form does matter. And not just for air quality. In relation to indicators such as energy consumption, self-containment of sub-urban regions and vehicle kilometres travelled, there appeared to be universal concurrence from the landuse-transport-environment modelling that to maintain a business-as-usual model of urban development (viz. relatively laissez faire, low density, dispersed) is to condemn the population and industry of that city to a sub-optimal living and working environment into the future. All three tiers of government must become more proactive in reshaping their cities for a more sustainable future'.* (Newton, 1997, p.163).

There are major research needs and opportunities with respect to better understanding of the relationships between urban systems and their environmental performance as monitored by the indicators recommended in this report. Key research questions to explore are:

- To what extent do urban centres differentiated by population size, growth and area, socio-economic and demographic profile, average residential density, local economic or industry structure, and other selected variables, perform differently with respect to key environmental outcomes, such as: air and water quality, energy usage, efficiency of waste disposal, quality of life, and so on? It is as data come to be assembled against the Indicator set prescribed in this report that we can begin to address these key questions.

- What conceptual and methodological approaches can be developed or improved to answer the question(s) posed above?

- How do Australian urban centres perform environmentally in relation to similar centres in other countries, and how does relative performance change over time?

Energy

To assist in monitoring the impact of programs directed at energy efficiency, greater efforts are required for data collection and analysis in relation to *end-use* than are presently the case (viz. all industry sectors plus domestic). Significantly greater effort is evident in Canada, for example the National Research Council (NRC).

Population is the basic activity indicator for domestic energy demand. However, structural characteristics of a population (such as age distribution of households, stage of life, household composition and income) affect residential energy utilisation even where energy prices and incomes are identical. Furthermore, whereas energy for cooking and water heating in the residential sector may be primarily a function of household size, there is a certain level of energy consumption that is independent of this parameter and dependent primarily on dwelling size. This is the case for space heating and lighting. Climatic conditions, materials used in construction and the degree of penetration of amenity or degree of comfort provided by service facilities such as central heating or air-conditioning affect the demand for energy.

Allocation of energy to various end-uses in the domestic sector is therefore not a straight forward exercise. It is generally based on statistical modelling, since sub-metering of equipment, while reliable, is very expensive. Occupant surveys of energy use, combined with data on total energy use available from utilities, and modelling of residential thermal performance in various climatic zones for typical constructions, provide a more reliable modelling tool for the allocation of energy to end-use in the sector. Improved accuracy is necessary to evaluate the impact of government measures for improved energy, (for example, the effect of mandatory ceiling insulation).

Similar issues arise in the commercial sector, where energy consumption is related to floor area and sectoral activity. Since measured end-use data are rare, the most reliable measure is probably building type with a statistical distribution of activity, construction and climatic zones combined to describe the allocation of end-use energy. Typically, 50% of energy use for cooking is consumed in restaurants. The balance is used in hotels, schools, hospitals, etc.

As for the domestic sector, energy use needs to be modelled and analysed to evaluate the impact of changes and measures. The link between the physical environment and its relevance to community perceptions and priorities is difficult to assess. This value judgment by the community is nevertheless essential to a meaningful policy debate. One can take expenditure on 'greener' energy-related products as a measure of these views vis-à-vis energy-related environmental issues. Typical products could be solar air and water heaters, and higher efficiency appliances as indicated by their star rating. The problem is confounded, of course, by the economics of alternatives, and requires analysis to discriminate between competing factors.

Materials

Material use is attracting attention in the sustainability debate, particularly since the final product used by the community exerts a load on production and, in turn, on the environment. Industry has focused efficiency on better ways of extracting and delivering these loads, and on disposal of unwanted residues at the lowest cost, with externalities often excluded. *Australia: State of the Environment 1996* addressed energy, water and waste in relation to sustainability, and mentioned briefly forest and non-forest building materials. Further research is needed on indicators to satisfy the need for:

- design/use of goods and services that require less virgin materials;

- promotion and support for material recovery (policies, strategies);

- promotion of material re-use, recycle, re-purchase and need for associated standards to encourage their subsequent use; and
- the extent to which these are observed in Australia to promote material sustainability.

Water

Many areas of the human settlement environment for water are important, and, consequently, identifying such a small number of key indicators is difficult. As these are the first national indicators to be established in such a detailed and comprehensive form, it was necessary to understand, at least from the perspective of water management, the state of and pressures on our environment. These include issues of water supply and demand, wastewater disposal and treatment.

When water resource managers, decision-makers and the community have a better understanding of the state of the environment, and the pressures unfolding from current human settlement practices, our indicators may need to be modified. One objective for the future would be to replace the condition and pressure indicators (which dominate here), with a majority of response indicators that reflect more detailed information on wastewater re-use implementation, stormwater quality control and land management practices that conform to water quality guidelines and environmental needs.

The extent to which regularly recorded data are available on water quality, extraction and consumption is a major limiting factor to the 'survival' and accuracy of these water indicators over time. To overcome this problem, land managers, water utilities and communities must be made accountable for the impacts of human settlement practices on the environment, and be required to not only monitor environmental impacts (such as water quality at stormwater discharge sites, BOD concentrations at wastewater outfall sites, etc.) but regularly record this information on a *public* registry.

In line with these recommendations, there should also be greater emphasis placed on community awareness indicators than currently exists across all indicator sets, this one included.

Finally, as urban water indicators may also impact on 'estuaries and the sea' and 'inland waters', defining key indicators may lead to considerable overlap and/or omissions between the other key indicator areas. *Wastewater treatment levels,* for example, has been identified as a key indicator within the 'inland waters' chapter. However, wastewater treatment levels will also significantly impact on ocean environments (for example, in 1996, discharge of treated wastewater from the Eastern Treatment Plant in Melbourne accounted for 99.5 percent of total wastewater treated at this site), and are a direct result of human settlement practices. The separation of water issues into three Chapters (defined above) means that some indicators will have to be repeated unnecessarily (in order to account for impacts on ocean, inland *and* groundwater areas; and impacts from both nature and human settlements), while other key issues will be overlooked (such as impacts on groundwater due to non-human practices).

Transport and accessibility

A number of the indicators for the Transport and Accessibility domain rely on the availability of comparable data from household travel surveys from across Australian cities. Presently, continuous travel surveys are being conducted in Melbourne (since 1993) and Sydney (since 1997), while Brisbane is also considering the adoption of a continuous travel survey program from 1998 onwards. Other cities have recently conducted periodic travel surveys, such as Brisbane (1992) and Perth (1996), while the remainder of the capital cities have conducted periodic travel surveys which are now becoming dated. A major problem with these surveys, however, is that most of them have used different survey techniques and adopted different definitions and coding conventions. The only truly national travel survey of Australian Cities was in 1985-86, when the Federal Office for Road Safety (FORS) sponsored the conduct of a travel survey in 30 cities of Australia, including all capital cities. Unfortunately, that survey has not been widely used because the origins and destinations of the trips recorded in that survey were not geographically coded. Nonetheless, limited analyses of the FORS data by the Transport Research Centre has demonstrated its value in making comparisons of travel and activity patterns between Australian cities. A key area for further work in monitoring environmental conditions in the transport domain is the conduct of a national survey of travel and activity patterns using a common methodology in all major Australian cities.

Many of the indicators rely on the readily availability of GIS descriptions of the transport and land-use networks in Australian cities. As a complement to the national survey of travel and activity patterns described above, the development of comprehensive GIS descriptions of transport and land-use networks would be invaluable in the calculation of a wide range of transport indicators.

Apart from the development of the two key databases described above, there are a number of specific research directions in the transport indicators area:

- The calculation of perceived residential and daytime densities should be expanded to all cities, with a particular emphasis on identifying what residents perceive as their 'local area' within which they make a mental calculation of the density at which they live or work.
- The estimation of link and route travel speeds from household travel surveys is a promising development which enables the maximum information to be extracted from the data, and which obviates the need for expensive and limited traffic surveys of travel speeds to obtain measures of transport system performance.
- The concept of travel time budgets should be explored more comprehensively for all Australian cities to see whether there is an underlying consistency in the time resource devoted to travel. If so, the implications of this for transport and land-use planning need to be thoroughly explored.
- Data on travel exposure need to be related to accident data to calculate measures of accident risk, and hence identify those in the population who are most at risk of injury or death per unit of exposure.
- Comprehensive studies of transport energy consumption, including the 'grey energy' involved in the production of vehicles and infrastructure, need to be undertaken, and the results related to transport system output to get measures of energy consumption per unit of transport output.
- Metropolitan-wide estimates of the costs of congestion should be developed for all cities, using data from recent household travel surveys and employing GIS analysis methods.

Given the development of comprehensive GIS databases on the location of facilities in urban areas and on the connecting transport networks, an immediate application for these databases is in the calculation of *accessibility* to these facilities by various means of transport (especially private car vs public transport) from different regions in the urban area. These accessibility measures could then be linked to demographic profiles for these regions to investigate the equity implications of accessibility to a range of facilities. The measures of accessibility could also be related to actual travel patterns (obtained from the National Household Travel Survey) to determine the effect that changes in accessibility (due to changes in land-use arrangements or transport services) might have on travel patterns and the associated environmental consequences.

Population

Most static population figures are already collected in some detail down to very small areas. Population movement and visitor figures are available, but normally at statistical local area (SLA) level or above. Inter-censal estimates of migration and household formation are undertaken via forecasting studies in some jurisdictions. These were formerly undertaken by the Indicative Planning Council for the Housing Industry but have now been abandoned. Visitors figures emerge from regular ABS surveys and other State or local initiatives, but do not go down to individual settlement levels. There is a need to re-assess the process of data collection on population movement, household formation and visitors to ensure that the most important figures are readily available as required, and to resume forecasting activities in these areas.

GIS techniques can be employed to provide population profiles for specified 'environments' (see Hamilton and Cocks, 1996), thereby providing a basis for examining relativities in environmental impact of population change in different settings (eg. major urban, coastal, inland town, etc.).

Unemployment data are available at small area level, but poverty indices are normally only calculated at capital city/rest of State level. These measures of inequality could be examined at the urban hierarchy level using data held by the Department of Social Security (see Birrell *et al.*, 1995). More work on the effects of poverty and unemployment on health and environmental conditions also needs to be carried out. This linkage is well established in developing countries but the effects on the physical environment in industrial societies warrant closer examination.

Housing

There have been a number of major national surveys on housing conditions and occupancy conducted at regular intervals, but results are rarely available from these at a geographical scale below the capital city/rest of State level. Typical analyses relate to rural-urban dichotomies.

Relatively little data have been available, until recently, on housing conditions and the quality of the stock. While this has been remedied in part by a recent (1994) survey, one problem is the lack of a workable definition of inadequate housing. This could be the subject of research.

House price data are available at a detailed level in some States, through Valuer-General data, but not in others. ABS publishes house price indices for capital cities, but data for non-metropolitan areas are scarce. Real estate indices of house prices are primarily at capital city level.

Average housing size in square metres is only available for new stock. As this is a major measure of consumption which has varied a good deal over time, this needs to be remedied. Data on land and average block size are also not readily available. Information on dwellings constructed on greenfield sites is also not available, and might have to be constructed from municipal data.

Over several years, CSIRO and others have investigated energy embodied in housing constructed of different materials. The trade-off between energy used in construction and energy in operation has not been studied in detail, and this remains an important area of study in the context of energy efficiency and greenhouse gas emissions. Further work on energy efficiency through the star rating system also needs to be done to ensure the reliability and comparability of State rating systems, and to extend the concept to existing dwellings and to commercial buildings.

Indoor air quality

Few data relevant to indoor air quality indicators are presently being collected. A few one-off studies of air infiltration rate have been carried out. There is no routine monitoring of ventilation rates in commercial buildings. Emissions of nitrogen dioxide and formaldehyde from some building materials are measured, but not systematically or by standard tests. One-off studies of nitrogen dioxide and radon concentrations have been carried out, but there is no systematic monitoring of any of the suggested state indicators.

It is unclear at present where official (ie, government) responsibility for monitoring indoor air quality lies. Some aspects may be within the purview of health departments, especially where occupational health issues are involved. Others may be a matter for environment agencies. The lack of clearly defined responsibility for monitoring and setting standards for indoor air quality may be a factor contributing to the lack of data in this area.

Further research is needed to gather information and understanding of indoor air quality in relation to several of the indicators. This research need not delay the application of the indicators but will support their refinement and their interpretation.

There is a lack of systematic investigation to date into occupant satisfaction with commercial indoor environments. Many of the indicators require knowledge of physical characteristics of the Australian building stock, which is currently unavailable. Development and utilisation of this knowledge is a pre-requisite before planning and application of the indicators can occur. Indicator 7.1 recommends the application of a UK Royal Society of Health questionnaire, so that comparison with international findings is possible. A preliminary pilot survey of this questionnaire is essential to gauge its suitability to Australian populations (in terms of cultural and social differences in responses). Indicator 7.9 considers all unflued gas heaters as a single entity, even though current products are likely to be low–NO_x emission heaters; research needs to clearly establish the impact of the latter on indoor air pollutant levels in residences and schools before the indicator is modified to reflect this situation.

Indicator 7.10 is based on the finding of high formaldehyde levels in mobile buildings in surveys conducted over the last 5 years. Manufacturers have reduced formaldehyde emissions from reconstituted wood products over this period, but no data exist by which to assess the impact of this on formaldehyde exposure in mobile buildings.

Indicator 7.11 is based on the understanding that house dust mite allergen levels are highest in coastal climates of Australia and virtually zero in inland climates. The rate at which allergen levels decline with distance from the coast (particularly on the eastern seaboard) is unknown, but needs better understanding for specification and interpretation of the Indicator.

Indicator 7.13 requires the development of standard procedures by which VOC emission properties of building products can be measured and classified. Such development is taking or has taken place in many developed countries and Australia needs to catch up on this issue.

Environmental health

Any strategy to develop environmental health indicators (EHIs) needs to consider several issues:

Toxic dose/personal exposure. Monitoring of air quality is largely motivated by concerns over the effects on human health of exposure to pollutants. However, there are no established methods available to assess the total overall exposure of individuals or populations to various pollutants. Neither are there methods to assess the synergistic effects of various levels of exposure to several different pollutants. Developing such methods should be a priority for further research. It is especially important to find ways of measuring and integrating exposure to indoor and outdoor air pollutants.

Causality and environmental health. It is difficult to draw direct links between environmental influences on health and actual health outcomes. Further research to clarify these relationships and develop better tools for quantifying them would be useful. In particular, a better understanding of these links would enable more indicators of the actual state of human health to be included in the set of indicators of environmental health.

Stage of life effects. Environmental conditions have varying effects on the health of human populations in different stages of life. Even for chronic conditions, the degree of severity varies with age. An attempt has been made to select indicators balanced across the three major life stages. For health conditions spanning across life, no attempt has been made here to design chronology-specific indicators. However, it is expected that future SoE reporting will provide disaggregated information in various age brackets as required.

Appropriate model. The P-S-R model, proposed by the OECD (1993), has several limitations when applied to environmental health. The model does not readily accommodate the consequential aspect of environmental change for human health. Modifications to this model have been proposed to help guide the development of EHIs (Kjellstrom and Corvalan, 1995), but fall short of providing a matrix which can be used for the generation of potential EHIs. The revised P-S-R framework, called *driving forces-pressure-state-effects-actions* or DPSEA (Kjellstrom and Corvalan 1995), recognises *effects* as a separate component. This has consequences for the type of response (organised or adapting) that may occur and its objectives. While the organised response may be aimed at improving the health of the population or the state of the environment, the adapting response is likely to be more passive. The overall response will also include *actions* to identify infrastructure needs, such as legislative and regulatory frameworks, workforce and workforce development, and *information systems.*

Data availability. Finally, there are issues of data availability. Small area analysis of health-related information, at a statistical local area (SLA) or a local government area (LGA) level, is feasible for only a small number of indicators. Time-series information on several of the key EHIs is limited. While reliable mortality data are available at State/Territory, Local Government Area (LGA) and Statistical Local Area (SLA) levels, the quality and level of identification for various population groups is indeterminate. Several annual or quinquennial data points are now available from hospital admissions and Medicare payments data, and through National Health Surveys. However, time series information for many of the indicators is limited in scope and content, and may require a concerted effort for further improvement.

Noise

Since industrial deafness is the fastest growing occupational disease, it is important to determine the reliability of relevant indicators and to establish robust data collection and analysis processes. In particular, it is necessary to determine the industries most likely to be affected, the noise sources and the corresponding noise levels. An extension of this is concerned with establishing robust data collection and analysis appropriate to noise injuries indicators and compensable claims.

Air traffic noise is not uniform across all airports in Australia. It is necessary to determine with confidence the most appropriate measure of traffic density, and other variables which impact on air traffic noise, (size of aircraft in any one airport, distance to settlements, number of landings).

Air traffic noise: determination of most appropriate measurement of air traffic density and the relevant variables (size of aircraft, distance, number of landings).

The link between the physical state of the environment and its relevance to community views needs further assessment for different sources of noise in the light of changing tolerances with time and various tradeoffs (e.g. convenience of being close to work or transport versus loss of property value and environmental amenity in a noisy environment). There are many tradeoff positions to be considered and the mechanisms of assessment are not clear.

Waste

Target setting and monitoring at the waste output end of materials management system will not provide solutions to waste management. A comprehensive materials information system with a life cycle assessment and including the combination of raw material, energy used and emissions produced will make it possible for producers to incorporate design improvements in existing processes and to compare options for new processes and products (AWD 1993).

Interpretation of trends has some inherent difficulties that need to be considered, such as reduced waste associated with an economic recession; incineration to reduce landfill with and without energy recovery; recycling activities that consume more energy than is recovered; waste reduction per household by increasing people per household.

It should also be emphasised that in many cases, prevention may be a desirable option, particularly when remediation is prohibitively expensive, and may take decades to achieve.

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Appendix 1: List of proto indicators

What follows are a set of proto-indicators, selected from an extensive mining of published reports related to environmental indicators. They constituted a basis for 20 May 1997 Workshop discussions in proceeding towards a definition of Key Indicators.

Indicator	C	P	R
Energy and resources			
Cost recovery for electricity	Yes	Yes	Yes
Electricity price	Yes	Yes	Yes
Electricity primary source - grid /local (coal, hydro, etc.)	Yes	Yes	No
Line losses	No	Yes	No
Electric connections	Yes	No	No
Electric capacity to load ratio	Yes	No	No
Energy price - per source	Yes	Yes	Yes
Industrial/transport/domestic energy consumption/Gross Domestic Product	Yes	Yes	No
Heat generated per hectare of urban space	Yes	Yes	No
Waste heat generated per hectare of urban space	No	Yes	No
Source of energy (production by type of plant/source)	No	Yes	No
Renewable energy production	No	Yes	No
Household energy consumption, by source and purpose	No	Yes	No
Attitudes regarding household appliances	No	Yes	No
Energy use for heating and cooling	No	Yes	No
Energy use - domestic, industrial, commercial	No	Yes	No
Attitudes regarding energy sources and use	No	Yes	No
Waste light generated per person affected by above determined livability standard	No	Yes	No
"Energy intensity (production/energy usage) or reciprocal"	No	Yes	No
Attitudes regarding energy conservation measures	No	Yes	No
Consumption of forest products (including firewood)	Yes	Yes	No
Resource usage (wood, metals)	Yes	Yes	No
Non-forest building materials usage (bricks, steel, aluminium)	No	Yes	No

Indicator	C	P	R
Consumption of imported oil	No	Yes	No
Imported forest products consumption	No	Yes	No
Fuelwood usage	No	Yes	No
Ecological footprint (area necessary to support population -food and energy biomass)	No	No	Yes
Water			
Species at risk - percent of aquatic and wetland species currently at risk of extinction	Yes	Yes	No
Wetland acreage loss rate	No	Yes	No
Water bodies that can support safe shellfish and fish consumption	Yes	No	Yes
Water bodies that can support safe recreation (%)	Yes	No	Yes
Water bodies that can support healthy aquatic community (%)	Yes	No	Yes
Water quality indices	Yes	No	No
Underground storage tanks	Yes	Yes	Yes
Sewage treatment (number and capacity of plants by level of treatment)	No	Yes	Yes
Sewage disposed to oceans, inland water, land, and re-used.	No	Yes	Yes
Toilet disposal systems (sewerage, septic treatment, neither).	No	Yes	Yes
Sewage disposed to ocean/river by treatment level	No	Yes	Yes
Sewage treated at least to secondary level	No	Yes	Yes
Sewage sludge generated	No	Yes	No
Public toilets	Yes	No	Yes
Biological Oxygen Demand (BOD) removed from sewage	No	No	Yes
Expenditure on sewage collection, treatment and disposal	No	No	Yes
Cost recovery for water, sewerage	Yes	Yes	Yes
Cost to income ratios (expenditure on water, sewerage)	Yes	Yes	No
Infrastructure expenditure per capita (all sources)	Yes	No	Yes
Household connection levels (to piped water, sewerage)	Yes	No	No
Drainage water quality, volume and re-use for each drainage scheme	Yes	Yes	Yes
Discharges by industry (oil, pulp-paper)	Yes	Yes	No

Indicator	C	P	R
Treated wastewater to: primary, secondary, tertiary, no treatment levels.	No	Yes	Yes
Discharges to coastal waters Total suspended solids (TSS)/BOD)	No	Yes	No
TSS discharged to coastal and fresh waterbodies	No	Yes	No
Number of days per year beaches or rivers above World Health Organization levels for sewage pathogens	No	Yes	No
Dwellings not connected to network sewerage systems	No	Yes	No
Stormwater, grey water and black water re-used (%)	No	No	Yes
Re-use water consumption levels by sector (household, industry, manufacturing, agriculture, mining, other)	No	No	Yes
Investment in improving and repairing stormwater infrastructure	No	No	Yes
Use of bottled water or filters	Yes	Yes	Yes
River water quality - percent of groundwater resources classified as good, fair, bad	Yes	Yes	Yes
Cost of wastewater treatment	Yes	Yes	Yes
Groundwater quality - percent of groundwater resources classified as good, fair, bad	Yes	Yes	No
Municipal discharges to fresh water: BOD, TSS and phosphorus	Yes	Yes	No
Level of trihalomethanes in drinking water	Yes	Yes	No
Market share of phosphate-free detergents	No	Yes	Yes
Urban surface water testing	No	Yes	Yes
Amounts of recognised pollutants to water (total volume and per capita)	No	Yes	No
Faecal coliform bacteria in urban surface water	No	Yes	No
Heavy metal contamination of water	No	Yes	No
Bathing water quality breaches: days/yr beaches or rivers are above Australian Water Quality or WHO levels for sewage pathogens	No	Yes	No
BOD discharged to coastal and fresh waterbodies	No	Yes	No
Community drinking water systems violating WHO health-based requirements	No	Yes	No
Drinking water quality violations - persons potentially affected	Yes	No	No
Bathing water quality (breaches)	Yes	No	No

Indicator	C	P	R
Water quality - domestic, recreational and industrial	Yes	No	No
Faecal coliform bacteria in urban surface water	Yes	No	No
Wetland water quality/water levels	Yes	No	No
Ground/surface water quality	Yes	No	No
Concentrations of Pollutants in water (phosphorus, nitrogen, heavy metals, pesticides)	Yes	No	No
Expenditure on water resources protection and conservation	No	No	Yes
Extent of drinking water testing	No	No	Yes
Number and capacity of plants by level of treatment (primary, secondary, tertiary, nil)	No	No	Yes
Drinking water testing	No	No	Yes
Water price/000 litres	Yes	Yes	Yes
Lowering of groundwater table	Yes	Yes	No
Ground water dependence (percent supply)	Yes	Yes	No
Water consumption per person (domestic)	Yes	Yes	No
Water use by sector: residential, commercial, industrial, losses.	Yes	Yes	No
Residential water consumption under a fixed versus flexible water pricing regime (volume and cost).	No	Yes	Yes
Improved public attitudes to water conservation: Number of councils involved in water conservation education and advertising.	No	Yes	Yes
Water withdrawal rate by key economic sectors (Municipal, manufacturing, power, mining, agriculture)	No	Yes	No
Water losses from supply	No	Yes	No
Frequency, duration and extent of water shortages	No	Yes	No
Industrial water consumption per unit of GDP output	No	Yes	No
Households recording excess water consumption - (percent of households; volume of water; and cost of excess water)	No	Yes	No
Groundwater reserves where licensed abstractions exceeds effective rainfall	No	Yes	No
Number of days/yr water restrictions imposed within municipality	No	Yes	No
Point and non-point source loadings to surface and ground water resources	No	Yes	No

Indicator	C	P	R
Water usage by water body (surface/groundwater) and by sector (household, agriculture, industry, manufacturing, mining, recreation, government, other)	No	Yes	No
Attitudes regarding water sources and use	No	Yes	No
Cost of water abstraction, treatment and distribution	No	No	Yes
Rates of water recycling by sector	No	No	Yes
Proportion of settlements/population served by treated water supply	No	No	Yes
Design			
Embodied energy in building materials	Yes	Yes	No
Plot ratio	No	Yes	Yes
Building height	No	Yes	Yes
Housing on fragile land	Yes	Yes	No
Insured property loss - by category (fire, flood, typhoon, earthquake)	Yes	Yes	No
Storm surge threat (dwellings, commerce)	Yes	Yes	No
Cyclone hazard (dwellings, commerce)	Yes	Yes	No
Propensity to flood (dwellings, commerce)	Yes	Yes	No
Bushfire threat (dwellings, commerce)	Yes	Yes	No
Housing destroyed	Yes	No	No
Disaster mortality	Yes	No	No
Expenditure on disaster mitigation	No	No	Yes
Economic growth (urban/rural)	No	Yes	No
Urban green space	Yes	Yes	Yes
Percentage of population concerned about environment (by age and sex)	No	Yes	No
Nature of environmental concern (by age and sex)	No	Yes	No
List of endangered fauna and flora in remnant bushland areas	No	Yes	No
Settlement area of high landscape value	Yes	No	No
Remnant vegetation	Yes	No	No
Access to green space	Yes	No	No
Green space, parkland or open space	Yes	No	No

Indicator	C	P	R
Urban forestry/tree planting programs	No	No	Yes
Tourism	No	Yes	No
Home based workers	Yes	No	Yes
Index of industrial diversity	Yes	No	No
Disadvantages (Disadvantage index by Local Government Area (LGA)	Yes	No	No
Land rezoning time	Yes	Yes	No
Development time	Yes	Yes	No
Per head consumption of urban land	Yes	Yes	No
Area rezoned for residential use	Yes	Yes	No
Planning permission land cost multiplier	Yes	Yes	No
Change from rural to urban Collector's District (CDs)	No	Yes	No
Rural to urban land conversion (CDs)	No	Yes	No
Land development cost multiplier	Yes	No	Yes
Land development controls	No	No	Yes
Impervious surfaces	Yes	Yes	No
Mixed use areas	Yes	No	Yes
Percentages of medium and high density developments	Yes	No	Yes
Quality urban design (see Gehl, 1994a,b; Prime Minister's Urban Design Task Force, 1994)	Yes	No	Yes
Land use (residential, commercial, industrial, recreational)	Yes	No	No
Mix of office/retail/residential	Yes	No	No
Minimum lot size	Yes	No	No
Land availability	Yes	No	No
Presence of regulatory controls (checklist)	No	Yes	Yes
Code violations (planning or building)	No	Yes	No
Green metro index	Yes	No	No
Local government revenue per person (response capability)	No	No	Yes
Expenditure on environmental management by category	No	No	Yes

Indicator	C	P	R
Planning and building code violations	No	Yes	No
Quality urban design (see Gehl, 1994a, b; PrimeMinister's Urban Design Task Force, 1994)	No	No	Yes
Personal safety (assault, burglaries)	Yes	No	No
Settlement area of high landscape value	Yes	No	No
Heritage and cultural assets list	Yes	No	No
% of population afraid to walk at night	Yes	Yes	No
Fatal industrial accidents	Yes	No	No
Spatial concentration of poverty	Yes	Yes	Yes
Residential density	Yes	Yes	No
Land price gradient	Yes	Yes	No
Mean distance of population and employment from centre	Yes	No	No
Transport and Access			
Commuting intensity (Number of commuters in and out of conurbation)	Yes	Yes	Yes
Access to transit (people within walking distance of a transit stop)	Yes	No	No
Access to other facilities (libraries, child care, recreation, neighbourhood houses or orgs)	Yes	No	No
Access to employment	Yes	No	No
Access to supermarkets	Yes	No	No
Access to emergency services (police, fire, ambulance)	Yes	No	No
Number and kind of airports	Yes	No	No
Airport activity/trends (passengers/flights)	Yes	No	No
Bicycle ownership	Yes	No	No
Cycle path construction and maintenance	No	No	Yes
Fuel pricing and taxing	Yes	Yes	Yes
Transport household budget share	Yes	Yes	Yes
Cost per passenger km	Yes	Yes	Yes
Expenditure on transport infrastructure by mode	Yes	Yes	Yes
Indirect subsidies/relative taxation by mode	No	Yes	Yes

Indicator	C	P	R
Expenditure on transport (Government expenditure on transport (road, water, rail, other))	No	Yes	Yes
Congestion costs	No	Yes	Yes
Transport fuel consumption (petrol, diesel, electric, liquid petroleum gas per person, per using vehicle or per passenger)	No	Yes	No
Freight movement (goods moved in and out of city by mode)	Yes	Yes	Yes
Transport land use (land use for transport as % of total urban area)	Yes	Yes	No
Cost recovery from fares	Yes	Yes	Yes
Mass transit passenger miles	Yes	Yes	No
Railways (km)	Yes	No	Yes
Public and mass transport seats	Yes	No	No
Bus times, stops and strategies	No	No	Yes
Commuting distance/time/speed, by mode	Yes	Yes	Yes
Modal split by trip purpose by area (car/mass/walking or cycling)	Yes	Yes	Yes
Vehicle stocks	Yes	No	No
Travel time to work (or other destinations)	Yes	No	No
Parking space provision (sq m)	Yes	No	Yes
Parking strategies (e.g. costs, limits)	No	No	Yes
Fuel efficiency of new cars/existing fleet	Yes	Yes	Yes
Traffic volumes on major roads	Yes	Yes	No
Vehicles failing emission standards	Yes	Yes	No
Driving licence holders by age and sex	Yes	Yes	No
Characteristics of road vehicle stock (road vehicle stock by type and age)	Yes	Yes	No
Parking supply and taxing, CBD	No	Yes	Yes
Contribution of motor vehicles to urban air pollution	No	Yes	No
Traffic volume (vehicle km)	No	Yes	No
Service stations per 100 sq km	No	Yes	No
Automobile fuel consumption	No	Yes	No
Road traffic volume (number of vehicles on main routes	No	Yes	No

Indicator	C	P	R
Parking availability at work	No	Yes	No
Freeway, access controlled roads (km)	Yes	No	No
Automobile ownership (Passenger/Commercial)	Yes	No	No
Road density (km/km2)	Yes	No	No
Road congestion (length of road in excess of 80% rated capacity, peak hour)	Yes	No	No
Length of road per vehicle or vehicles/km	No	No	Yes
Number/cost of accidents	Yes	Yes	No
Road traffic fatalities	Yes	Yes	No
Transport fatalities	Yes	Yes	No
Pedestrians killed	Yes	Yes	No
Pedestrian friendly streets	No	No	Yes
Traffic calming (% suburban streets)	No	No	Yes
Telecommunications activity/telecommuting	Yes	No	Yes
Households connected to telephone (or telephone lines/pop)	Yes	No	Yes
Cost recovery for telephone	Yes	No	Yes
Population			
Rank size distribution of cities	No	Yes	No
Household type (i.e single person, couple, single parent etc)	Yes	No	No
Average household size	Yes	No	No
Age of population	Yes	No	No
Regional distribution of education and training	Yes	No	Yes
Local employment availability	Yes	No	No
Long term unemployed by sex and age	Yes	No	No
Labour market participation	Yes	No	No
Household formation rate	No	Yes	No
Households in poverty (by family type, tenure)	No	Yes	No
Children in poverty	No	Yes	No

Indicator	C	P	R
City population	No	Yes	No
Migration rates (international/internal)	No	Yes	No
Birth and death rates	No	Yes	No
Urbanisation	No	Yes	No
Coastal population change (total change by LGA/SLA)	No	Yes	No
Urban growth rate (capital/other cities).	No	Yes	No
Visitors' reasons for coming	Yes	Yes	Yes
Hotel accommodation (beds by number and occupancy rate by statistical division/LGA)	No	Yes	Yes
International tourism into Australia (+ business visits)	No	Yes	Yes
Visitor numbers (by length of stay by SD/LGA)	No	Yes	No
Visitors coming for environmental reasons	No	No	Yes
Housing			
House price to income ratio	Yes	No	No
Energy used for heating/cooling by type, per house	No	Yes	No
Floor area per person	Yes	No	No
Housing size (bedrooms per capita)	Yes	No	No
Homelessness	Yes	No	No
Dwelling type (detached house, medium density, etc)	Yes	Yes	No
Average age of dwellings	Yes	No	No
Housing units meeting warmth/ventilation standards	Yes	Yes	Yes
Energy efficiency ratings for housing	No	No	Yes
Renewable sources (eg solar hot water, heat exchange)	No	No	Yes
Energy efficiency of housing	No	No	No
Building materials used in new housing/embodied energy	No	Yes	No
% new houses constructed on greenfield sites	Yes	Yes	No
Average site area of new residential buildings	Yes	Yes	No
Ranges of lot size, all dwellings	Yes	Yes	No

Indicator	C	P	R
Vacant dwellings (in context of declining areas)	Yes	Yes	Yes
House production	Yes	Yes	Yes
Demolitions/conversions	Yes	Yes	Yes
Housing investment	Yes	Yes	Yes
Environmental Health			
Premature abortions	Yes	No	No
Infant mortality	Yes	No	No
Babies with low birth weight/very low birth weight	Yes	No	No
Maternal mortality	Yes	No	No
Births with inadequate care/teenage mothers/drug problems	Yes	No	No
Congenital abnormalities	Yes	No	No
Blood lead levels in children	Yes	No	No
Child mortality	Yes	No	No
Suicide	Yes	No	No
Death rate by social advantage/disadvantage (heart disease,, stroke, cancer, respiratory, digestive, infectious, injury)	Yes	No	No
Acute respiratory deaths	Yes	No	No
Life expectancy at birth	Yes	No	No
Age standardised mortality rate	Yes	No	No
Mortality - male/female, age (infectious, neoplasm's, circulatory, respiratory, injuries)	Yes	No	No
Incidence of skin cancer (Mortality rates and total number of deaths by melanoma of skin)	Yes	No	No
Indigenous and non-indigenous variations in health (Degree of difference between morbidity and mortality indicators for indigenous and non-indigenous community)	Yes	No	No
Diseases that are environmentally linked	Yes	No	No
Burden of disease (life-years lost for different diseases)	Yes	No	No
Long standing illness	Yes	No	No
Asthma hospitalisation rate, children	Yes	No	No

Indicator	C	P	R
Children with full immunisation	No	No	Yes
Mental health (commitments/treatment)	No	No	No
Level of toxins in food (National market survey data.)	Yes	Yes	No
Per head food consumption (Kcals and gms protein)	Yes	Yes	No
Food consumption (Per capita food consumption)	Yes	Yes	No
Contamination of food	No	Yes	No
Fats in diet	No	Yes	No
Food consumption (calories)	No	Yes	No
Level of toxins in food	No	Yes	No
People in care (infirm aged, disabled)	Yes	No	Yes
General Practioners, specialists/1000 population	Yes	No	Yes
Alternative health care	Yes	No	Yes
Healthy household audit	Yes	No	No
Access to health care	Yes	No	No
Workers compensation claims (amount)	Yes	No	Yes
Invalid pension	Yes	No	Yes
Sick days from work	Yes	No	No
Product spent on health	No	No	Yes
Use of hospital Casualty for non-emergency	Yes	No	No
Health care expenditure	No	No	Yes
Number of specialised facilities/instruments (eg. CAT)	No	No	Yes
Hospital beds per 1000 pop	No	No	Yes
Hospital admissions (by cause)	No	No	Yes
Exposure to risk from hazardous industries	No	Yes	No
Population sensitive to pollutants	Yes	Yes	No
Injury (hospital separations all; motor vehicle, drowning, falls, suicide, poisoning, burns, other) by age group)	Yes	No	No

Indicator	C	P	R
Accidental death (by external cause (motor vehicle, drowning, falls, suicide, poisoning, burns, other), by age group)	Yes	No	No
Indoor Air Quality			
Radon in indoor air	No	Yes	No
Particulates in indoor air	No	Yes	No
Exposure to indoor air (metropolitan travel)	No	Yes	No
Unflued gas heaters in residences and schools	No	Yes	No
People housed in mobile buildings	No	Yes	No
Thermal comfort in commercial buildings	Yes	Yes	Yes
Legionnaires' Disease incidence	Yes	Yes	No
Residences with high house dust mite allergen	No	Yes	No
Mechanical ventilation rate of commercial buildings	Yes	Yes	No
Asbestos products removed from workplaces	No	Yes	Yes
Air infiltration rates of new housing	No	Yes	Yes
Lead dust concentrations	No	Yes	No
Adult smokers with children	No	Yes	No
Occupant satisfaction with commercial indoor air quality	Yes	No	Yes
Production of low-Volatile Organic Compound emission building products	No	No	Yes
Commercial and recreational buildings with smoking prohibition	No	No	Yes
Noise			
Aircraft noise	No	Yes	No
Road/air traffic density	No	Yes	No
Noise in recreational/residential areas	No	Yes	No
Noise complaints (% domestic, industrial, transport other)	No	Yes	No
Industrial noise injury	No	Yes	No
Number of people affected by noise above World Health Organization ecommended limits	Yes	No	No
Population exposed to transport noise	Yes	No	No
Population severely affected by noise	Yes	No	No

Indicator	C	P	R
Dwellings exposed to noise from road, rail and aircraft activities	Yes	No	No
Cost of noise control	No	No	Yes
Waste			
Waste reduction indices (current and potential reduction)	No	No	Yes
Industrial waste per unit of product	No	Yes	No
Industrial solid waste recycled	No	No	Yes
Building and demolition waste recycled	No	No	Yes
Commercial and industrial liquid waste recovered	No	No	Yes
Hazardous waste stored by type	Yes	Yes	Yes
Domestic hazardous waste collected (%)	Yes	Yes	Yes
Hazardous waste generated/recovered/treated	Yes	Yes	Yes
Special and prescribed waste generated/recycled/to landfill	Yes	Yes	Yes
Contaminated sites (number, area) by type	Yes	Yes	No
Hazardous waste imported/exported or tonne/km moved	Yes	Yes	No
Noxious facilities	Yes	Yes	No
Heavy metal contamination (concentration)	Yes	Yes	No
Disposal methods for hazardous wastes	No	Yes	Yes
Recognised intractable wastes	No	Yes	No
Hazardous waste or toxic releases (acid/alkaline, heavy metals, Inorganics, Solvents, oils, Organics, Pesticides, PCBs, Contaminated soils, hospital wastes, ship wastes)	No	Yes	No
Lead emissions (tonnes per capita)	No	Yes	No
Lawn pesticide use	No	Yes	No
Pesticide contamination (incidence, type and degree of pesticide contamination)	Yes	No	No
Cost recovery (% solid waste cost from user charges)	Yes	Yes	Yes
Average cost of waste disposal	Yes	Yes	No
Litter - incidence, expenditure	No	Yes	No
Disposal methods for solid waste (landfill, recycling, incineration, composting)	Yes	Yes	Yes
Biodegradable waste	Yes	Yes	No

Indicator	C	P	R
Landfill capacity used per annum	Yes	Yes	No
Waste and recycled materials imported and exported (transported)	No	Yes	Yes
Proportion of industrial waste treated before disposal	No	Yes	Yes
Landfill space occupancy	No	Yes	Yes
Regular waste collection (and frequency)	No	Yes	Yes
Solid waste generated per person (by weight, volume)	No	Yes	No
Industrial waste (non-toxic, toxic)	No	Yes	No
Regulated waste (by broad category) produced per urban area	No	Yes	No
Garden/household waste to collection points	No	Yes	No
Use of "big bins""	No	Yes	No
Household waste composition	No	Yes	No
Waste incinerated (tonnes per capita)	No	Yes	No
Landfill volume received by waste type (tonnes per capita)	No	Yes	No
Scavenging at dumpsites	Yes	No	Yes
Urban household access to kerbside recycling collection	Yes	No	Yes
Number of disposal sites and transfer stations	Yes	No	Yes
Municipal expenditure on solid waste management (collection, transfer, street sweeping, incineration, composting, recycling)	No	No	Yes
Recycling rate (% glass, aluminium, paper, coal ash)	No	No	Yes
Landfill gas being tapped for energy	No	No	Yes
Waste recovered - recycling (domestic/industrial)	No	No	Yes

APPENDIX 2: REVIEW PROCESS FOR KEY INDICATORS

INDICATOR	CRITERIA FOR INDICATOR SELECTION							
	CPR	Metabolism	Sustainability	SOE Criteria*				
	CPR	• Resource Input • System Dynamics • Livability • WasteOutput	• Econ • Soc • Envir	Important	Feasible	Credible	Understand-able	Useful
ENERGY								
Total energy use	C	SD/RI	EC/EN	5	5	5	5	5
Energy use in industry	C	SD/RI	EC/EN	4-5	4-5	5	4	5
Energy use in transport	C	SD/RI	EC/EN	5	4	4	4	5
Domestic energy use	C	SD/RI	EC/EN	4	5	4	5	5
Commercial energy use	C	SD/RI	EC/EN	4	5	4	5	5
Expenditure on energy programs	R	SD	EC	5	3	3-4	4	4
Renewable energy	R	RI EN	5 5	5	5	5		
Cost of energy	C	RI EC	5 5	5	5	5		
WATER								
Proportion of settlements served by treated water	C	RI/L	EC	5	4	5	5	4
Municipal household water consumption	C	L	S	4	4	4	4	4
Total annual water usage by sector	P/C	RI/L	EC	5	3	4	4	5
Wastewater disposed to oceans, inland waters, land and re-used	P/R	WO	EN	5	3	4	5	5
Wastewater discharged by domestic, industrial and other	P	WO	EN	5	4	4	5	5
Population served by treated wastewater	R/P	RI/L	EC	5	4	5	5	5
Stormwater discharged to receiving environments	P	WO	EN	5	3	4	5	5
Contaminants in stormwater discharges	P	WO	EN	5	3	4	5	5
Stormwater recycled	P	WO	EN	5	4	5	5	5
Volume (& %) of wastewater re-used by type of application	R		EN	5	3	4	5	5
Residential water consumption under fixed vs flexible water prices	R	RI/L	EC	4	4	4	4	5

* The categories of criteria are provided on p.182 of this report. Rating: 1 = Low; 5 = high

Appendix 2 (cont.)

Investment in waste (storm) water technology as a percentage of total expenditure	R	SD	EC	5	3	3	4	4
Community drinking water violations	P	L	S/EN	5	4	4	4	4
URBAN DESIGN								
Stock of heritage and cultural assets	C/R	L	EN/S	4	5	3-4	4	4
Land converted from non-urban to urban use	P	R	EN	4	4-5	4	4	4
Public urban green space per capita	C/R	L/RI	EN/S	4-5	4	4	4-5	4
Residential density	P/C	SD/L	S	4-5	4	4	3-4	4-5
Medium and high density construction	C/R	SD	EN/EC	4-5	4	4	3	4
Index of industrial concentration	C	SD	EC	4	4	4	5	3-4
Index of mixed land use	C/R	SD/L	EC/RI	4	2-3	3	3	4
Home-based workers	C	SD/L	EC/EN	3-4	3-4	4	4	4
Physical assaults in public places	C/P	L	SD	4	4	4	4	4
House burglaries	C/P	L	S	4	4	4	4	4
Indices of:								
-socio-economic inequality	P	L	S	4-5	4	4	4	4-5
-socio-spatial segregation	P	L	S	4-5	4	4	4	4-5
POPULATION								
Population and household growth rate	P	I/SD	S/EN/EC	5	5	5	5	5
Households in poverty	C	L	EC/S/EN					
Unemployment rate	C	S/L	EC/S	4-5	3	4	3-4	5
Visitor numbers (by category, by reason)	P	I	EC/S/EN	4-5	4	4	4	4-5
HOUSING								
Floor area per person	C	L/SD	EC/S/EN	4	3-4	4	4-5	4
House price to income ratio	C	SD/L	EC/S	4	3-4	4	4-5	4
Housing on greenfield sites	P/R	SD/L	E/S/I	4-5	3-4	4	4	4-5
Lot size distribution	C/R	SD/L	EN/EC	4	3-4	4	4	4
Homelessness	C	L/S	S/EC	4-5	2	2	2	3-4
Building materials used / embodied energy	P	I	EN/EC	4-5	4	4	4	4-5
Operating energy efficiency	R	W/SD/L	EN/EC	4	3-4	4	3	5
New dwellings completed	P/C	SD/L	S/EC	4	4	4	5	5

Appendix 2 (cont.)

INDOOR AIR QUALITY								
Occupant satisfaction: commercial	C	L/SD	EN/EC	4	4-5	3	4	4
Mech. vent rate of commercial buildings	C	SD	EN	4-5	4	4-5	4-5	4-5
Air infiltration rate of new housing	C	SD	EN	3	2-3	4-5	4-5	2-3
Proportion of population sensitive to pollutants	C	SD	S	4	5	5	4	5
Proportion of adult smokers with children	P	L	S	5	5	4	3-4	5
Quantity of asbestos removed	P/R	SD	EN	2	4	3	3	2-3
No. of unflued gas heaters in resid/schools	C	SD	EN	5	4	4	4	4
No. of people in mobile buildings	P	SD/L	EN/S	4	4	4	4	4
Proportion of residences with high dust mite allergen	P/C	SD	EN	4-5	2-3	4	4	4
Incidence of legionnaires disease	C	SD	EN	4-5	5	5	5	5
Production of low VOC-emission building products	R	SD	EN/EC	4	2	3	3	4
Buildings without tobacco smoke (Comm/ Rec)	R	SD/L	EN/S	4	4	4	4	4
Thermal comfort (commercial buildings)	C	SD/L	EN/EC/S	4	4	4	4	4
NOISE								
Exposure to traffic noise	C	W	ENV	4	3	3	4	4-5
Exposure to aircraft noise	C	W	ENV	4	2	3-4	3-4	4-5
Exposure to industrial noise	C	W/SD	EC/EN	4	3-4	3-4	5	5
Cost of noise control	R	W	EC	4	3-4	3-4	4	4
Road traffic density	P	SD	EC/EN	4	3-4	3-4	4	4
Air traffic density	P	SD	EC/EN	4	3-4	3-4	4	4
Industrial noise injuries	C	SD	EC	5	4	5	5	5
WASTE								
Domestic solid waste generated	P	WO	EN	5	5	5	5	5
Domestic solid waste disposed to landfill	P	WO	EC/EN	5	5	5	5	4
Water recovered —recycling	R	SD/L/I	EC/EN	5	5	5	5	5
Commercial and industrial waste generated	P	WO	EC/EN	5	4-5	5	5	5
Energy recovered from waste	R	SD/RI	EC	5	3-4	5	4	4-5
Proportion of sludge and biosolids re-used	R	SD/RI	EC/EN	5	4-5	5	4	3-4
Hazardous waste generated	P	WO	EN	5	4-5	5	5	5
Domestic hazardous waste collected	R	WO	EC/EN	5	5	5	5	4-5
Contaminated land	P	WO	EN	5	3-4	5	4	4-5

Appendix 2 (cont.)

Categories of Criteria

The selection criteria for national environmental indicators is provided on page 8 of this report. For the purpose of this report, we have simplified these criteria by assembling them into the following five categories.

Important:

- Reflect a fundamental or highly valued aspect of the environment.
- Be either national in scope or applicable to regional environmental issues of national significance.
- Where possible and appropriate, facilitate community involvement.

Feasible:

- Be monitored regularly with relative ease.
- Be cost-effective.
- Contribute to the fulfilment of reporting obligations under international agreements.
- Where possible and appropriate, be consistent and comparable with other countries' and State and Territory indicators.

Credible:

- Be capable of being monitored to provide statistically verifiable and reproducible data that show trends over time and, preferably, apply to a broad range of environmental regions.
- Be scientifically credible.
- Where possible and appropriate, use existing commercial and managerial indicators.

Understandable:

- Be easy to understand.
- Have relevant to policy and management needs.

Useful:

- Serve as a robust indicator of environmental change.
- Provide an early warning of potential problems.
- Contribute to monitoring of progress towards implementing commitments in nationally significant environmental policies.

List of Acronyms

ABARE	Australian Bureau of Agriculture and Resource Economics
ABS	Australian Bureau of Statistics
AC	Asbestos Cement
ACIC	Australian Chemical Industry Council
ACM	Australian Chamber of Manufacturers
ACTA	Australian Chemical Trauma Alliance
ACTEW	Australian Capital Territory Electricity and Water
AIHW	Australian Institute of Health and Welfare
ALOS	Average length of stay
ANEF	Australian Noise Exposure Forecast
ANZECC	Australian and New Zealand Environment and Conservation Council
ANZSIC	Australian and New Zealand Standard Industrial Classification
ARMCANZ	Agricultural and Resource Management Council of Australia and New Zealand
ASH	Action on Smoking and Health
ASIC	Australian Standard Industrial Classification
AWRC	Australian Water Resources Council
BOD	Biological Oxygen Demand
CAA/FAC	Civil Aviation Authority/Federal Airports Corporation
CES	Commonwealth Employment Service
CCD	Census Collector's District
CSIRO	Commonwealth Scientific Industrial Research Organisation
CPI	Consumer Price Index
CPSU	Commonwealth Public Service Union
DEST	Department of the Environment, Sport and Territories (now Department of the Environment)
DPIE	Department of Primary Industries and Energy
DPSEA	Driving Forces-Pressure-State-Effects-Action
EEAP	Entreprise Energy Audit Programme
EHIs	Environmental Health Indicators
ETS	Environmental Tobacco Smoke
EPAs	Environment Protection Authorities
ESAA	Electricity Supply Association of Australia
FOI	Freedom of Information
FORS	Federal Office for Road Safety
GDP	Gross Domestic Product
GIS	Geographic Information Systems
GNP	Gross National Product
GP	General Practitioner
GPI	Genuine Progress Indicator
HSH	Department of Human Services and Health
ICD	International Classification of Diseases
IISD	International Institute for Sustainable Development
IRC	Industrial Relations Commission
IWGSDI	Inter--agency Working Group on Sustainable Development Indicators
JCB	Joint Coal Board
LG	Local Government
LGA	Local Government Area
MCS	Multiple chemical sensitivity
MRF	Materials Recovery Facility
MU	Major urban
NatHERS	The Nationwide Home Energy Rating Scheme
NHMRC	National Health and Medical Research Council
NPI	National Pollutant Inventory
NRC	National Research Council
NWMRS	National Waste Minimisation and Recycling Strategy
OECD	Organization for Economic Cooperation and Development
OH&S	Occupational Health and Safety
PET	Polyethylene terephthalate
QCB	Queensland Coal Board
REIA	The Real Estate Institute of Australia
RMIT	Royal Melbourne Institute of Technology
SD	Standard Deviation
SDI	Sustainable Development Indicators
SEDA	Sustainable Energy Development Authority
SLA	Statistical Local Area
SMR	Standardised Mortality Ratio
TRC	Transport Research Centre
TSS	Total Suspended Solids
UH	Urban Hierarchy
UNCHS	United Nations Centre for Human Settlements
UNEP	United Nations Environment Programme
URR	Urban, rural and remote
UV	Ultra-violet
VFT	Very fast train
VOCs	Volatile Organic Compounds
WBGT	Wet Bulb Globe Temperature Index
WHO	World Health Organisation

List of Environmental Indicator Reports

Environmental indicator reports for national state of the environment reporting are available in seven themes. An eighth report in the series examines community and local uses of environmental indicators. Bibliographic details are as follows:

Human Settlements

Newton P., J. Flood, M. Berry, K. Bhatia, S. Brown, A. Cabelli, J. Gomboso, J. Higgins, T. Richardson and V. Ritchie (1998) *Environmental indicators for national state of the environment reporting – Human Settlements,* Australia: State of the Environment (Environmental Indicator Reports), Department of the Environment, Canberra.

Biodiversity

Saunders D., C. Margules, & B. Hill (1998) *Environmental indicators for national state of the environment reporting – Biodiversity,* Australia: State of the Environment (Environmental Indicator Reports), Department of the Environment, Canberra.

The Atmosphere

Manton M. & J. Jasper (1998) *Environmental indicators for national state of the environment reporting – The Atmosphere,* Australia: State of the Environment (Environmental Indicator Reports), Department of the Environment, Canberra.

The Land

Hamblin A. (1998) *Environmental indicators for national state of the environment reporting – The Land,* Australia: State of the Environment (Environmental Indicator Reports), Department of the Environment, Canberra.

Inland Waters

Fairweather P. & G. Napier (1998) *Environmental indicators for national state of the environment reporting – Inland Waters,* Australia: State of the Environment (Environmental Indicator Reports), Department of the Environment, Canberra.

Estuaries and the Sea

Ward T., E. Butler, & B. Hill (1998) *Environmental indicators for national state of the environment reporting – Estuaries and the Sea,* Australia: State of the Environment (Environmental Indicator Reports), Department of the Environment, Canberra.

Natural and Cultural Heritage

Pearson M., D. Johnston, J. Lennon, I. McBryde, D. Marshall, D. Nash, & B. Wellington (1998) *Environmental indicators for national state of the environment reporting – Natural and Cultural Heritage,* Australia: State of the Environment (Environmental Indicator Reports), Department of the Environment, Canberra.

Local and Community Uses

Alexandra J., J Higgins & T. White (1998) *Environmental indicators for national state of the environment reporting – Local and Community Uses,* Australia: State of the Environment (Environmental Indicator Reports), Department of the Environment, Canberra.

SoE Reporting homepage:
http://www.erin.gov.au/environment/epcg/soe.html