
# 30/50

# THE TECHNOLOGICAL IMPLICATIONS OF AN AUSTRALIAN POPULATION OF 30 MILLION BY 2050

REPORT OF A STUDY FOR THE SCANLON FOUNDATION BY THE AUSTRALIAN ACADEMY OF TECHNOLOGICAL SCIENCES AND ENGINEERING (ATSE) 2007

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# Foreword

Over the past 30 years, the Australian Academy of Technological Sciences and Engineering (ATSE) has undertaken major assessments of Australian climate, water resources, energy, transport and most of the other factors that bear on the future population-carrying capacity of the continent, and several of our Fellows have led important national studies of Australian population futures.

The Academy was pleased, therefore, when, following discussions initiated by one of our Fellows, Dr Max Lay FTSE, in 2004, the Scanlon Foundation requested ATSE to undertake a study of the engineering, scientific and environmental issues associated with population growth in Australia. The Foundation's primary focus is a belief that the future prosperity of Australia, both economic and non-economic, will depend on the nation's ability to maintain social cohesion in our society – a society that will have even more cultural diversity than it has successfully accommodated historically. This focus is underpinned by a hypothesis "that a larger population is needed to support sustained economic growth in a rapidly ageing Australian society" and seeks to create and inform debate about Australia's population and its growth.

It was agreed that the Academy, in forming its advice to the Foundation, would draw on published and other available work, integrating it where appropriate and adding any critique that would place the work in context and emphasise its relevance to the ATSE study. The Academy established a Steering Committee for the study under the chairmanship of Dr Ian Duncan FTSE and overall management of the project was provided by successive ATSE Technical Directors, Professor Ian Rae FTSE and Professor Vaughan Beck FTSE, with major contributions from a number of other ATSE Fellows whose roles are acknowledged in the Acknowledgements on pages xiii and xiv.

I am pleased to present this report entitled *30/50 – THE TECHNOLOGICAL IMPLICATIONS OF AN AUSTRALIAN POPULATION OF 30 MILLION BY 2050* which marks the completion of the study and to acknowledge the support and collaboration of the Scanlon Foundation during its preparation.

The population debate in Australia is almost as old as European settlement. Towards the end of the 19th century, as the federation movement appeared certain of the success it achieved in 1901, the slogan Australia Unlimited summed up the feelings of those who felt that the Australian continent could sustain a large population. From time to time during the 20th century, the population debate re-emerged, often triggered by events or government policies that impacted, or could be held to impact, on sustainability, albeit the "sustainability" word came into vogue only late in the century. Governments approached the matter with caution, usually calling for studies of appropriate populations or development of a population policy, rather than setting targets for growth, stabilisation or reduction of the Australian population.

To provide a considered estimate of the growth of the Australian population, the Scanlon Foundation contracted the Australian Institute for Demographic Research (AIDR) at the Australian National University (ANU) to prepare a report on the magnitude and structure of such a population as it continues to expand. The AIDR paper (which is included in this report) contains a prediction of a total population of permanent and temporary residents for Australia in 2050 of 31.2 million. It is this population figure that forms the starting point for the Academy's study.

Previous studies have indicated that the growth of population in Australia would not be limited by resources. One recent study by the Academy[1] focused on "environmental constraints" to population growth in Australia. The investigation found that, while population pressures have undoubtedly caused significant environmental damage in the past and will continue to do so if not better managed, predictions of environmental disaster arising from population growth are ill-founded.

Bounded by the expectation that Australia's permanent and temporary population may grow to 31.2

[1] ATSE, *Population Futures*, Australian Academy of Technological Sciences and Engineering (ATSE), October 2000. (The paper is available at www.atse.org.au/index.php?sectionid=200 ).

million by 2050 – or approximately 30 million permanent residents (this is abbreviated to 30/50 and is used as shorthand for the project) – the present study considers the elements of climate variability and change, water, energy, transport, waste disposal, infrastructure and policy implications to meet future challenges. Most of the individual chapters in the report have been prepared by Fellows of the Academy while two chapters were prepared by specialist contributors from outside the Academy. The first was by two authors from AIDR, who wrote the chapter on population and settlement in Australia, and the second was by two authors from Insight Economics, who wrote the chapter on infrastructure.

There is a consistent theme that runs through most of the chapters of the report, which identifies that robust public policies are needed if environmental, economic and social shifts are to be accommodated in ways that solve problems, rather than create major new constraints on growth and on the nation's capacity to accommodate increased population.

The basic conclusion from the report is that Australia can support a population of some 30 million by the year 2050 but that there are some significant challenges that will need to be addressed if this is to be achieved. Whether government is focusing on cities, infrastructure, transport systems, climate change or responses to disasters, a prime challenge is to carry through strategic and integrated planning in a timely and non-bureaucratic way and to plan for and mobilise the necessary levels of investment.

I am pleased to commend the detailed findings of the ATSE study for consideration by all those with an interest in the future prosperity and social cohesion of Australian society.

**John W. Zillman AO FAA FTSE**

**President**

**Australian Academy of Technological Sciences and Engineering (ATSE)**

**November 2006**

# The Scanlon Foundation

The Scanlon Foundation believes that the future prosperity of Australia, underpinned by population growth, will depend on our ability to maintain social cohesion in a society with even more cultural diversity than we have successfully accommodated historically, whereby:

- almost one in four current Australians were not born in Australia. Also half of Australians have had at least one parent born overseas;
- Australia's population is currently just over 21 million. Without migration, based on expected fertility and mortality rates, and at the current level of people emigrating, Australia's population will not reach 22 million;
- in the year to June 2005, Australia's net permanent migration level reached 105,000. If this level were to increase by 1.5 per cent a year over the next 45 years, Australia would reach a population of 30 million by the year 2050; and
- the international competition for migrants and for our own educated youth and skilled workers will continue to increase, making it more difficult to attract the migrants Australia needs.

On advice from the Australian Institute for Demographic Research of the Australian National University, the Scanlon Foundation adopted, as a working hypothesis, a future population for Australia of 30 million people by 2050. In shorthand this is referred to as "30/50".

The Foundation commissioned the Australian Academy of Technological Sciences and Engineering (ATSE) to advise whether there were any engineering, scientific or environmental barriers to reaching 30/50.

The Foundation, in addition to the ATSE work, has also commissioned:

- the Demography and Sociology Program at the Australian National University – to pursue work on Positive Immigration Strategies, in recognition of the likelihood of increased levels of immigration, and
- Monash University's Institute for the Study of Global Movements, in partnership with the Australian Multicultural Foundation – to examine issues of social cohesion inherent in 30/50, particularly how to continue the successful immigration accomplishments of the past five decades. The findings of this study, launched in mid-2006, will be presented in October 2007.

# Overview

## THE PROJECT CONTEXT

The Academy of Technological Sciences and Engineering (ATSE) was commissioned by the Scanlon Foundation in 2004 to advise whether there were any engineering, scientific or environmental barriers to reaching an Australian population of 30 million by 2050. ATSE assembled a team of its Fellows with expertise in the critical areas to oversee the Study and to examine the specific engineering, scientific, environmental and planning issues associated with 30/50, including the potential impacts of climate change.

## PRINCIPAL FINDINGS

In summary, the ATSE study concludes that there are no insurmountable engineering, scientific or environmental barriers to 30/50, assuming that thorough analysis and planning occur and that leadership is exercised, especially by governments.

Specifically, ATSE's Study findings are:

- there are no inherent physical, resource or technological barriers;
- long-term planning is imperative to ensure timely and orderly provision of needed infrastructure; and
- leadership from governments is essential in setting clear policy directions.

The current study reaches conclusions which are consistent with a 2000 ATSE Study[2] that found predictions of environmental disaster arising from population growth were ill-founded.

Australia has suffered significant environmental damage in the past and might again in the future if land, water and air are not better managed.

However, increases in many environmental impacts are not related to population size, per se, but arise from other activities more broadly related to how we plan for, manage and develop towns and cities, regions, catchments and natural resources.

There are, of course, population-driven impacts – depletion of arable land, poor waste disposal, water availability and water and air pollution, for example.

Mitigation measures, achieved through technological development, lifestyle changes, market instruments, policy and regulation responses and education, are needed to address these problems.

## THE SCOPE OF THE ATSE STUDY

The ATSE Study showed that there are three systemic issues and five specific topics involved in meeting 30/50.

The systemic issues, common to all resource and infrastructure issues, are:

- the potential impacts of climate change;
- the investment required in infrastructure and the associated economic capacity, resulting from population growth and underlying economic trends; and
- the planning issues involved in integrating the complex and interlocking elements.

The ATSE Study also considered in detail five specific topics:

- water;
- energy;
- transport;

[2] ATSE, *Population Futures*, Australian Academy of Technological Sciences and Engineering (ATSE), October 2000. (The paper is available at www.atse.org.au/index.php?sectionid=200)

- waste management; and
- social infrastructure.

The ATSE 30/50 Report, which addresses these issues and topics in detail, is summarised in this section. The conclusions are those of the individual authors.

## THE SYSTEMIC ISSUES: CLIMATE VARIABILITY AND CHANGE

The Study concludes that climate change should not be a barrier to 30/50.

This will be achieved in the context of a growing public understanding that, just as climate has influenced Australia's population location and development in the past, so too will climate change affect Australia in the period to 2050 and beyond. This will require adaptation responses and the consequent planning and provision of appropriate infrastructure, but should not be a barrier to 30/50.

The impact of climate on Australia's development has been a constant, indeed limiting, factor since European settlement more than 200 years ago. But future climate change, driven by global, anthropogenic increases in greenhouse gas emissions, will complicate planning in many sectors – energy, water and agriculture especially.

Projections of future climate are inherently uncertain. Continued monitoring and research are critical to reducing these uncertainties. Because Australia's climate is unique and because of Australia's relative isolation in the Southern Hemisphere, it is important that the nation contributes to, and benefits from, international climate change science.

To attain stabilisation of atmospheric concentrations of greenhouse gases (and therefore achieve a reduction in the rate of rise of global surface temperatures) emissions must first be reduced substantially. But, given the slow responses of natural systems in absorbing existing concentrations, the timescales for stabilisation are far longer than the 50-year timeframe of the Study. As a consequence, the effects of the enhanced greenhouse effect will almost certainly be very apparent in 2050.

Varying impacts will be felt in different regional areas and there could be compounding effects. For instance, climate change will impact on water availability and therefore patterns of settlement and agriculture and, in turn, transport linkages and associated energy demands.

Among the sectors susceptible to climate change are:

- human health and well being;
- natural ecosystems;
- energy;
- water availability;
- agriculture; and
- natural disasters.

Migration from countries likely to be affected adversely by climate change, most of them in southern and south-east Asia and the Pacific Basin, could be an important factor in the migration mix and its impact on Australian society.

Policy responses to climate change involve both mitigation and adaptation. As direct signals of climate change are becoming apparent, there is now a significant focus on short- to medium-term adaptation.

In the key areas of susceptibility the Study identifies many planning and adaptation responses. These include prevention strategies for a potential increase in vector-borne diseases like malaria and dengue fever.

While there appears to be no trend in the rainfall deficit during widespread droughts, there has been an underlying upward trend in recent decades in temperatures in each successive major drought event. This is expected to lead to increased heat stress on humans, agriculture and ecosystems. These factors will need to be taken into account in planning for water storage, supply, Usage and distribution, among other factors.

The history of Australian crop production suggests that agricultural industries can adapt to difficult climatic conditions but accelerated climate change will place additional stresses on agri-business. The future for wheat crops is mixed. There is evidence that the 30 to 50 per cent increase in wheat yields from 1952 to 1992 was partly due to increasing overnight minimum temperatures. But, as maximum temperatures rise and water availability reduces, the positive impacts of frost reduction and of $CO_2$ fertilisation will be offset.

Some rural communities in the semi-arid regions of Australia could become marginally viable if rainfall deficiencies continue for long periods. Australia's competitive position in crop production may be affected by climate-driven changes in crop yields in other countries.

Taking into account the uncertainties associated with rainfall predictions, it is possible that the frequency of extreme rainfall events could increase in the Australian region, leading to more flooding events, and storm surges in coastal areas.

The impact of sea level changes needs to be an important planning criterion to ensure the safety of life and infrastructure along the coastline. Internal migration, potentially driven by water availability, could be a policy option, but one having social and cultural as well as economic implications.

In all of these areas it will be important to understand the impacts and to devise strategies to ensure that the affected sectors make adjustments. Given this, Australia will be able to develop and implement policies to manage climate variability and change (and capture any benefits), as population grows towards, and reaches, the 30/50 figure.

Climate change and its consequences are a global phenomenon with global causes. While Australia's contribution to this global phenomenon is modest, Australia must pursue strategies to mitigate and manage the effects of climate change.

## THE SYSTEMIC ISSUES: INFRASTRUCTURE NEEDS

With adequate planning and appropriate policy reform, there is little concern about Australia's ability to provide the necessary infrastructure to cope with 30/50, given the nation's resource endowment and capital availability.

The Study concludes that demands on natural resources and physical infrastructure in 2050 will be a function of both population and economic trends.

Economic projections for the ATSE Study were derived from a general equilibrium computer model run by the Centre of Policy Studies at Monash University. This is widely regarded as the most comprehensive and credible model available.

The model assumes no technological breakthroughs, industries are assumed to grow at similar rates as in the recent past and the overall rate of growth in the Australian economy is projected to be lower because of an ageing population. While economic modelling can be highly sensitive to these and other assumptions, long-term estimates for economic activity can be usefully derived for indicative planning.

Based on these projections, major investment in new infrastructure and brownfield expansions will be required. Australians are likely to be more than twice as wealthy on average, suggesting that different classes of infrastructure will be particularly important, including goods and services with a high income elasticity of demand such as tourism, health care, private education and motor vehicles. An ageing population and an imbalance of growth between regions will also influence the pattern of infrastructure spending.

Technological change is notoriously difficult to forecast. But it is highly likely that it will have a major impact on infrastructure investment.

Should climate change lead to the Australian Government's participating in a global effort to stabilise atmospheric concentrations of greenhouse gases, macro and micro effects would follow. At the macro level, policies to reduce emissions would almost certainly have a dampening impact on economic growth, thus lowering the required level of infrastructure investment. At the micro level, there would be impacts in certain sectors, particularly stationary energy. Nuclear power may be required for base-load electricity generation.

Despite the challenges described above and more specific ones associated with particular aspects of infrastructure needs (described later), the Study found that there were no infrastructure barriers to the 30/50 outcome, given adequate planning and appropriate policy formation.

## THE SYSTEMIC ISSUES: THE PLANNING IMPERATIVE

There are high levels of confidence in meeting the 30/50 figure across all the engineering, technological and environmental areas examined.

But the Study highlights the critical need for leadership, planning and coordination among governments, agencies and other industry and community participants if the challenges are to be met successfully.

The complexities involved are significant, and do not belong to governments alone. While governments must ultimately set the policy frameworks, the Study concludes that robust public policy positions are needed by all stakeholders if environmental, economic and social shifts are to be accommodated in ways that solve problems rather than create major new constraints.

Citizens expect governments to guide the introduction, review and reform of the major national systems and institutions, so that they operate in predictable ways and serve their vital interests. But ministerial portfolios and public authorities are structured around particular segments or issues, rather than systems as a whole. A shift in emphasis is required towards actions that focus on the needs and management of whole ecological systems such as air sheds, land-based regions, river basins and remaining forest areas.

A major issue is to insure that investment in infrastructure is timely and efficient. Federal and state Governments must play an important role in this by ensuring that appropriate signals reach investors in a timely way, particularly in respect of those investments requiring large, upfront capital outlays and having an economic life of up to 50 years.

Despite growth in private and public partnerships, governments themselves will continue to be investors in infrastructure, requiring them to take on greater levels of debt. Decisions will increasingly need to be made on a national basis. A much greater role for the Council of Australian Governments is called for.

Even given the necessary emphasis on the critical need for government leadership, the Study recognises the difficult balancing act required by governments as they seek to promote a competitive economy, to reallocate scarce resources and to contain public expenditure while responding to increased demands for services, enhanced lifestyles and greater equity among all citizens.

Striking a sustainable balance requires business and citizens, as well as governments, to pay greater attention to the needs and management of whole systems, whether they are technological, societal or environmental.

All the partners involved in creating a cohesive, forward looking nation have an interest in success.

The Scanlon Foundation's Social Cohesion Research Program – and the ATSE Study as part of it – is designed to contribute to this process.

**The ATSE study examines in detail several specific topics of resource availability, infrastructure needs and planning issues associated with 30/50. These are water, energy, transport, waste disposal, elements of social infrastructure including educational, health, aged care and welfare facilities, plus communications infrastructure. The conclusions in each area are outlined separately.**

## THE SPECIFIC TOPICS: WATER

The Study finds that there does not appear to be any insurmountable engineering, health, scientific, economic or environmental barriers in meeting the water needs of 30/50.

The main focus of the Study is urban water, since population growth is likely to be concentrated in existing cities. Responding to the challenge of providing adequate urban water supplies to meet future population growth is in the context that urban water (household, manufacturing and other) currently accounts for some 16 per cent of total water use, whereas agricultural use accounts for some 67 per cent of total water use.

Australia is the driest continent and is already seeing a drastic reduction in run-off over the past 32 years in south west Australia, due to climate change, and in the eastern states, due to drought (which may in turn be due to climate change). But demand management, with customer co-operation, is responding well to the challenge.

In aggregate terms, Australia has a plentiful supply of water (a view supported by the World Bank and studies conducted by the Barton Group).

However, much of the rainfall is in the under-populated north and it is currently uneconomical to transport water over thousands of kilometres from north to south. Many of the large water utilities have long-term planning in place (some for a 50-year period) and expect to meet future needs.

With the exception of Perth, Australia's major cities have added little new capacity since 1980 but this will need to change.

Current long-term planning will need to be strengthened by drawing on a diversity of sources, including those that are independent of rainfall and run-off – such as new surface and groundwater schemes, agricultural sources, improved catchment management, increased demand management, recycling and seawater desalination.

Generally, all future sources will cost more and have high energy needs. At this stage, economic studies of desalination have demonstrated the economic fragility of schemes for north-south diversions of water (over thousands of kilometres) and some of the larger recycling proposals.

There are obvious risks in planning, given the 2050 horizon of the Study and climate change uncertainties. Planning will therefore need revisiting every five years. Technological research, policy formation (particularly to encourage water trading) and building customer education are necessary to differentiate between sound economic proposals and some populist proposals.

## THE SPECIFIC TOPICS: ENERGY

The Study concludes that Australia has adequate primary energy resources and reserves, apart from oil, to meet 30/50, and beyond.

However, there are particular problems with liquid fuels for transport that require resolution.

In the case of stationary power, climate change and the pressures both for short-term adaptation and effective long-term response are likely to see growing reliance on resources that are not carbon-based, including nuclear energy and, to a lesser extent, renewable energy.

The potential for improvement in end-user efficiency in industry, commerce and the domestic sector remains hugely significant. Present and emerging technologies offer dramatic reductions in energy consumption. However, the extraordinarily low-cost of energy in developed economies, especially Australia, still constrains their more widespread acceptance.

Australia's energy research, development and demonstration capabilities are world class and strongly focused on long-term sustainability but they are an undervalued national resource.

Australia's 2050 energy resource mix will be different from the present. Hydro will reduce from eight per cent to about five per cent, natural gas can be expected to double from five to 10 per cent and perhaps 15 per cent, if competitive gas resources become available for base-load units, and renewable resources could reach 10 to 15 per cent, based on current economics, technology and government policies.

Time delays in achieving community acceptance of nuclear power generation and building nuclear generators would probably limit possible uptake of nuclear power to the five to 15 per cent range.

The balance of demand (notionally around two-thirds) will still need to be supplied by coal-integrated gasification combined-cycle/sequestration units, capable of poly-generation to produce transport fuels or hydrogen. This is providing the relevant technologies prove to be economic.

Australians are accustomed to highly reliable but extraordinarily low-cost electricity, leading to a conflict between convenience and sustainability.

Power system investment could be significantly reduced, without loss of convenience or reliability but with enhanced sustainability, using effective peak-demand management. Investment in peaking capacity is unattractive at present retail prices, thus a reduction in peak demand is critical to limit poor infrastructure investment as well as to conserve energy.

How this is to be done, short of draconian regulation or realistic price signals, is difficult to see. Real-time charging initiatives, now being trialled, offer encouragement. Electricity prices will inevitably rise as resources become harder to recover and environmental sustainability costs are factored in, but it is believed that increased prices will not unduly affect or constrain the quality of life of a 30/50 population.

They could, however, inhibit new energy-intensive industries being established in Australia.

Perhaps the most likely pathway to meet the energy needs of 30/50 is a strategic mix of all fuel sources and technologies. The energy conservation and delivery mix will not, however, change quickly. It is therefore essential to develop long-term national strategic plans to move the energy mix in the desired direction, using government regulation where market forces alone would trend towards short-term optimisation.

This warrants a far more substantial policy and planning framework, based on national agreements, in part to overcome constitutional difficulties between state and federal jurisdictions.

Australia's oil production is falling due to depletion of reserves, with the rate of discovery of new oil reserves not keeping up with production. Accordingly, Australia must adopt a number of strategies.

Industry must be encouraged to explore for remaining Australian oil deposits (particularly in new frontier areas), diversify the sources of liquid fuel supply and/or attempt to mitigate demand. The development of alternative sources requires very long lead times, at least the order of a decade or more for hydrocarbon fuels and much longer for alternative sources of transportation power. This is where government can play a significant role.

In the case of petroleum-based transport fuels, it will be necessary to manage a transition to a larger, mixed economy in which liquid fuels are derived from a number of sources. This transition is not expected to present problems for fuel technologies. But the transition will be most difficult for aircraft fuels.

Changes can also be expected in vehicle design. These include improved consumption and environmental efficiencies for internal combustion engines and the use of smaller cars and other vehicles that will have intrinsically lower fuel consumption requirements.

## THE SPECIFIC TOPICS: TRANSPORT

The Study found that no significant insurmountable or uneconomic engineering, scientific or environmental barriers to providing adequate transport for 30/50.

But this assumes a change from the current transport planning and development systems which are often driven by political imperatives and operate on a short-term basis with little policy transparency – and more than a hint of the pork barrel.

Planning will have to be cast beyond the lifetimes of current governments and divorced from their traditional over-reactive approach.

These problems are compounded by another major obstacle – the differing priorities and overlapping responsibilities of local, state and Commonwealth authorities, particularly in land transport infrastructure. This implies a much greater role for the Council of Australian Governments in establishing agreed policies, priorities and modes of funding.

The scale of the challenges is indicated by the economic modelling undertaken by the Centre of Policy Studies at Monash University, and used elsewhere in this study. This shows that by 2050:

- the rail transport sector is expected to have grown by 3.6 times current levels;
- the road sector by 3.4 times;
- air transport by 3.7 times; and
- sea transport by 2.0 times. (This could be an underestimate, given industrialisation of regional economies).

While funding levels need not differ greatly from current levels, they will need to be ongoing and continuous. Current facilities are less than optimum and there is no leeway to accommodate investment shortfalls.

The largest transport problems will arise in urban areas, where the existing mass transport facilities are already struggling. In particular, arterial public transport routes will need to be upgraded and new road infrastructure built, requiring careful land use management controls.

Road vehicles will continue to play a major transport role but will be smaller, more fuel-efficient and travel at lower speeds. These changes will be partly driven by market forces but government regulation and incentives will be needed to ensure safety and alignment with national policy priorities. It is probable that "fit for purpose" rental fleets of vehicles will be used for personal travel.

Buses will be the dominant transport mode in outer urban fringes, improved through the use of better telecommunications and on-board electronics. Similarly, systems will be needed to electronically lock personal vehicles together into virtual "buses" when operating on high-demand routes.

Railway systems will have to be rejuvenated and firmly linked to other transport modes to provide an integrated transport system, supported by advanced information and communications technologies.

Australia's relatively large urban areas, with mixtures of housing and industry, are inefficient for freight distribution. Major capital expenditure and alternative technologies will be needed to provide good regional freight links to urban distribution centres. In cities, greater use of tunnels, carrying autonomous delivery vehicles, might contribute to solutions.

For regional areas there is an even greater need for integrated planning of road transport, leading to an effective grid of freeways and tollways. Attention will inevitably return to rapid transit trains to connect city centres, at speeds approaching that of aircraft.

The planning of Australia's transport needs will require an international perspective. Global trade and alliances will be key components in successful policy making. Under-investment in the nation's international transport systems would significantly diminish our trading ability.

## THE SPECIFIC TOPICS: WASTE DISPOSAL

The Study concludes that Australia has the space and resources necessary for waste management and therefore this should be no barrier to 30/50.

With acceleration of waste management programs (for example urban waste reduction, recovery and recycling) there is an opportunity for Australia to produce less waste in the future than it does now.

Australians currently generate more waste per capita than in most other developed countries, partially in response to its low density of population and abundant space for landfill disposal.

Research for the Study shows the collection, sorting and recycling of materials is not driven by the economies of the recovered materials. The combined costs for doing so in respect of most glass, plastic, paper and metals is seldom less than the selling price of the recovered materials. Yet recovery and recycling is supported at all levels of society and it is recognised that recycling can reduce the demand for landfill, lessen the environmental impacts and make some financial contribution.

All states and territories have ambitious goals for waste minimisation but available information indicates that these have not been met in full.

Management of wastes is an important health and environmental issue. Some wastes are toxic and can harm living organisms. Their safe disposal is of particular importance.

## THE SPECIFIC TOPICS: SOCIAL INFRASTRUCTURE

No social infrastructure barriers are seen to 30/50, providing a substantial increase in infrastructure spending occurs in various areas.

Several social infrastructure issues were considered (as part of an integrated assessment of infrastructure). These include educational, health, aged care and welfare facilities and communications.

An impediment to infrastructure development is the current overlapping of governmental and other agency responsibilities, leading to under-investment, or inefficient investment. Reforms are needed.

Using a "high" alternative, by 2050 life expectancy for men will be 92.2 years and for women 95 years. Low rates of savings, increased used of pharmaceuticals and increased life expectancy are expected to increase demand for public housing, health facilities and community health services.

While migration patterns will have an influence, it is expected that there will be fewer children as a percentage of the total population. Some educational assets may therefore be converted to other uses. In particular, growth in the economy, particularly productivity growth, will require workers to upgrade their skills continually.

This implies rates of demand for education services growing at rates faster than employment growth.

Apart from the demographic effects, increased wealth for Australians will create a significant demand led expansion in the use of medical services.

A constant recurring theme through the Study is the need for vastly improved communications infrastructure – telephone lines, broadband capabilities, cable infrastructure and wireless connectivity. The economic modelling undertaken for this Study predicts roughly a 500 per cent increase in the need for communications services by 2050.

Despite the high take-up of internet access (84 per cent), penetration of high-speed broadband is comparatively low. Australia's projected GDP growth will be driven by increased use of communications and this, in turn, will fuel greater demand for more services. Inadequate communications facilities will place business at a serious competitive disadvantage.

Much of the needed infrastructure will be funded by the private sector but there are clear roles for government to act strategically to ensure adequate investment in communications. Strategies include demand aggregation and other targeted infrastructure funding schemes.

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## This project was overseen on behalf of the Academy by a Steering Committee:

- Dr Ian J. Duncan FTSE, Chair
- Dr John F. Brotchie FTSE
- Dr Peter J. Crawford AM FTSE
- Mr Ian E. Galbally FTSE
- Dr John K. Langford FTSE
- Mr Martin H. Thomas AM FTSE

Once the project had been established, and as Chair of the Steering Committee, **Dr Ian Duncan** FTSE was responsible for the initial stages of the project, providing proposed drafts for several chapters and commissioning two of the specialist contributions. Members of the Steering Committee were actively involved in the development and review of the project.

## The Project was established and managed for ATSE by:

- **Professor Ian D. Rae** FTSE, Technical Director (to February 2006), and
- **Professor Vaughan R. Beck** FTSE, Technical Director (since February 2006), ably supported by the staff of the Academy.

Following his role as Technical Director, Professor Rae provided text for several chapters.
The production of this publication was overseen by **Mr Bill Mackey**, Communications Director, ATSE.

## Specialist contributions were made in drafting the chapters by the following authors:

### Chapter 2: Population and Settlement in Australia: The Next 50 Years

**Professor Peter McDonald**, who is Professor of Demography at the Australian National University. He has recently been elected Vice President (2006-2009) and President (2010-2013) of the International Union for the Scientific Study of Population. He is frequently consulted on the issue of population futures (causes, consequences and policies) by governments around the world, especially in Europe and East Asia; and
**Rebecca Kippe**n, who is a Research Fellow in Demography at the Australian National University. She is one of Australia's leading authors on Australian demographic trends, past, present and future.

### Chapter 3: Climate Variability and Change

**Dr Michael J. Manto**n FTSE, whose career included scientific research on climate and participation in international for a while Chief, Bureau of Meteorology Research Centre in Melbourne.

### Chapter 4: Water

**Mr Barry S. Sanders** OAM FTSE, whose career included executive management in the Water Corporation of WA, President of the Australian Water Association and Chair of the National Water Technology Commission.

**Dr Peter Crawford** AM FTSE, previously Managing Director of Sydney Water and NSW Commissioner for Healthy Rivers.

## Chapter 5: Energy in Australia

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**Mr Martin Thomas** AM FTSE, who was a Member of the Uranium Mining, Processing and Nuclear Energy Review (UMPNER) and is Chairman, Dulhunty Power Ltd; and formerly Principal, Sinclair Knight Merz and Managing Director, CRC for Renewable Energy.

## Chapter 6: Transport

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## Chapter7: Waste Disposal

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## Chapter 8: Infrastructure

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**Melanie Kelly**, who is also a founding Director of Insight Economics, having previously worked at the Allen Consulting Group. Melanie specialises in resources and health economics.

## Chapter 9: Policy Considerations: Meeting the Challenges

**Dr Peter Crawford** AM FTSE (see above, Chapter 4)

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# CHAPTER 1
# Introducing the study

## 1.1 AUSTRALIA'S POPULATION DEBATES

The population debate is almost as old as European settlement of Australia. Towards the end of the 19th century, as the federation movement appeared certain of the success it achieved in 1901, the slogan 'Australia Unlimited' summed up the feelings of those who felt that the Australian continent could sustain a large population. Perhaps arguing from the then population of England (30.5 million in 1901, and rising rapidly) and the relative areas of the two countries (ratio approximately 6:1), population figures of more than 100 million were confidently proposed.

In opposition was heard the voice of geographer Thomas Griffith Taylor (1880-1963), who argued that environmental factors would limit the carrying capacity of the Australian continent to a figure more like 20 million. Taking note of the failure of agriculture to be sustained in Australia's arid and semi-arid regions, and warning against the expansion of settlement in the frontier states, Western Australia and Queensland, Taylor's argument was based on his professional assessment of what he termed 'climatic controls' together with his identification of resource limitations. For his opposition to the expansion of the British Empire on Australian soil – for this is how his views were often portrayed by opponents – he was widely vilified, although his work was highly regarded in international circles. At Sydney University, where he had accepted an appointment after more than a decade with the Commonwealth Weather Service, his career was impeded and he eventually left Australia for good in 1928.

From time to time during the remaining three-quarters of the 20th century the population debate re-emerged, often triggered by events or government policies that impacted or could be held to impact on sustainability (although the "sustainability" word came into vogue only late in the century). Thus, opponents of Australia's migration program sometimes raised the spectre of over-population, although their voices were usually muted by the fact that supporters of smaller populations were the same people who supported immigration of refugees and other disadvantaged people such as the Europeans whose lives were disrupted by World War II and its immediate aftermath, and those fleeing conflict in South-east Asia.

Governments approached the matter with great caution, usually calling for studies of appropriate populations or development of a population policy, rather than setting targets for growth, stabilisation or reduction of the Australian population. The House of Representatives Standing Committee for Long Term Strategies, chaired by Academy Fellow Hon B. O. Jones MP, reported in 1994 on its inquiry into Australia's population carrying capacity but was unable to come to a clear recommendation on this. Instead, they recommended "ongoing community involvement and debate" on four realistic alternatives for an appropriate, stable population – one resulting from high growth (30 to 50 million), and others from moderate growth (25 to 30 million), stabilisation close to present levels (17 to 23 million) and one that could be brought about by moderate-to-major reduction (five to 17 million). The essence of the report was that a population policy needed to be developed, and that this should be done by consideration of the scenarios posed, followed by a political decision on the most desirable outcome.

Some non-government stakeholders are less restrained, and their calls for a population policy are often accompanied by statements that 40 to 50 million would be appropriate targets for the Australian population by the middle of the 21st century. On the other hand, there are loud voices calling for a smaller population and supporting their cases by reference to the environmental impact of even the present population, which is deemed unacceptable. There is, of course, an international dimension to this interest in sustainable populations, harking back to Thomas Malthus (1766-1834) who drew attention in 1803 to the dichotomy between geometric increase in population and arithmetic increase in food supplies. Two hundred years later, the prominent naturalist and television personality Sir David Attenborough sharpened his warnings about global over-population with a call for Britain to reduce its population from the present 59 million to about 30 million by 2030. His counterpart in Australia is Dr Tim Flannery, who has stated that a sustainable population in Australia would be six-12 million, based on his claim that sustainability would only be achieved if the population were held to not more than 20 to 30 per cent of the country's carrying capacity, a figure advanced on environmental grounds.

Although being careful to avoid such precise specification, the organisation Sustainable Population Australia (SPA) generally supports Flannery's view. The SPA's questioning whether a higher population with increased economic activity "will make us any happier" has its counterpoint in the statement by a group with more industry support, The Australian Population Institute (API). "Contrary to popular views," API says, "increasing the population will benefit every facet of our lives ... and this includes the environment." More measured approaches to the population question are to be found in articles in the Monash University publication *People and Place*, whose authors include Professor Peter McDonald (on population growth, see Chapter 2 of this report), Anne-Marie Willis (on urban design) and Professor Bob Birrell.

## 1.2 A NEW APPROACH

A more sophisticated consideration of the implications of population growth was undertaken in 2000 by the Australian Academy of Technological Sciences and Engineering. The study was commissioned by the Business Council of Australia and conducted by the Academy in conjunction with urban planners Gibbons Spiller Swan. It addressed the question "what are the possible environmental impacts of a larger Australian population and what should we do to prepare for or alleviate them?" The completed study[3] developed the argument that population growth was most likely to take place in Australia's major cities and that only a small number of environmental impacts were directly linked to population size. The four areas of concern in which impact was strongly connected to population size were:

- pollution of land and groundwater;
- pollution of coastal rivers and of rivers and lakes near major urban areas;
- depletion of fresh water stocks near major urban areas; and
- pollution of urban airsheds.

The report of the study directed attention to policy development and technological infrastructure that would be required to avoid such impacts. The Academy was careful to avoid over-optimism about the "technological fix" but nonetheless concluded that the necessary technology was already in service or had demonstrated the necessary capability. In each of the identified areas, recent decades had seen improvements resulting from the applications of technology and there was every prospect that future impacts could be similarly managed.

The views developed in the Academy study were presented by Mr Jerry Ellis FTSE at a national symposium and included in the resulting publication, *Australia's Population Challenge*[4].

Similar considerations of infrastructure requirements (possibly involving provision by governments), and the addressing of possible impacts, underlie the numerous studies undertaken by governments and private organisations of development in Australia, although population size is seldom explicitly considered. Such studies have been focused on the need for new railway, port facilities, major roads, intermodal transfer nodes, and new patterns of settlement, including suburban development. One long-running contention, with potentially significant effects on movement of goods and people was resolved with the completion of the north-south railway – Alice Springs to Darwin – in 2004.

[3] ATSE, *Population Futures*, Australian Academy of Technological Sciences and Engineering, October 2000. (www.atse.org.au)

[4] Ellis, J., *Technology and the Environmental Constraints on Population Growth*, in Vizard, S., Martin, H. and Watts, T. (eds.), *Australia's Population Challenge*, Penguin Books, 2003, pp.156-159.

## 1.3 THE COMMISSION

In 2004 the Scanlon Foundation requested the Australian Academy of Technological Sciences and Engineering (ATSE) to undertake a study of the engineering, scientific and environmental issues associated with population growth in Australia.

The Foundation's mission is "to support the creation of a larger cohesive Australian society".

The Foundation believes that the future prosperity of Australia, underpinned by population growth, will depend on our ability to maintain social cohesion in a society with even more cultural diversity than we have successfully accommodated historically.

The Foundation, in seeking to create awareness and knowledge-based discussion about Australia's population growth and its relationship to social cohesion, has commissioned the following areas of research:

1. The Australian Institute for Demographic Research at the Australian National University, led by Professor Peter McDonald and Rebecca Kippen, have undertaken projections of Australia's population that have enabled the Foundation to adopt, as a working hypothesis, a future population of 30 million Australians by 2050. In shorthand, this is referred to as "30/50". This population will result from stabilising the fertility rate around its present level and acknowledging that the level of immigration will increase largely in response to future demand for labour;
2. The Australian National University, under their Demography and Sociology Program, through Professor Peter McDonald and Professor Glenn Withers, are pursuing work on Positive Immigration Strategies in recognition of the strong likelihood of increased levels of immigration;
3. The Australian Academy of Technological Science and Engineering was requested to advise the Foundation on whether there were any engineering, scientific or environmental barriers to reaching 30/50; and
4. Monash University's Institute for the Study of Global Movements, in partnership with the Australian Multicultural Foundation, has embarked upon a major Social Cohesion Research Program, the outcomes of which will be presented at Metropolis 2007 to be held in Melbourne in October 2007. This research will examine issues of social cohesion inherent in 30/50, particularly how to continue the successful immigration accomplishments of the past five decades.

It is the third of these four areas that this ATSE study is directed. It was agreed that the Academy, in forming its advice to the Foundation, would draw on published and other available work, integrating it where appropriate and adding critique that would place the work in context and to emphasise its relevance to the overall program.

## 1.4 POPULATION SIZE

In order to provide an authoritative estimate of the growth of the Australian population, the Scanlon Foundation contracted the Australian Institute for Demographic Research of the Australian National University to consider the magnitude and structure of such a population as it continues to expand. The paper, *Population and Settlement in Australia: the Next 50 Years*, by Peter McDonald and Rebecca Kippen, is central to this exercise as it plots the trends for births, deaths and net migration that are likely to underwrite Australia's future. It also draws attention to ageing, gender, work places and those available for work. McDonald and Kippen's paper is included in this report as Chapter 2. At this point it is sufficient to note that the authors have predicted a total population of permanent and temporary residents for Australia in 2050 of 31.2 million.

## 1.5 APPROACH TO THE STUDY

The overall timeframe of the study was the period 2005 to 2050, the latter figure being always regarded as an outer limit for meaningful analysis based on extrapolation of the present and easily foreseeable situations. Some uncertainties – although not their likelihood or their possible impact – can be identified at the outset and they include national, international and natural events. A major war or a regional conflict close to Australia could change our outlook, and political upheaval in the Asian/Pacific sphere could impact at any time. The effects of the collapse of communism in the Soviet Union are still being felt. Turning to natural catastrophic events, we have recent experience of drought at home, and tsunami and earthquake in our region.

Domestic politics, perhaps influenced by our response to climate change, could reshape Australia in a decade, let alone over four or five decades. In addition to these unknowns that we can at least glimpse, there are the "the unknowns that we don't know" – to paraphrase a recent statement by a senior member of the administration in the US. Among these we may count future technologies. If the year 2000 was envisioned in 1955, we would have probably failed to recognise jumbo jets, computers, email, lengthening of life, Asian immigration, extended peace, resource discovery and development and the global warming issue. Two decades ago, the collapse of communism, growth of Chinese and Indian populations and their strengthening economies would not have been foretold.

We therefore suggest that this study be regarded as relevant to the growth of Australia with today's social cohesion, quality of life, resources, technologies, wealth distribution and climate. The level of uncertainty increases as the projections go further out in time and ATSE recommends that the Foundation periodically review this field.

Bounded by the expectation that Australia's permanent and temporary population could grow to 31.2 million by 2050, the authors of this report have considered the elements of water, climate change, energy, travel and transport, waste disposal, infrastructure and policy which are covered in later sections [5].

ATSE concentrated on the technological aspects of an expanding population, but was reminded on many occasions that any accompanying change to the infrastructure or resources can only take place with changes to policy at the three levels of government.

The means to beneficially bring about change rests with the key stakeholders in Australian society and this work highlights that essential step for the planning and management of growth.

[5] This report, by its very nature, covers a complex range of issues. Also, given that the report has been prepared by several authors, there has been an inevitable degree of overlap between chapters. This overlap has been fostered so that each chapter can provide a coherent framework without requiring the reader to frequently cross-reference between chapters.

# CHAPTER 2
# Population and settlement in Australia: the next 50 years

## 2.1 INTRODUCTION

Following the Second World War, Australian planners considered the future population of Australia to be an integral component of their plans for post-war reconstruction. At the time, based on the trends in migration and fertility that had applied up to 1945, Australian demographers were projecting that Australia's future population would peak at around eight million people and the population would be falling by 2000[6]. This was a trajectory for population that was inconsistent with the goals of the post-war reconstructionists. For them, growth of population and labour supply was seen to be a necessary component of post-war reconstruction. Accordingly, they instituted a vigorous immigration program to address the perceived labour shortages and promoted employment and housing construction as longer-term approaches to raise the birth rate. By 2000, the Australian population had risen to almost 20 million. Of the additional 12 million people, about seven million were due to increased immigration and four million due to higher birth rates during the baby-boom era. Faster falls in mortality than had been predicted added another million people[7]. The question can be asked: is Australia today a better place than it would have been if the post-war reconstructionists had not intervened in the progress of its demography?

In contrast with the post-war reconstructionists, the standard (neoclassical) assumption of economists and planners today is that future demography is pre-determined (exogenous). In this standard approach, future demography is estimated from trends in past demography and then becomes the "front end" of complex economic planning models. The implicit assumption of this approach is that the economy is expected to adjust to whatever future demography turns out to be. Population policy in this context becomes an irrelevance. The Australian Government's periodic *Intergenerational Reports* are an example of this type of approach.

In contrast to this standard approach, historical analysis of demographic trends shows plainly that demographic behaviour is strongly influenced by the contemporary economic and social situation. For example, in Australia in the early 1930s, the fertility rate fell to a very low level and international migration was close to zero. A similar situation occurred in the mid-1970s. When the economy is unfavourable, births are delayed and migration is forgone. When the economy is strong, birth rates rise and new migrants are attracted. The story of demographic trends following the Second World War shows that policy can make a considerable difference to future demography.

Rather than future demography being predetermined inevitably and inexorably by past trends in demography, estimates of future demography should be made in consort with projections of planned future economic and social trends. If the Australian economy were to go into steady decline over the next 50 years, we could expect that population growth rates would be much lower than if the economy

[6] Kippen, R. and McDonald, P., *Australia's Population in 2000: The Way We Are and the Ways We Might Have Been*, People and Place, Vol.8, No.3, 2000, pp.10-17.
[7] *ibid*

were to remain strong throughout most of the next 50 years. We cannot predict the timing of economic fluctuations (recessions and booms) but, at least, long-term demographic projections should be consistent with an argued position about broad economic and social futures. Those who wish to assess the likely accuracy of the demographic projections can then evaluate the reliability of this argued position. Effectively, this is an argument for Australia to abandon the notion that its future demography is pre-determined and to evaluate, within the bounds of likelihood, what demographic futures are desirable as an integral component of desired longer-term economic, social and environmental goals.

## 2.2 THE FUTURE ECONOMIC AND SOCIAL SETTING IN AUSTRALIA

The demographic projection described in this paper is based on the assumption that, in broad terms, the Australian economy will be strong across the coming decades. This is both the likely and the desirable future. This outcome is likely because sustained economic development of the two Asian giants, China and India, will underwrite continued economic growth of the Australian economy. The inevitable shift from oil-based energy to other energy forms will also be beneficial to Australia on a global scale. Of course, continuation of the economic strength of the Australian economy is a desirable future because it will bring increased living standards for Australians and increased wealth that can be applied to the improvement of environmental, economic and social infrastructure.

The likely domestic implications of this future are:

1. **Substantial increases in standard of living**. The Treasury's 2002 *Intergenerational Report* [8] projected a doubling of the living standards of Australians between 2002 and 2040. This was confirmed by the 2005 Productivity Commission report: *Economic Implications of an Ageing Australia* [9].
2. **Major investment in new physical infrastructure**. Infrastructure development has been neglected to a large extent in Australia since the 1970s. Massive new investment is required to deal with environmental degradation including greenhouse gas emissions, water supply, the transformation from an oil-based economy, and transportation and communications inefficiencies. Of course, this would need to be undertaken with a strong regard to short-term fiscal responsibility.
3. **A considerable demand for labour** related to the construction of new physical infrastructure and new demands for service workers arising from increased living standards and the ageing of the population. Ageing of Australia's population is inevitable whatever reasonable assumptions are made about Australia's future demography.
4. **Substantial new investment in education and training infrastructure**. This will be required to service the needs of the expanding economy and to deal with the rapidity of change in technology. We can predict that technology changes in the next 50 years will be faster than ever before in human history. The inevitable substantial changes in the "way we live our lives" because of global warming, changes in energy forms, new approaches to water supply and sewerage, transport and communications will be demanding of highly skilled technological workers. Any country that is lacking in the highly sophisticated skills that will be needed to adapt new technologies to local environments runs the risk of failing to capture its share of global capital investment.
5. **Changes in social institutions** to enhance social cohesion and the capacity for all Australians to share in the increased wealth of the country. Social disharmony is an obvious threat to economic progress. It can be addressed through changes in the structure of the tax-transfer system and investment in social infrastructures such as health systems, early childhood education and care, community services and aged services. The capacity for workers to combine their work and caring responsibilities across their lifetime will be an important component of this outcome.

[8] The Treasury *Intergenerational Report*, Budget Paper No.5, 2002-2003 Budget, Commonwealth Government, May 2002.
[9] Productivity Commission, *Economic Implications of an Ageing Australia*, Commonwealth Government, April 2005.

## 2.3 LABOUR SUPPLY: THE ESSENTIAL INTEGRATING COMPONENT

The essential linkage between demographic and economic futures is labour supply. The neo-classical economic model sees labour supply largely as effective (elastic) response to labour demand. Potential workers will contribute more or less of their supply to the labour market depending upon the demand signals of the market especially the level of wages. This model may have been relatively effective in the past 30 years but these were years in which the potential labour supply grew rapidly because of immigration, the labour force entry of the baby boom generation and the opening of the labour market to much larger numbers of women.

Between 1970 and 2003, the Australian labour force increased by around 85 per cent. On present population and participation trends, the future growth of labour supply is considerably slower, being between 10 and 20 per cent over the next 50 years [10]. Fundamentally, this turnaround in labour potential is the result of the high fertility baby-boom years being succeeded by 30 years of below-replacement levels of fertility. Future labour supply is likely to be much less responsive to changes in labour demand than has been the case in the past 30 years.

Existing economic models of future labour demand used by government in Australia are very limited because they are reliable over a timeframe of no more than about five years. Because these models are only effective in measuring the short-term economic impacts of immigration, the conclusion that they draw is that immigration has only a marginal impact upon the economy. The same models applied in 1947 would have produced the same conclusion because, inevitably, the impact of immigration in the short-term can only ever be marginal. Because of the hegemony of these models in government decision-making, immigration policy targets have been set conventionally on a one-year basis and the targets are addressed at meeting only short-term labour demands. There is no effective planning for long-term labour needs in Australia.

The post-war reconstructionists had relatively primitive tools to apply to their economic planning. In retrospect, however, this may have been an advantage because they were not as constrained as current-day planners are by the hegemony of short-term economic modelling. With low unemployment and projected very slow growth of labour supply, particularly the supply of young technologically skilled workers, future labour supply is likely be relatively inelastic to demand (giving rise to inflationary pressures) – unless longer-term planning of labour supply is in place.

We cannot increase labour supply by increasing the birth rate 25 years ago; we cannot increase the supply of workers with a particular skill by increasing the training intake for that skill five years ago. While Australian immigration policy has been relatively responsive to immediate labour demand, the increasingly competitive international market for skills increases the risk of relying solely on short-term immigration policy.

In the tradition of the post-war reconstructionists, without being explicit about precise numbers, a strong growth in labour demand is an obvious implication of a strong Australian economy over the coming decades. Without a major increase in potential labour supply, Australia will not be able to undertake the massive physical infrastructure projects that it needs to improve the degraded environment, convert to non-oil based energy, improve water supplies and sewerage and eliminate transport and communications inefficiencies. Without a major increase in labour supply, Australia will not be able to provide the service workers consistent with a wealthier and ageing population. Without an emphasis on young skilled workers, Australia will not be able to assimilate new technology as rapidly as it will need to do. Again, without being as explicit about long-term labour demand as we would prefer to be, the demographic projection described below sets out to maximise future labour supply within the constraints of what is feasible in relation to the demographic variables – fertility and migration. Even then, the growth of labour supply over the next 50 years will be well below that experienced by Australia over the past 50 years.

[10] McDonald, P. and Kippen, R., *Labor Supply Prospects in 16 Developed Countries, 2000-2050*, Population and Development Review, 27(1), 2001, pp.1-32.

## 2.4 THE FUTURE COURSE OF FERTILITY

Since 1978, the fertility rate in Australia has fluctuated within a relatively narrow band ranging between 1.73 and 1.97 births per woman. In the decade up to 2002, the Australian fertility rate fell slowly but steadily, giving rise to a concern that it may continue to fall perhaps even to the very low levels (around 1.3) now common in many European and East Asian countries. Countries with these very low fertility rates universally and correctly see their low fertility as a considerable threat to future economic performance. However, the Australian fertility rate has risen again and, when published, the 2005 rate will be above 1.8 births per woman. Indeed, we have argued recently that the fall in fertility in the 1990s may have been partly due to increasing under-registration of births such that the Australian fertility rate may never have fallen more than slightly below 1.8 births per woman [11].

From the perspective of future labour supply, the birth rate should provide a strong and predictable foundation. A fertility rate of around 1.8 births per woman provides an adequate foundation and policy should be directed at sustaining Australian fertility around this level. Evidence from surveys of preferences indicates that Australians want to have children at a level that is consistent with a fertility rate at about this level. It remains for governments to provide the institutional support that enables young Australians to have the number of children that they want to have. The current Australian Government seems to have accepted this message and has been expanding its support for families with children. Thus, the population projection used in this paper assumes that Australian fertility will be unchanged at 1.8 births per woman throughout the projection period. Of course, there will be fluctuations in fertility as the economy turns up or down but a long-term average of 1.8 is both feasible and desirable.

## 2.5 THE FUTURE COURSE OF MIGRATION

If fertility has provided a strong foundation for future labour supply, migration can be used to fine-tune longer-term labour supply planning, both in terms of numbers and skills. While the policy agenda has been primarily short-term, Australian immigration policy has been operating over the past decade in ways that are largely consistent with this approach. In general terms, immigration policy in this period has been effective and responsive to each new challenge. The principal new challenge has been the development of a global labour market for skilled labour. This has led to greater international competition for immigrants and to a rapidly rising level of emigration of skilled Australians. The new policy approaches used in the past decade include a considerable expansion of temporary migration, new permanent residents being recruited onshore from among temporary immigrants, recruitment of new immigrants (both temporary and permanent) through Expos in major cities around the world, and closer cooperation with states and cities seeking immigrants through regional migration schemes. All of these changes have been pursued through more direct involvement with employers. The out-migration of skilled Australians has meant that the target numbers of the skilled immigration program have needed to be increased from time to time, but this has been done effectively.

Despite the evident successes of recent migration policies, when a longer term perspective is taken, it is apparent that net migration will need to increase over the next 50 years if the labour supply needed to meet economic, social and environmental goals as described above is to be met. It would be preferable for longer-term migration targets to be based on empirical modelling of future long-term labour demand. However, work of this nature currently does not exist. In its absence, we assume that net permanent migration (including onshore conversions) could rise by 1.5 per cent per annum from its 2004 level of 103,000. This would roughly double the numerical level of migration over the next 50 years. As a percentage of the population, annual net permanent migration would rise slowly from around 0.5 per cent to 0.65 per cent. By 2050, both the population and level of net permanent migration in Australia would be very similar to the levels in Canada today. In the absence of long-term labour demand projections, this level carries the status of a rough guess. Its selection has been based upon notions of feasibility (absorptive

[11] McDonald, P., *Has the Australian Fertility Rate Stopped Falling?*, People and Place, Vol.13, No.3, 2005, pp.1-5.

capacity) and desirability (future labour demand). The absorptive capacity of Australia in relation to this population trajectory is assessed in other chapters of this report.

Of course, annual net migration cannot be expected to follow the course of a uniform annual percentage increase. There will be annual fluctuations arising from economic cycles, from the relative standing of the New Zealand and Australian economies, from competition from other countries, from recruitment policy changes and from presently unknown future global events. Thus, future annual migration targets will necessarily fluctuate but this does not negate the feasibility of a long-term target.

Much migration to Australia in the past 15 years has consisted of temporary migration (not permanent, but for a period longer than 12 months). With an increasingly globalised labour market, it is expected that the demand for temporary immigrants will continue to rise. In particular, temporary migration is able to meet shorter-term labour demands arising from particular skill shortages. The projection assumes that the stock of temporary residents of Australia will increase by 1.7 per cent per annum (an annual increase of 7650 in 2005). At this rate the stock of temporary residents would rise from 450,000 in 2004 to around one million in 2050.

## 2.6 THE FUTURE COURSE OF MORTALITY

Future changes in mortality will have little direct impact on labour supply as the vast majority of potential additional 'survivors' will be aged 75 years and over. For our projection, we follow the Australian Bureau of Statistics Series B (medium) assumption that has future expectation of life rising to 84 years for men and 88 years for women by 2054 [12]. There is a credible argument that the increase in expectation of life will be greater than this [13]. If this proves to be the case, the effect would be higher numbers at the older ages than we observe in our projection. This would provide an even stronger argument in support of the long-term labour supply planning that we advocate here.

## 2.7 FUTURE LABOUR FORCE PARTICIPATION RATES

Australia's labour force grew from 5.4 million in 1970 to just over 10 million in 2003. Labour force growth has outstripped population growth over this period due in large measure to the substantial increase in the labour force participation of women.

Male labour force participation rates have declined at all ages since 1970. Most of the decline has occurred at older ages. For example, at age 60-64 years, participation has fallen from 79 per cent in 1970 to 50 per cent in 2003. Virtually all of this decline took place prior to 1980.

Female labour force participation rates have increased at all ages under 65 years since 1970. The biggest increases have been in the ages at which women traditionally left the workforce, temporarily or otherwise, to bear and rear children. Participation rates for women aged 25-54 years have risen by more than 30 percentage points since 1970. This is largely the result of both falling fertility rates and the increased labour force participation of married women and women with young children. Rates at older ages have also increased substantially as cohorts of women with a long attachment to the labour force continue to work into their 50s and 60s.

To project future labour force participation rates, we have taken the average of two possible future pathways. The first (low participation) pathway is derived from Australian Bureau of Statistics projections of labour force participation rates to 2016 [14]. In the ABS estimates, male participation rates decline slightly at all ages under 65 years. Female participation rates increase for all age groups 20-74 years. However, we have adjusted the ABS rates upwards to take into account recent increases in female participation rates at the older ages. The second pathway (high participation) is based on a 'best case' scenario of significantly increased participation rates for both men and women. Under this assumption, male rates at ages 25-64

[12] ABS, *Population Projections Australia, 2004 to 2010*, Australian Bureau of Statistics, Cat.No. 3222.0, Canberra, November 2005.
[13] Booth, H. and Tickle, L., *Beyond Three Score Years and Ten: Prospects for Longevity in Australia*, People and Place, Vol.12, No.1, 2004, pp.15-27.
[14] ABS, *Labour Force Projections, Australia, 1999 to 2016*, Australian Bureau of Statistics, Cat.No.6260.0, Canberra, September 1999.

years increase over the next 30 years to the Australian levels observed in 1970. Female participation rates at ages 25-64 years increase over the next 30 years to those observed in Denmark in 2003. The female participation rates for women are highest in the Nordic countries, but current Australian rates are also well below those in other English-speaking countries including New Zealand.

## 2.8 PROJECTION OUTCOMES

The results of our projection are summarised in Table 2.1. Australia's total population would rise to 31.2 million in 2050, roughly the same level as Canada today. The proportion of the population aged 65 years and over would rise to a maximum of 21.7 per cent around 2040 and then fall a little. This is an extremely favourable result in that it is much lower than the ageing levels that have been projected in other Australian projections and also much lower than the levels projected for most of Australia's international competitors. As discussed above, there is a chance that future expectation of life may be higher than we have used in this projection but this would only serve to add more weight to the other directions of the projection described here.

Under the assumptions of the projection, the Australian labour force would grow by 51 per cent between 2004 and 2050. We consider this to be a more desirable result for Australia than the current projections made by public agencies of 10-20 per cent increase in labour supply. Finally, although not designed with this target in mind, the projection would see Australia's total population growing by around one per cent per annum throughout the period of the projection. In the early years of the projection, about half the growth would be due to net migration but the contribution of migration rises to two-thirds by 2050. These growth rates compare with averages of 1.4 per cent in the 1970s, 1.5 per cent in the 1980s and 1.2 per cent in the 1990s.

Table 2.1 – Selected outcomes for the total population (permanent and temporary), 2004-2050

| | **2004** | **2010** | **2020** | **2030** | **2040** | **2050** |
|---|---|---|---|---|---|---|
| Population (millions) | 20.1 | 21.5 | 23.8 | 26.3 | 28.7 | 31.2 |
| Aged 65+ (per cent) | 13.0 | 14.2 | 17.6 | 20.5 | 21.7 | 21.6 |
| Labour force (millions) | 10.2 | 11.1 | 12.2 | 13.1 | 14.1 | 15.4 |
| | **2004-09** | **2014-19** | **2024-29** | **2034-39** | **2040-49** | **2050** |
| Average annual rate of population growth | 1.1 | 1.0 | 1.0 | 0.9 | 0.8 | 0.9 |

## 2.9 POPULATION DISTRIBUTION

Besides projecting the future national population, it is equally important to consider how the future population will be distributed across the nation. In another report for the Scanlon Foundation, we have done this by examining what had happened to settlement patterns in Canada as its population increased from 20 million to 31 million [15]. The comparison with Canada is justified because there are considerable similarities in the settlement patterns of the two countries and in their economies. In Canada, settlement patterns did not change much as the population increased by 11 million. No substantial new cities emerged. Growth was absorbed largely within the existing areas of settlement with the growth being somewhat larger outside the largest cities. In the same report, we discussed potential future settlement patterns in Australia. The conclusion from this research, taking into account what happened in Canada, was that relative population growth rates in the period 1986-2003 provided a reasonable indication of relative regional population growth rates in the future. On the basis of this assumption, we have estimated the population distribution of Australia in 2050 as shown in the second column of Table 2.2. Table 2.2 also compares our results with those of an Australian Bureau of Statistics projection (final column) that

[15] McDonald, P., *The Population Distribution of Australia in 2050: A Report Prepared for the Scanlon Foundation*, The Scanlon Foundation, Melbourne, 2005.

has a very similar population total. The ABS projection yields a total population for Australia in June 2051 of 31.4 million.

## Table 2.2 – Distribution of Australia's Population in December 2004 and 2050/2051

| Region | Population Dec 2004 ('000s) | Population June 2050 (McDonald and Kippen) ('000s) | Population June 2051 (ABS Series A)[16] ('000s) |
|---|---|---|---|
| Sydney | 4232.1 | 5851.6 | 6587.6 |
| Rest of NSW | 2527.9 | 3463.8 | 3005.6 |
| Melbourne | 3600.1 | 4864.1 | 5561.7 |
| Rest of Victoria | 1402.2 | 1645.1 | 1410.0 |
| Brisbane | 1774.9 | 3798.2 | 3776.9 |
| Rest of Queensland | 2144.6 | 4958.4 | 4317.0 |
| Adelaide | 1124.3 | 1249.2 | 1241.7 |
| Rest of South Australia | 413.6 | 417.7 | 373.8 |
| Perth | 1457.6 | 2783.3 | 2752.2 |
| Rest of Western Australia | 540.8 | 849.6 | 821.7 |
| Hobart | 202.1 | 215.4 | 240.1 |
| Rest of Tasmania | 281.9 | 266.0 | 312.1 |
| Australian Capital Territory | 324.3 | 491.2 | 538.0 |
| Darwin | 109.5 | 237.6 | 257.1 |
| Rest of Northern Territory | 91.3 | 108.7 | 197.2 |
| Australia | 20,227.2 | 31,199.9 | 31,392.7 |

The table shows that we project much smaller future populations for Sydney and Melbourne than does the ABS. The results are very similar for Brisbane, Perth and Adelaide. This means that, compared to the ABS projections, our projections distribute people from the two largest cities to areas outside the major cities, principally to the 'rest of state' parts of New South Wales, Victoria and Queensland.

More speculatively, Table 2.3 shows sub-regional population estimates for regions outside of the capital cities based upon a consistent methodology[17]. The results show some potentially challenging futures, especially in relation to south-east Queensland. In broad terms, the projections show that most of the additional 11 million people in Australia by 2050 would be located in four major agglomerations: Sydney/Hunter/Illawarra, Melbourne/Barwon/Central Tablelands/Loddon, south-east Queensland and Perth/Peel/south-west.

[16] ABS, *Population Projections, Australia, 2002-2101*, Australian Bureau of Statistics, Cat.No.3222.0, September 2003, p.44. This projection has the same fertility rate as assumed in our projections but lower migration and higher expectations of life.
[17] Maps and extensive description of these regions are provided in National Economics and the Australian Local Government Association, *State of the Regions Report 2003-2004*, National Economics, Melbourne, November 2003.

## Table 2.3 – Projected Sub-Regional Population Totals in 2050 – five states

| State and Region | Population ('000) | |
|---|---|---|
| **New South Wales** | **2003** | **2050** |
| Central West | 179.1 | 200.9 |
| Far and North-West | 143.7 | 127.7 |
| Hunter | 599.4 | 824.3 |
| Illawarra | 410.8 | 672.7 |
| Mid-North Coast | 287.0 | 443.7 |
| Murray | 114.4 | 125.4 |
| Murrumbidgee | 153.1 | 160.5 |
| North | 180.0 | 177.6 |
| Richmond–Tweed | 220.7 | 337.8 |
| South-East | 198.7 | 393.2 |
| | **2486.9** | **3463.8** |
| **Victoria** | | |
| Goulburn | 198.6 | 272.8 |
| Barwon | 263.6 | 397.0 |
| Central Highlands | 144.3 | 173.0 |
| Gippsland | 243.7 | 258.3 |
| Loddon | 170.9 | 226.3 |
| Mallee–Wimmera | 142.4 | 122.8 |
| Ovens-Hume | 94.8 | 110.3 |
| West | 101.0 | 84.7 |
| | **1359.3** | **1645.2** |
| **Queensland** | | |
| Agricultural SW | 215.9 | 329.8 |
| Far-North | 233.9 | 345.4 |
| Fitzroy | 184.4 | 178.4 |
| Gold Coast | 804.4 | 2175.0 |
| Mackay | 129.0 | 144.2 |
| North and North-West | 241.0 | 301.6 |
| Pastoral | 39.7 | 42.9 |
| Sunshine Coast | 262.8 | 910.1 |
| West Moreton | 184.3 | 222.7 |
| Wide–Bay–Burnett | 242.4 | 308.4 |
| | **2537.8** | **4958.5** |
| **South Australia** | | |
| SA Eyre and Yorke | 163.0 | 219.6 |
| SA Murraylands | 68.4 | 103.6 |
| SA South-East | 63.0 | 94.5 |
| | **294.4** | **417.7** |
| **Western Australia** | | |
| Gascoyne–Goldfields | 115.2 | 67.3 |
| Peel–South-West | 216.2 | 571.6 |
| Pilbara–Kimberley | 73.5 | 95.2 |
| Wheatbelt Great South | 126.5 | 115.5 |
| | **531.4** | **849.6** |

# CHAPTER 3
# Climate variability and change

I love a sunburnt country
A land of sweeping plains,
Of rugged mountain ranges,
Of droughts and flooding rains

**Dorothea Mackellar, My Country, 1908**

## SYNOPSIS

**Australia's climate should not be a barrier to the population reaching 30 million by 2050**. In the future, as the population and the economy grow, Australia will have the ability to sustain a larger population than was previously the case when the Australian economy was based mostly on primary industry.

In 1911, based on a comparison of the climate and development between the US and Australia, Griffith Taylor predicted that Australia's population would be 19 million at the end of the 20th Century – a pretty good 90-year forecast. The climate constraint is not only due to much of the country being semi-arid with an annual rainfall below 400 mm, but also due to the large year-to-year variability of the rainfall across most of the country.

Most of the population of Australia lives within100 kilometres of the coast, where there is sufficient reliable rainfall to support large urban societies. Agriculture and pastoral development in some regions has been limited by the variability of the rainfall, although the annual mean value would normally be considered sufficient for farming in those regions.

It has taken many decades for modern societies to learn how to manage the variability of the climate. The general nature of the large-scale drivers of Australian climate is now well understood and documented. The main driver of the high variability of our climate is the El Niño – Southern Oscillation (ENSO), which involves large-scale interactions between the tropical oceans and atmosphere. Other phenomena also affect our climate, including the tropical monsoon circulation in the north of the country and the large-scale circulation of the polar vortex in the south. The dominance of the ENSO phenomenon is demonstrated by the historically high correlation between an El Niño event and national-scale drought in Australia.

Each El Niño event tends to follow a cycle that extends over about a year, and this behaviour means that there is some capacity to predict the evolution of large-scale drought in Australia. Such predictability provides a means to manage the variability of our climate. While there has been some progress in the development of computer-based models to predict seasonal climate variations, there is a continuing international effort to extend this capability and so improve our ability to manage the impacts of climate variations.

The high variability of Australian climate affects a range of human activities, including the location of our urban areas and the occurrence of vector-borne diseases such as Australian encephalitis. Water-storage dams in Australia have a larger capacity and take longer to fill than dams in countries with less variability. The large inter-annual variability of Australian climate has been a driver of unique flora and fauna that optimises the occurrence of infrequent heavy-rainfall events.

Thus, Australian climate has an inherent uncertainty associated with the variability of our rainfall due to ENSO. In recent decades, this uncertainty is being compounded by global climate change associated with increasing concentrations of greenhouse gases in the atmosphere. There is evidence of an underlying trend of increasing temperature on global and continental scales (including Australia) that can be scientifically linked to the enhanced greenhouse effect. Moreover there is now accumulating evidence of the regional impacts of such climate change on natural and human systems. For example, while the rainfall deficit during the major drought of 2002 was comparable with that in earlier droughts (such as 1982 and 1994), the daily maximum temperature was nearly a degree warmer than during past droughts. The observed trend of increasing daily temperatures during drought periods is expected to lead to increased heat stress on humans, agriculture and natural ecosystems.

It now seems very certain that climate change has affected, and will affect Australia in the period to 2050 and beyond. This will require adaptation responses and the consequent planning and provision of appropriate infrastructure. Specific aspects are dealt with later in this report, in respect of water, energy and infrastructure.

As societies become increasingly averse to risk, governments continue to refine policies aimed at reducing societal vulnerability to hazards, including drought and climate change. As the nature of drought in Australia is expected to be affected by climate change, policy options for managing these two climate features will need to be coupled in the future. Indeed climate change is expected to impact on a range of sectors in Australia, including water availability, human health, energy, agriculture and disaster management. In order to manage these sectors responsibly, it will be necessary for policy development to include actions to account for climate variability and change.

In addition, international policy development will be desirable to limit climate change itself through cooperative mitigation strategies. These strategies can vary from investments in technologies that may limit the overall emission of greenhouse gases to economic instruments, such as the trading of carbon emissions.

International policy development is needed not just for the establishment of mitigation strategies, but also to allow Australia to adapt to global-scale impacts of climate change. For example, our competitive edge in crop production may be affected by climate-driven changes in crop yield in other countries. Sea-level rise may lead to emigration from small island states in our region, and so impact on Australia's immigration policies.

It is expected that the compounding effects of climate change and variability will lead to substantial uncertainties in the future development of Australia, and so careful policy development and continuing research will be required to manage these uncertainties as the population increases over the next 50 years.

## 3.1 INTRODUCTION

It has long been recognised that the climate of Australia has cast a constraint on the development of the nation. A hundred years ago Griffith Taylor [18] wrote that countries with "unfavourable climates have small populations and little commerce". Indeed, by comparing the climate and rate of development of the US with those of Australia, he estimated that "Australia should have a population of some 19,000,000 white (sic) people at the end of the century". The accuracy of this estimate alone highlights the importance of climate in any consideration of the future population of Australia, the land of "droughts and flooding rains".

Taylor [19] points out that the US , with a comparable overall area to Australia, has about four times as much land with a "well-watered temperate" climate. However, Australia's climate is made harsher by its variability from year to year. Comparison across countries shows that the inter-annual variability of Australian rainfall is much greater than that of most other countries with similar mean annual rainfall [20].

[18] Taylor, G., *Australia in its Physiographic and Economic Aspects*, Oxford, Clarendon Press, 1911, 256pp.
[19] *ibid*
[20] Nicholls, N., *El Niño-Southern Oscillation and Rainfall Variability*, Journal of Climate, Vol.1, American Meteorological Society, Boston, US, 1988, pp.418-42.

Similar variability is found only in countries like South Africa that are significantly affected by the ENSO phenomenon. The irregular fluctuations between floods and droughts have limited the development of agriculture and pastoral farming in Australia even in regions with adequate mean annual rainfall.

After more than a century of experience, the development of Australian industry and commerce is starting to account for the harshness and variability of our climate. However, the Intergovernmental Panel on Climate Change (IPCC) has pointed out in its Third Assessment Report [21] that the global climate is changing and that a substantial component of the change can be associated with human activities, especially with an enhancement of the natural greenhouse effect of our atmosphere due to the additional release of gases such as carbon dioxide. There remain significant uncertainties in the extent and impact of climate change in the future, especially at regional scales. However, given the sensitivity of Australian development to our inherent climate and its variations, climate change imposes an additional level of uncertainty on our future planning.

In this chapter, the nature of Australian climate and the impacts of our climate on the natural and social features of the country are briefly reviewed. Against this background, the scientific basis of global climate change is then considered by drawing largely on the assessments of the IPCC, which was established jointly by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) in 1988 to be the international authority on climate change, including the science, the impacts and possible response strategies.

The inherent uncertainty in future estimates of climate change means that estimates of climate change impacts have a second-order level of uncertainty. Nonetheless, it is possible to draw on IPCC and other sources to consider potential impacts of future climate change in Australia. Based on the range of potential impacts of climate change, some policy questions associated with future climate change are also considered. Policy actions can be categorised essentially as being aimed at either mitigation or adaptation.

Over that last decade, much international focus has been on policy options for the long-term mitigation of the impacts of the enhanced greenhouse effect. However, as direct signs of climate change are becoming apparent, there is now a significant focus on policies associated with short to medium term adaptation to climate change. The chapter is closed with a summary of the conclusions reached on the role of climate change and variability on the population of Australia in 2050.

## 3.2 AUSTRALIA'S CLIMATE AND ITS IMPACTS

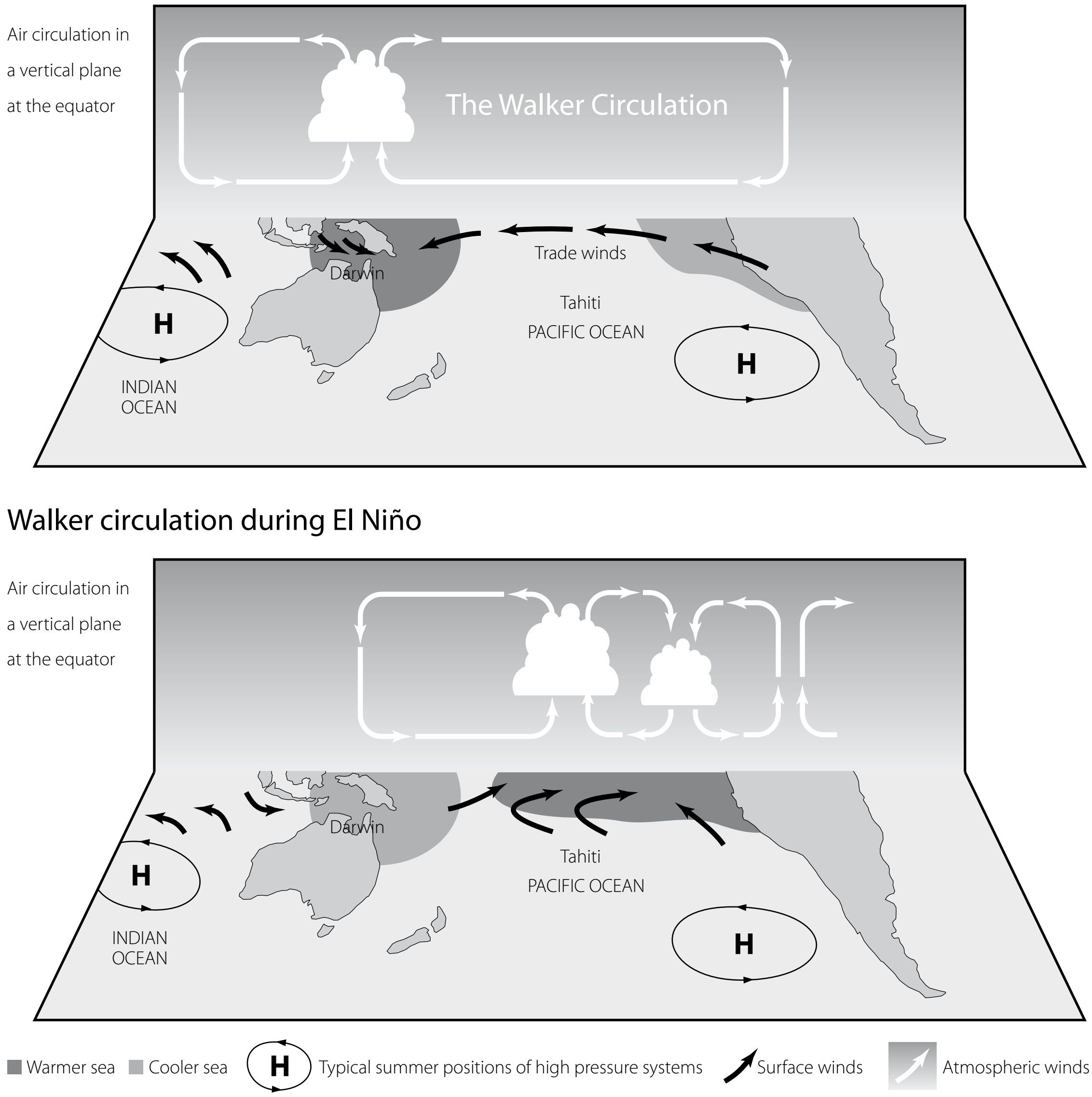
### 3.2.1 Large-scale influences on Australian climate

Australia is a largely flat, semi-arid island continent extending across about 30 degrees of latitude. It is isolated in the southern hemisphere and is greatly affected by the surrounding oceans. The north of Australia experiences a classical monsoon climate, with a dry winter and wet summer as the cloud mass of the Asian monsoon progresses with the annual solar cycle. Associated with the global belt of cloud of the monsoon, known as the Inter-Tropical Convergence Zone (ITCZ), is a meridional circulation with rising air in the cloud belt due to the release of latent heat by cloud formation and with sinking air in the sub-tropics. The semi-arid regions of Australia are influenced by the warm subsiding air of this meridional circulation, called the Hadley Cell. The earth's rotation gives rise to Coriolis forces, which act on the Hadley Cell to generate the easterly trade winds that prevail over much of the tropics and sub-tropics.

In summer the northern parts of Australia can receive a substantial fraction of their annual rainfall from tropical cyclones. About 10 tropical cyclones develop off the coast each year, and about six of them move on to the coast. As they move inland, the tropical cyclones weaken into tropical depressions, which can also have destructive winds and flooding rains.

[21] IPCC, *Climate Change 2001: The Scientific Basis, Summary for Policymakers and Technical Summary of the Working Group I Report*, World Meteorological Organisation and United Nations Environment Program, Cambridge University Press, Cambridge, United Kingdom, 2001, 98pp.

Figure 3.1 – Typical Walker circulation pattern




**Source: Bureau of Meteorology**

The major storm tracks of the southern hemisphere tend to extend around the Southern Ocean to the south of Australia, and so southern Australia is affected by the continual passage of cold fronts especially in the winter months. A feature of the interaction between the weather of the tropics and that of the sub-tropics and mid-latitudes is an occasional burst of moist tropical air extending from the north-west across to the south-east of Australia. These North-West Cloud Bands bring a significant fraction of winter rainfall to much of the country.

The North-West Cloud Bands are influenced by the pattern of sea-surface temperature in the Indian Ocean. Indeed the detailed distribution of sea-surface temperature of the oceans has a significant impact on Australia's rainfall. Warm temperatures in the Tasman Sea can promote the development of intense low-pressure systems, known as East Coast Lows, which can bring gale-force winds and heavy rain to the coastal regions of NSW. These systems can be compared with tropical cyclones, and about one occurs each winter.

The dominant pattern of sea-surface temperature affecting Australia is that associated with the ENSO. The ENSO phenomenon involves a large-scale interaction between the tropical oceans and atmosphere, and it is the cause of much of the inter-annual variability of climate in the tropics and sub-tropics. The atmospheric component of ENSO is the Walker Circulation [22], in which latent heat from storm clouds

[22] Walker, G.T., *Correlations in Seasonal Variations of Weather IX. A Further Study of World Weather*, Mem. Indian Meteorological Department. 24, 1924, pp.275-332.

over the Indonesian archipelago induces air to rise and flow eastward at high levels across the Pacific. The circulation is closed by sinking air in the eastern Pacific and a low-level return flow from the east, as shown in Figure 3.1. The Southern Oscillation refers to the strength of the Walker Circulation. An El Niño event occurs when the Circulation is weak, and the storm area of the western Pacific moves eastward. Major droughts in Australia are usually associated with El Niño events. A La Nina event is when the Circulation is abnormally strong, with enhanced rain activity (leading to floods) in the Indonesia – north Australia region.

The ocean component of ENSO is apparent in the upper layers of the Pacific Ocean. The warmest waters in the world occur in the Indonesian archipelago, and these high sea-surface temperatures (SSTs) drive the storms associated with the Walker Circulation. During an El Niño event, the warm SSTs move to the east and so move the storm areas eastward, as shown in Figure 3.1.

While the primary action of ENSO is across the Pacific, its impact is felt on a global scale. Indeed the effects of ENSO often mask (or enhance) the weaker influences of the Indian Ocean and Southern Ocean on Australian climate.

The climate of southern Australia is influenced by variations in the large-scale circulation of the polar vortex in the southern hemisphere. The strength of this circulation is estimated by an index known as the Southern Annular Mode (SAM), which varies on a multi-year scale. Recent research suggests that the rainfall of southern Australia is influenced by the strength of the SAM.

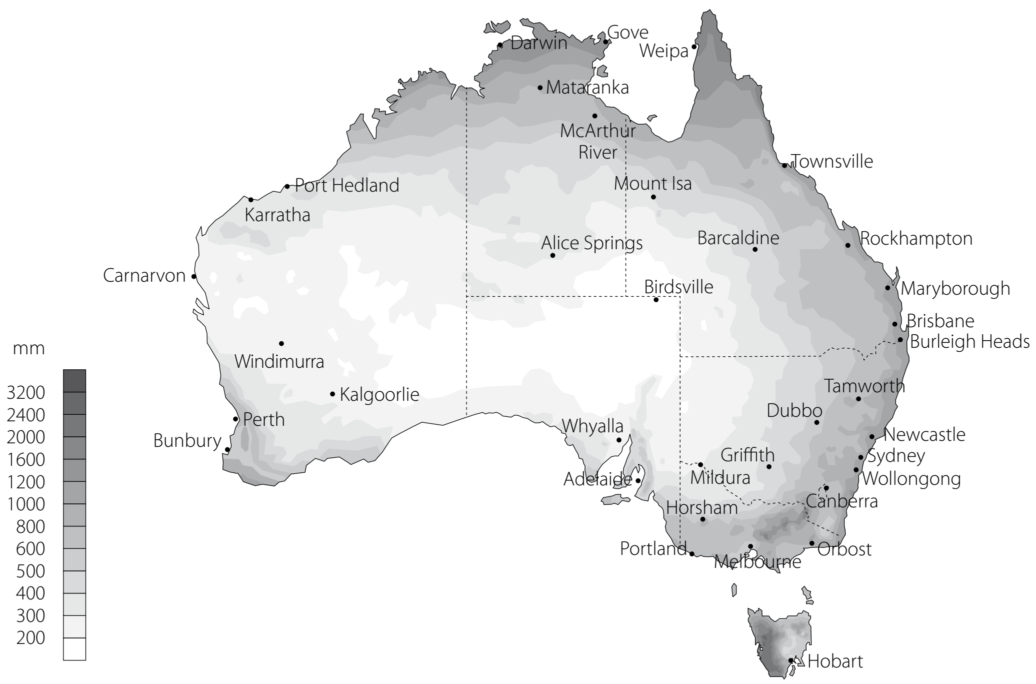
Another index of large-scale climate variability is the Pacific Decadal Oscillation (PDO), which accounts for multi-year variations in the Pacific Ocean. The PDO appears to be linked to decadal-scale modulation of ENSO, but it is unclear whether the modulation is physically-based and predictable or simply the result of random internal fluctuations of the climate system.

### 3.2.2 Climatology of Australia

It is apparent that the climate of Australia is influenced by many factors. The overall climatology of the continent can be considered against these features. Figure 3.2 shows the mean annual rainfall distribution across Australia.

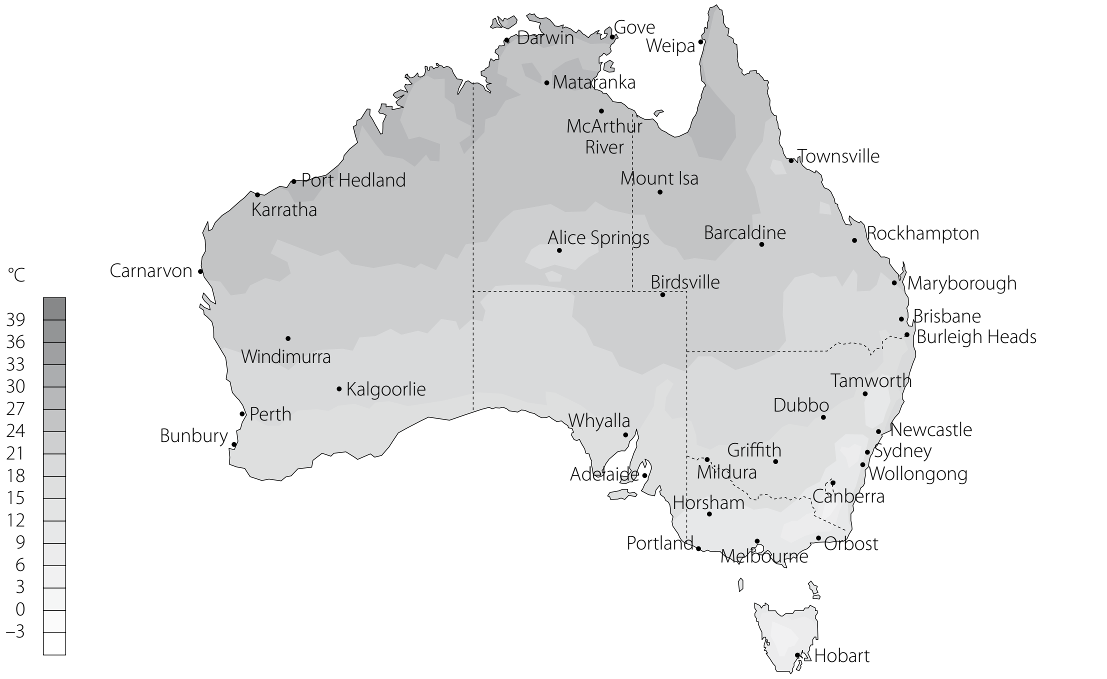
It is apparent that the regions with rainfall above 500mm/year are confined to the south, east and

Figure 3.2 – Mean annual rainfall across Australia



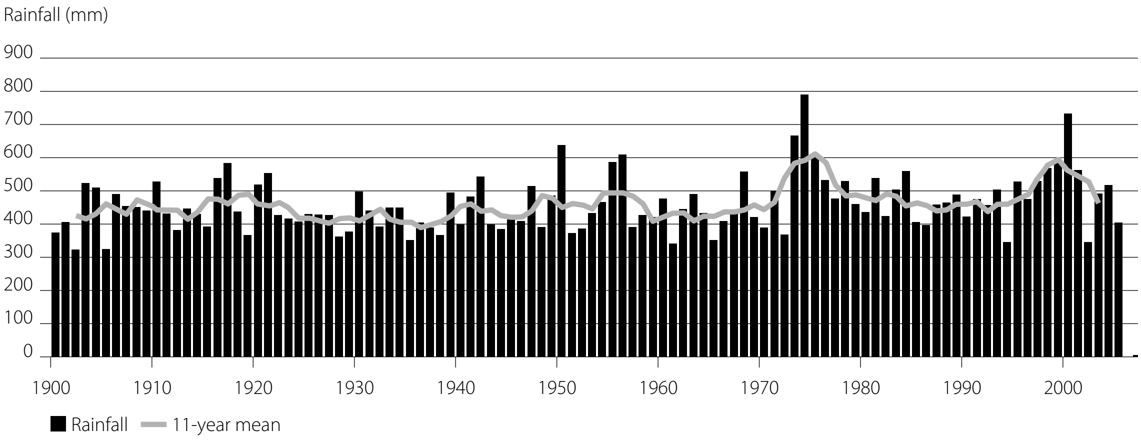

Source: Bureau of Meteorology

Figure 3.3 – Mean daily temperature across Australia




Source: Bureau of Meteorology

Figure 3.4 – Annual rainfall for Australia




Source: Bureau of Meteorology

north coastal areas of the continent. The rainfall has its maximum in the summer in the northern parts of the country largely under the influence of the summer monsoon, while the southern parts have a winter rainfall maximum associated with the passage of mid-latitude frontal systems.

Figure 3.3 depicts the distribution of mean daily temperature across Australia. In the north of the country, the mean temperature varies almost zonally indicating the effect of incoming solar radiation. On the other hand, comparison of Figures 3.2 and 3.3 in the south indicates the correlation between rainfall and temperature. This correlation reflects the shading effect of cloud to reduce the day-time maximum temperature in regions of higher rainfall.

Figures 3.2 and 3.3 indicate the mean climate of the country. However, under the influence of ENSO there is substantial inter-annual variability, as shown in Figure 3.4. The annual rainfall is seen to range from 317 mm in 1902 to 785 mm in 1974. The black curve in Figure 3.4 also demonstrates that there is significant decadal-scale variability in rainfall.

The years of very low rainfall are almost invariably associated with El Niño events, such as 2002-03, 1994-95 and 1982-83. It is interesting to note that the most severe El Niño event of the 20th century occurred in 1997-98 when the Australian rainfall was about average. However, the average rainfall was reached only because of some good spring rains that broke a preceding dry spell.

### 3.2.3 Impacts of Australian climate

The obvious impact of climate on the Australian population is that most people live within 100 kilometres of the coast. Nicholls [23] points out that the climate has had a major influence on the development of many aspects of its culture. Aboriginal communities had learned to understand and adapt to the variations in Australian climate when European settlers arrived, but it took many decades for the new settlers to understand the constraints imposed by the climate. It is now understood that the climate extremes of ENSO can affect human health, for example through outbreaks of arbovirus diseases during La Niña events. Nicholls also notes that anterior cruciate ligament injuries in Australian Rules Football occur more frequently on the hard ground in dry conditions, and that there was a five-fold increase in the occurrence of these injuries in Melbourne during the El Niño event in 1997.

The variations associated with ENSO have affected not only human life in Australia but also the flora and fauna [24]. It is apparent that ENSO must have been acting for thousands of years in order for adaptations such as the breeding habits of the red kangaroo to have evolved naturally.

While noting the importance of temperature, Taylor [25] stated that "most people do not realise that rainfall is of paramount importance for all industries except mining". He recognised that the orography of Australia, with few regions over one kilometre in elevation that could help generate downstream rainfall by lifting moist air streams, also contributed to the low rainfall and hence to the 40 per cent of semi-arid area. Through the adaptation of farming practices to the Australian climate, primary industries in suitable areas have become a major source of export revenue for Australia. However, inter-annual fluctuations in national crop production are generally well correlated with rainfall and hence with the strength of the Walker Circulation.

Farming has not always been carried out in the most suitable areas. At the time of a major drought in 1865, the Surveyor General of South Australia, George Goyder, was sent out to assess the region around Adelaide that was suitable for agriculture. Based on several surveys (but no historical rainfall data) he defined a line (the Goyder Line) north of which the land was deemed to be suitable only for grazing. Under the belief that "rain follows the plough", the government allowed farming north of the Goyder Line in the early 1870s as the population of South Australia grew rapidly. Wheat growing appeared to be successful north of the Line during the 1870s, but the extended drought of the early 1880s led to the abandoning of many settlements and the reinstatement of the Goyder Line policy.

A consequence of Australia's low rainfall and high temperatures is that the river runoff is also low compared with other continents. The non-linear relationship between rainfall and river runoff means that the inter-annual variability in runoff is extremely large. Consequently the capacity of Australia's water storage dams needs to be much greater than that in other countries, where dams can be refilled in weeks rather than years.

Australia's climate is relevant to both the sources and sinks of energy. The relatively steady winds along the southern coast of the country are increasingly being used as a source of energy feeding into the national electricity grid. It is also recognised that the inland regions have relatively high solar insolation and so they could be suitable for direct solar energy sources. Some crops, such as sugar cane, can be used as indirect sources of energy through ethanol production. While the Snowy Mountains hydro-electricity system has proved to make a valuable addition to the national grid, the low rainfall and runoff of the continent means that hydro-electricity cannot be a substantial source of energy for the country.

The major factor in the determination of irregular variations in the load on the national electricity

[23] Nicholls, N., *Climate and Culture Connections in Australia*, Australian Meteorological Magazine, Vol.54, No.4, December 2005.
[24] Nicholls, N., *How old is ENSO?*, Climatic Change, 14, 1989, pp.111-115.
[25] Taylor, G., *Australia in its Physiographic and Economic Aspects*, Oxford, Clarendon Press, 1911, 256pp.

grid is the weather. The National Electricity Market Management Company (NEMMCO) finds that the extreme summer load can be up to about 10 per cent above the average summer load due to extremely hot days [26]. Moreover difficulties in forecasting future annual demand are primarily associated with uncertainties in the daily summer temperatures [27].

In Australia the weather is the major cause of losses from natural disasters as defined by Emergency Management Australia (EMA). (The EMA definition does not include sustained natural disasters such as drought, and so the following figures under-estimate the total cost of natural disasters from meteorological roots.) For the period 1967 to 1999, 18 per cent of the total cost of natural disasters was due to just two extreme weather events: Cyclone Tracy in 1974 and the Sydney hailstorm of 1999 [28]. The only other disaster of comparable magnitude was the Newcastle earthquake of 1989 which accounted for 13 per cent of the total cost. The most frequent and most costly annual causes of natural disasters are weather-related. There is very large inter-annual variability in the number and magnitude of disaster costs, but there is no statistically significant trend in either the number or magnitude in the period 1967-1999.

Table 3.1 – Costs and human losses associated with weather-related natural disasters in Australia over the period 1967-1999 [29]

| Type | Mean Annual Cost ($M) | % Total Mean Annual Cost | Total No. of Deaths | Total No. of Injuries |
|---|---|---|---|---|
| Flood | 314 | 29 | 99 | 1019 |
| Storms | 284 | 26 | 58 | 942 |
| Tropical Cyclones | 266 | 25 | 154 | 958 |
| Bushfires | 77 | 7 | 223 | 4185 |

Table 3.1 summarises the relative costs and losses due to each type of weather-related natural disaster. It is apparent that, while floods cause the most damage to property, bushfires tend to cause more deaths and injuries to people. Over all causes of natural disasters, the four events causing the most human loss (death and injury) were weather-related: the Ash Wednesday bushfires of 1983, Cyclone Tracy of 1974, the Brisbane floods of 1974, and the Tasmanian bushfires of 1967.

It is clear that the substantial inter-annual variability of Australia's climate impinges on most natural and human activities across the country. The natural systems have generally adapted to this variability while some human systems are still learning to adapt.

## 3.3 GLOBAL CLIMATE CHANGE

Climate change in this report follows the definition of the Intergovernmental Panel on Climate Change (IPCC), and it is defined as "any change in climate over time, whether due to natural variability or as a result of human activity". This definition contrasts with that of the Framework Convention on Climate Change (FCCC) where climate change is associated specifically with human activity. The IPCC definition allows one to clearly separate the function of detection of a climate change from that of attribution of a cause (human or natural) to a detected climate change.

As noted earlier, the IPCC was established in 1988 to provide the authoritative forum for the assessment of the science of climate change, the impacts of climate change, and the possible response strategies to manage climate change impacts. Since that time it has completed three formal assessment reports and it is now preparing the Fourth Assessment Report, due for publication in 2007. The Third Assessment Report (TAR) was published in 2001, and it will be a primary source for this chapter.

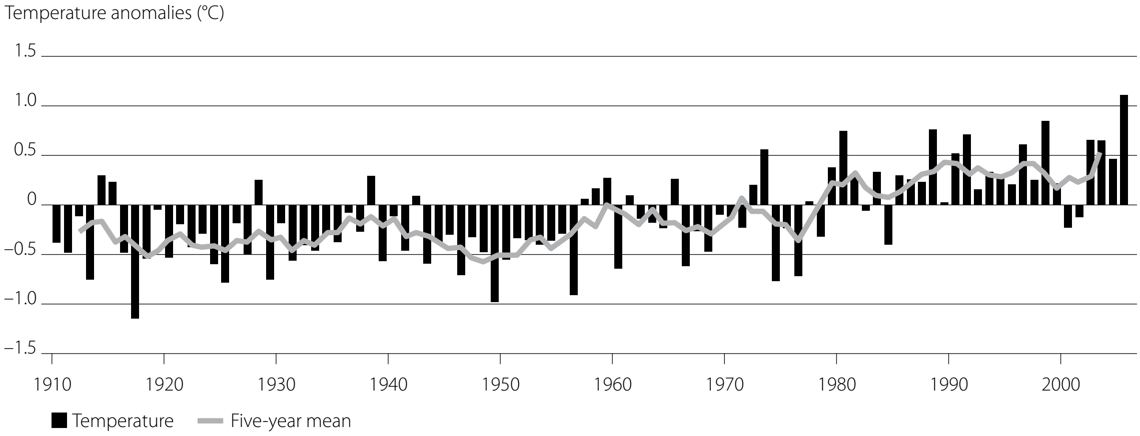
[26] NEMMCO, *Australia's National Electricity Market 2005 Energy and Demand Projections, Summary Report*, NEMMCO, July 2005, 20pp.
[27] NIEIR, *An Assessment of the Forecasting Accuracy of the Current Summer MD Forecast Methodology for Victoria and South Australia: A Backcasting Exercise*, National Institute of Economic and Industry Research, Clifton Hill, Victoria, June 2006,18pp.
[28] BTRE, *Economic Costs of Natural Disasters in Australia*, BTRE Report 103, Bureau of Transport and Regional Economics, Commonwealth Government, 2001, 170pp.
[29] *ibid*

Indeed it is useful to quote the key findings in the Summary for Policymakers of the TAR[30]:

- an increasing body of observations gives a collective picture of a warming world and other changes in the climate system;
- emissions of greenhouse gases and aerosols due to human activities continue to alter the atmosphere in ways that are expected to affect the climate system;
- confidence in the ability of models to project future climate has increased;
- there is new and stronger evidence that most of the warming observed over the past 50 years is attributable to human activities;
- human influences will continue to change atmospheric composition throughout the 21st century;
- global average temperature and sea level are projected to rise under all IPCC SRES[31] scenarios;
- anthropogenic climate change will persist for many centuries; and
- further work is required to address remaining gaps in information and understanding.

Research since 2001 has continued to confirm these findings. It is now appropriate to consider each one of the findings and its relevance to Australia.

Figure 3.5 – Annual mean temperature anomalies for Australia - departures from 1961-1990 mean




Source: Bureau of Meteorology

### 3.3.1 Observations of climate change

The TAR noted that the mean global surface temperature has increased by over 0.6°C over the 20th century. Since the publication of the TAR, the global surface temperature has continued to be above the 1961-1990 average. The global temperature for 2005 was 0.47°C above the average, with 1998 keeping the record as the warmest year since 1850 with a temperature of 0.52°C above the average. It is worth noting that 1998 corresponded to the largest recorded El Niño event (which leads to high global temperatures), while there was no El Niño during 2005. For Australia, 2005 was the warmest year on record, beating the 1998 temperature by the huge margin of 0.25°C. Figure 3.5 shows that the surface temperature across Australia has increased by about 1°C over the past century.

Globally the five warmest years since 1850 are in order 1998, 2005, 2002, 2003 and 2004. It is worth noting that the global mean temperature is computed by considering both the land and sea-surface temperatures; both the land and the ocean (where there are clearly no urban "heat island" effects) have been found to warm. Moreover, as flaws in the earlier satellite analyses and in the analysis of balloon soundings have been corrected, it is now apparent that there is warming in the free atmosphere consistent with that found at the surface.

In addition to direct measurements of temperature, there are many other indicators of a global

[30] IPCC, *Climate Change 2001: The Scientific Basis, Summary for Policymakers and Technical Summary of the Working Group I Report*, World Meteorological Organisation and United Nations Environment Program, 2001, 98pp.

[31] IPCC, *Emission Scenarios*, A Special Report of Working Group III of the Intergovernmental Panel on Climate Change Special Report, Cambridge University Press, Cambridge, United Kingdom, 2000, 599pp.

warming. In recent decades there has been a decline in the extent of sea ice in both the Artic and Antarctic. It is also apparent that most of the world's glaciers are retreating. In Australia, warmer temperatures are causing the snow in the Snowy Mountains to melt more quickly than in the past, and so the snow depth in October has decreased by 40 per cent over the past 40 years [32].

Most places in Australia do not show simple linear trends in rainfall and temperature over the last century. South-western Australia is the one region where there has been essentially an upward trend in maximum and minimum temperature and a downward trend in rainfall. On the other hand, rainfall across the Murray Darling Basin (MDB) tended to increase in the first half of the 20th century and then to decline in the second half. Because there is generally a negative correlation between maximum temperature and rainfall, maximum temperature in the MDB tended to decrease in the first half of the century and then increased steadily. The minimum temperature in the MDB tended to rise throughout the century. Thus, regional climate variations need to be studies carefully in order for them to be fully understood.

### 3.3.2 Emissions of greenhouse gases and aerosols

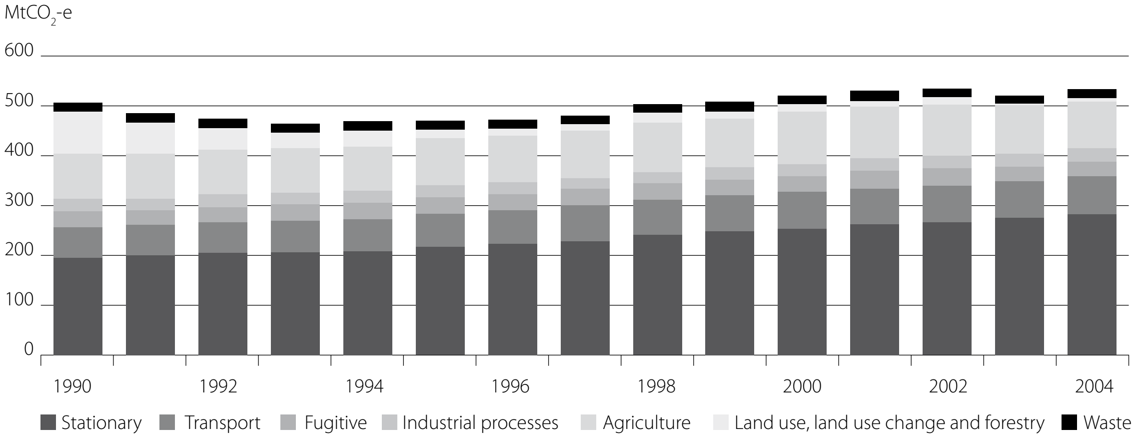
The natural greenhouse gases such as water vapour and carbon dioxide ($CO_2$) absorb infra-red radiation from the surface of the earth. Some of the absorbed radiation is re-radiated back to the surface, leading to a warming of the surface. This is the natural greenhouse effect, which warms the surface of the earth by about 30°C. The same phenomenon keeps the surface of Venus at a temperature about 520°C hotter than it would be in the absence of very high levels of $CO_2$.

There is clear evidence from a range of measurements that the concentration of greenhouse gases associated with human activities has continued to rise in the atmosphere since the beginning of the industrial revolution. Australian scientists continue to make major contributions to the international effort to carefully measure the current and past concentrations of greenhouse gases (for example, Ferretti *et al* [33]. ). They particularly analyse observations from the Cape Grim monitoring station in Tasmania that is jointly managed by the Bureau of Meteorology and CSIRO.

Estimates of past concentrations of greenhouse gases are obtained from measurements of gases trapped in air bubbles in ice in the Arctic and Antarctic. From these it is found that the concentration of $CO_2$ has increased by more than 30 per cent since 1750, and the present concentration has not been exceeded over at least the past 420,000 years (that is over the last three glacial to inter-glacial cycles).

Figure 3.6 shows the time series of greenhouse gas emissions in Australia over the period 1990 to

### Figure 3.6 – Australia's greenhouse gas emissions




**Source: Australian Greenhouse Office, 2005**

[32] Nicholls, N., *Climate Variability, Climate Change, and the Australian Snow Season*, Australian Meteorological Magazine, 54, 2005, pp.177-185
[33] Ferretti, D.F., Miller, J.B., White, J.W.C., Etheridge, D.M., Lassey, K.R., Lowe, D.C., MacFarling Meure, C.M., Dreier, M.F., Trudinger, C.M., van Ommen, T.D. & Langenfelds, R.L., *Unexpected Changes to the Global Methane Budget Over the Past 2000 Years*, Science, 309, 2005, pp.1714-1717.

2003. The values shown are millions of tonnes of $CO_2$ equivalent ($CO_2$-e), which accounts for the relative contributions of other gases, such as methane and nitrous oxide, to global warming. The concept has been developed under the FCCC with scientific input from the IPCC. It is apparent from Figure 3.6 that Australia's emissions have increased by about one per cent since 1990, and that a 30 per cent increase in energy-related emissions has been offset by a 72 per cent reduction in land-use emissions (especially a reduction in deforestation). Australia's emissions per capita have declined by 13 per cent and its emissions intensity (emissions per dollar of real GDP) has declined by 33 per cent over the period 1990 to 2003 (Australian Greenhouse Office).

Aerosols associated with human activities, such as biomass burning and fossil fuel burning, tend to mask the warming effects of the greenhouse gases by reflecting solar radiation back to space. The aerosols also affect the microphysical properties of clouds, impacting on their radiative properties and on their ability to precipitate. Unlike the long-lived greenhouse gases, aerosols are generally washed out of the atmosphere within a few days so that their impacts tend to occur locally. However, the extent of aerosol emissions in the northern hemisphere has been so large that there is a net global impact. As countries improve their air quality, the concentration of aerosols will decrease. Aerosol levels in Australia, and across the southern hemisphere, are generally not substantial.

### 3.3.3 Climate modelling

Climate models are computer programs that use mathematical techniques to solve the formal physical equations for the conservation of heat, mass, momentum and other quantities across the globe. The numerical techniques, which are also applied to provide daily weather forecasts, essentially involve dividing the atmosphere (and ocean and land) into boxes, and the exchange of heat, mass, momentum, etc between neighbouring boxes is calculated. The boxes may have a horizontal size (or resolution) of about 100 kilometres for a global climate model. Starting with a specified initial state of the climate system, the exchanges between boxes are stepped forward in time in steps that may vary from a few minutes to hours. The precision and accuracy of model results generally are increased by decreasing the size of the boxes and decreasing the time steps. There is always a trade-off between precision and the elapsed time for the computer calculation to be completed. High-resolution climate experiments may run for months on the largest supercomputers.

Models are also limited by the imperfect representation of small-scale processes that occur within the model "boxes". These "sub-grid-scale" processes, such as turbulence and clouds, are represented by sub-models that link these processes to the primary variables of the model. There is continuing international research to improve these sub-models or parameterisations.

Over the past 15 years the scientific community, largely under the auspices of the World Climate Research Program [34], has developed protocols and methods to assure the quality of models through strict inter-comparison with observations and to measure progress in model accuracy through monitoring of indices of model skill. Global climate models from both CSIRO and the Bureau of Meteorology Research Centre in Australia have been involved in these studies. A clear message from the inter-comparisons is that there is no overall best model, rather each good model tends to have some features that are represented better than in other good models. The continuing interchange of ideas and even computer code between modelling groups around the world ensures that there is steady progress in model skill. In Australia the process of collaboration is being taken to a high level by the development of the Australian Community Climate and Earth System Simulator (ACCESS) as a joint project between the Bureau of Meteorology and CSIRO. The university community will also be involved in ACCESS through the ARC Network on Earth System Science.

While the simulation of large-scale features of the climate system are reasonably well represented by current climate models, there is increasing uncertainty in simulations as the scale of the region of interest is reduced. The difficulty in simulating and predicting regional and local scale features arises

[34] World Climate Research Program. (www.wmo.ch/web/wcrp/wcrp-home.html)

from two primary causes. The first cause is the uncertainty associated with the limited resolution of models and the representation of sub-grid-scale processes, as described above. However, a major cause of uncertainty in modelling is that the climate system is inherently chaotic; that is, even if a model is perfect, the non-linearity of the system means that any error or uncertainty in the initial state of the system or in the specification of external forcings (such as variations in solar radiation) will grow with time. A consequence of the chaotic nature of the climate system is that, rather than running a model once to get a "best estimate", an ensemble of model runs (or even an ensemble of different model ensembles – a super-ensemble) is taken to provide an estimate of the expected probability distribution of the future climate state.

The inherent variability of the climate system increases as the scale of interest is decreased, and so natural fluctuations in the climate system tend to act as "noise" and to mask any "signal" associated with forcings such as an increase in greenhouse gases. Different techniques are being developed to estimate regional features of the climate system, while accounting for the inherent uncertainty. Regional detail can be estimated by "nesting" a regional-scale model in a global climate model; that is, the resolution of a regional model can be made high by focusing just on the region of interest (such as Australia) and taking any required large-scale information from a "parent" global climate model. Several studies using a regional climate model (for example, Walsh and Ryan [35]) have been carried out to investigate the possible impact of future climate change on Australia.

Regional scale information can also be estimated by using statistical methods to relate the large-scale variables of a climate model, such as the surface pressure patterns, to observed local variables, such as the daily mean temperature. Because these statistical downscaling methods are based on actual observations, they can reduce systematic bias from the large-scale model features as well as provide useful estimates of local climate detail; for example, see Timbal and McAvaney [36].

### 3.3.4 Attribution of global warming

The Second Assessment Report of the IPCC in 1996 concluded that "the balance of evidence suggests a discernible human influence on global climate". At that time the conclusion was seen to be somewhat controversial, but the scientific evidence since then has continued to accumulate so that a human influence is now being identified at continental scales (that is, not just at the global level). Attribution involves comparison between the observed climate record and model results obtained with different external forcings. Models can be run with and without greenhouse gas forcing, aerosol forcing, forcing from volcanic aerosols, and variations in solar radiation. The global (or continental) patterns or "fingerprints" associated with each type of forcing can be calculated from the model results, and these patterns can then be compared with the observed climate record. The increasing patterns for greenhouse gas forcing are becoming quite clear.

Karoly and Braganza [37] compare the results of a number of global climate model simulations with the observed average temperature across Australia. They find that the temperature changes over the 20th century are "very unlikely to be due to natural climate variations alone", and that the changes are likely to have been influenced by human emissions of greenhouse gases and aerosols.

### 3.3.5 Future concentrations of greenhouse gases

Models have been developed to make estimates of future emissions of greenhouse gases and aerosols over the 21st century and beyond. These scenarios [38] are based on assumptions about human activity, technological advances and economic development which are inherently fraught with uncertainty. The

[35] Walsh, K.J.E. & Ryan, B.F., *Tropical Cyclone Intensity Increase Near Australia as a Result of Climate Change*, Journal of Climate, 13, 2000, pp.3029-3036.
[36] Timbal, B. & McAvaney, B.J., *An Analogue Based Method to Downscale Surface Air Temperature: Application for Australia*, Climate Dynamics, 17(12), 2001, pp.947–963.
[37] Karoly, D.J. & Braganza, K., *Attribution of Recent Temperature Changes in the Australian Region*, Journal of Climate, Vol.18, 2005, pp.457-469.
[38] IPCC, *Emission Scenarios*, A Special Report of Working Group III of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom, 2000, 599pp.

scenarios attempt to include both high and low estimates of carbon intensity, as well as the positive and negative feedbacks in the natural global carbon cycle. It is found that the emission of $CO_2$ due to burning fossil fuel will be the dominant influence on greenhouse emissions in future decades. The low and high range of SRES scenarios lead to the concentration of $CO_2$ in the atmosphere by 2050 lying between about 450 and 550 ppm; the $CO_2$ concentration was at 280 ppm before the industrial revolution.

Castles and Henderson [39] suggest that the greenhouse emission levels in the SRES scenarios may be too high because they are based on market exchange rates (MER) rather than purchasing power parity (PPP) in calculating economic growth. Grübler *et al* [40] provide a measured response to the criticism, noting that the SRES (as with all IPCC assessments) was based on available published research and that the differences between MER and PPP methodologies would not necessarily imply that the SRES over-estimates greenhouse emissions. Despite the controversy, a report to the Australian Greenhouse Office [41] notes that, for studies limited to a timeframe of a few decades, the differences are not expected to be significant because any climate change will be dominated by emissions that have already occurred.

### 3.3.6 Projections of future climate change

As the concentration of greenhouse gases continues to increase in the atmosphere, the natural greenhouse effect will continue to be enhanced leading to an increase in surface temperature and other induced climate changes. In order to explore the range of possible future climate states associated with the uncertainties in the emission scenarios, in the climate models and in the climate system itself, a very large number of climate model runs must be made. A technique has therefore been developed that uses simplified climate models [42] rather than the full global climate models. The simplified models are calibrated to yield a response equivalent to that of a full global climate model when forced by enhanced greenhouse gas concentrations. The simplified models have a rather simple (although physically based) representation of the climate system, but they include a representation of the global carbon cycle so that they are driven by the specified anthropogenic carbon emissions of the SRES scenarios.

It is found that the average global surface temperature is projected to increase by 1.4°C to 5.8°C over the period 1990 to 2100 [43]. The range of the temperature increase across an ensemble of models driven by a given emission scenario is comparable with the range obtained from a single model driven by the ensemble of emission scenarios – ie: the uncertainty associated with the emission scenarios is comparable with the uncertainty associated with the climate models. At 2050 the range in the projected increase in global surface temperature is about 1.7°C to 2.6°C.

In order to obtain estimates of climate changes on sub-global scales, an ensemble of nine full global climate models are run for just a few of the SRES concentrations [44]. It is found that many features of the geographical response to the enhanced greenhouse effect are similar for different SRES scenarios, and so patterns of regional variations can plausibly be scaled with the magnitude of the global temperature change. Recognising the increasing uncertainty as the region of interest is reduced, the IPCC assessment provides estimates of regional changes across the globe on a fairly course scale; Australia is decomposed into a north and a south region. From an ensemble of nine models, no consistent difference from the global trend is found in summer or winter temperatures for southern Australia. In northern Australia the ensemble indicates a warming above the global mean in winter.

[39] Castles, I. and Henderson, D., *The IPCC Emissions Scenarios: An Economic-Statistical Critique*, Energy & Environment, Intergovernmental Panel on Climate Change, 14, 2003, pp.159-185.

[40] Grübler, A., Nakicenovic, N., Alcamo, J., Davis, G., Fenhann, J., Hare, B., Mori, S., Pepper, B., Pitcher, H., Riahi, K., Rogner, H.H., La Rovere, E.L., Sankovski, A., Schlesinger, M., Shukla, R.P., Swart, R., Victor, N., & Jung, T.Y., *Emissions Scenarios: A Final Response*, Energy & Environment, 15, 2004, pp.11-24.

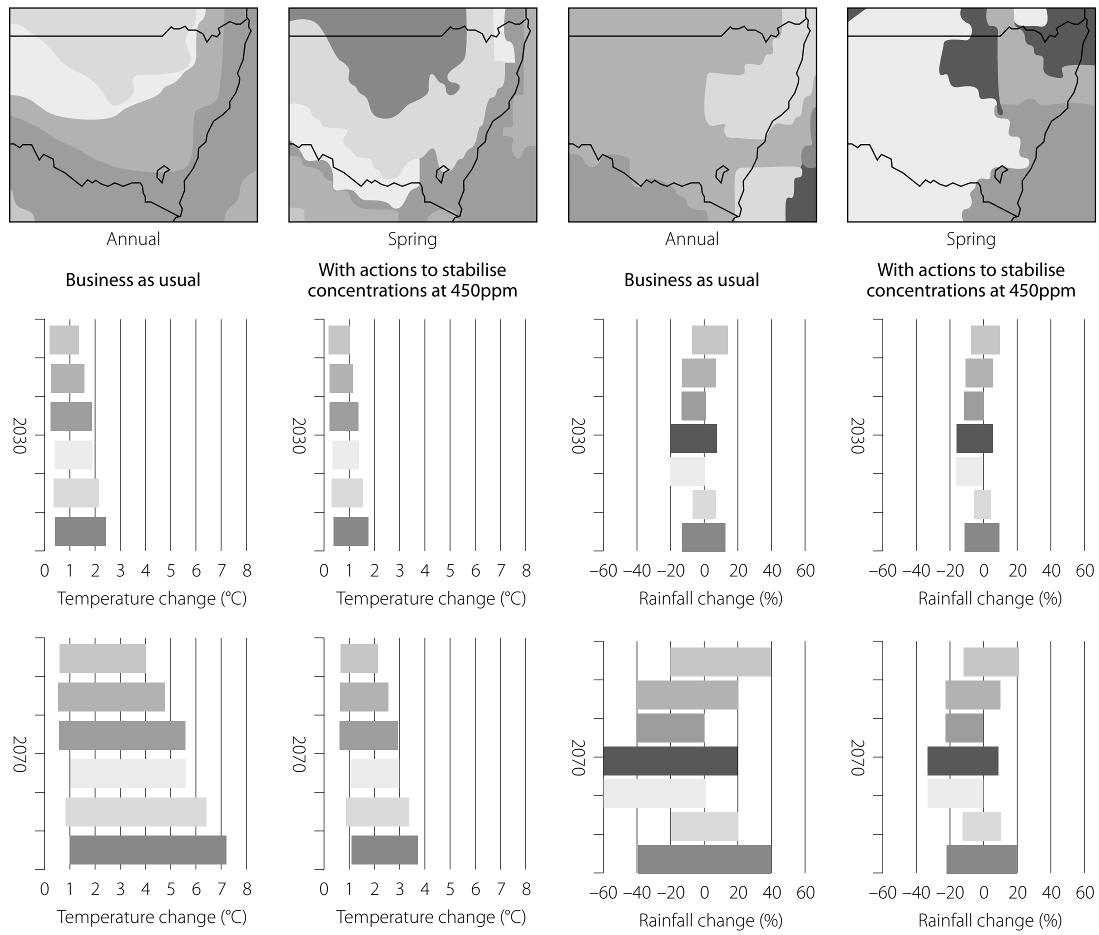
[41] Allen Consulting Group, *Promoting an Efficient Adaptation Response in Australia – Final Report, Climate Change: Risk and Vulnerability*, Australian Greenhouse Office, March 2005, 159pp.

[42] IPCC, *An Introduction to Simple Climate Models Used in the IPCC Second Assessment Report*, IPCC Technical Paper II, Intergovernmental Panel of Climate Change,1997.

[43] IPCC, *Climate Change 2001: The Scientific Basis, Summary for Policymakers and Technical Summary of the Working Group I Report*, World Meteorological Organisation and United Nations Environment Program, 2001, 98pp.

[44] IPCC, *An Introduction to Simple Climate Models Used in the IPCC Second Assessment Report, IPCC Technical Paper II*, Intergovernmental Panel on Climate Change 1997.

## Figure 3.7 – CSIRO projections for NSW temperature and rainfall for years 2030 and 2070




**The bars show the ranges of temperature and rainfall for the corresponding shaded areas in the maps.**
**The Business as Usual projections are based on the IPCC Special Report on Emission Scenarios.**

**Source: NSW Govt., 2005**

The ensemble of climate models indicates that on global scales there will be an increase in water vapour, evaporation and precipitation. However, at regional scales, precipitation could either increase or decrease [45]. Both Australian regions show a small (between five and 20 per cent) decrease in rainfall in winter. In summer there is no consistency in the model results, except for the "high" emissions scenario when the southern region shows a small increase.

In Australia CSIRO has developed techniques using a large ensemble of global and regional climate models to estimate climate change on regional scales (for example, Hennessy *et al* [46], The NSW Government [47] has used such fine-scale projections of potential changes in temperature and rainfall (as shown in Figure 3.7) to prepare a strategic plan for managing greenhouse-related changes.

As has been noted, much of Australia is affected by the ENSO phenomenon and this has two implications for the interpretation of future projections of regional climate change. The first issue is that any change due to the enhanced greenhouse effect will be incurred against the continuing background of "natural" ENSO variability which (as seen from Figures 3.4 and 3.5 for national scales) is large. The second point is the recognition that current climate models do not replicate the ENSO phenomenon perfectly and so there remains uncertainty on how it will evolve in future. There is some indication [48] that there may "little change or a small increase in the amplitude of El Niño events over the next 100 years".

[45] IPCC, *An Introduction to Simple Climate Models Used in the IPCC Second Assessment Report, IPCC Technical Paper II*, Intergovernmental Panel on Climate Change 1997.

[46] Hennessy, K., Lucas, C., Nicholls, N., Bathols, J., Suppiah, R. & Ricketts, J., *Climate Change Impacts on Fire-Weather in South-East Australia*, CSIRO, December 2005, 91pp.

[47] NSW Government, *NSW Greenhouse Plan*, NSW Government, November 2005, 64pp.

[48] IPCC, Climate Change 2001: *The Scientific Basis, Summary for Policymakers and Technical Summary of the Working Group I Report*, World Meteorological Organisation and United Nations Environment Program, 2001, 98pp.

Between 1990 and 2100, the global mean sea level is projected to rise by 0.09 to 0.88 metres using estimates from all SRES scenarios [49]. For 2050, the projected rise is between about 0.05 and 0.3 metres. However, there continues to be uncertainty about the water balance of Antarctica. A recent report of a meeting of the Royal Society of London [50] suggests that the warm waters of the Antarctic are melting the base of glaciers so that the glaciers are flowing from the land faster than in the past and the ice sheets are also breaking up faster.

### 3.3.7 Persistence of human-induced climate change

A key feature of the greenhouse gases like $CO_2$ and methane is that they remain in the atmosphere for at least decades. When the concentrations of greenhouse gases have stabilised in the atmosphere, the rate of rise of the global surface temperature will be reduced substantially. However, because of the slow response of the deep ocean, sea level will continue to rise for hundreds of years after the stabilisation of greenhouse gas concentrations [51]. To attain stabilisation of atmospheric concentrations, the emission of greenhouse gases must first be reduced substantially. Thus the time scales for stabilisation are far greater than the 50-year timeframe of this study. That is, the effects of the enhanced greenhouse effect will almost certainly be very apparent in 2050.

### 3.3.8 Uncertainties

A persistent theme of this chapter is the inherent nature of uncertainty in any projections of future climate. The IPCC [52] emphasises that continuing monitoring of and research on the climate system are required to understand and reduce these uncertainties. Because of the uniqueness of the Australian climate and because of its relative isolation in the southern hemisphere, it is important for Australia to benefit from and contribute to the international efforts aimed at reducing uncertainties. For example, Australia has been active in all the international assessments of the IPCC, including current preparation of the Fourth Assessment Report which will be completed in 2007. Much of the research that is assessed by the is conducted under the auspices of the World Climate Research Program (WCRP) and its partner programs in the Earth System Science Partnership, the International Geosphere Biosphere Program (IGBP) and the International Human Dimensions of Global Change Program (IHDP). Australia's contributions to these programs, and to additional nationally-focused research on climate change is carried out by the Bureau of Meteorology, CSIRO, other government agencies and the universities. A program of climate change research is sponsored by the Australian Greenhouse Office.

International cooperation on monitoring global climate and its associated changes is carried out under the auspices of the Global Climate Observing System (GCOS), which promotes activities across the earth system domains of the atmosphere, ocean and land surface. A key task of GCOS is to establish and maintain in situ and satellite-based networks that can measure climate variables with sufficient accuracy and precision that future climate changes can be detected and causes attributed to those changes. The past climate record is generally inadequate for this purpose. Australia has been active in the development of GCOS, and in its related observing systems for the atmosphere (Global Observing System of WMO), the ocean (Global Ocean Observing System) and the land surface (Global Terrestrial Observing System).

In July 2003, the First Earth Observation Summit was held in Washington, US and it established the Group on Earth Observations (GEO). Subsequently the GEO has developed a 10-year implementation plan for a Global Earth Observation System of Systems (GEOSS), which builds on existing observing systems (such as GCOS) to strengthen systems for monitoring the overall global environment. Directly and through its involvement in existing systems, Australia is contributing to the evolution of the GEOSS.

[49] IPCC, *Climate Change 2001: The Scientific Basis, Summary for Policymakers and Technical Summary of the Working Group I Report*, World Meteorological Organisation and United Nations Environment Program, 2001, 98p.
[50] *Southern Ice Pours into Seas*, New Scientist, 22 October 2005, p.7.
[51] IPCC, *Climate Change 2001: The Scientific Basis, Summary for Policymakers and Technical Summary of the Working Group I Report*, World Meteorological Organisation and United Nations Environment Program, 2001, 98p.
[52] *ibid*

## 3.4 IMPACTS OF CLIMATE CHANGE

It has been seen earlier in this chapter that many facets of Australian life are affected significantly by the climate, especially by the variability of the climate. There are now indications of climate change both globally and across Australia. It follows that future climate change will at the least add another level of uncertainty in managing the impacts of climate variability. There have been several summary reviews of the impacts of climate change in Australia, such as Pittock [53] and Allen Consulting Group [54]. Using these and other sources, some possible and some observed impacts of climate change on a range of activities in Australia are now considered.

### 3.4.1 Human health and well-being

McMichael *et al* [55] describe a range of health impacts that climate change could have in the Australian region up to 2050. The study is a risk assessment so that it may be possible to ameliorate some of the impacts through appropriate policy strategies. The climate projections are based on a CSIRO analysis of climate model results, as described earlier. The study finds that direct effects of extreme temperature (heat stress) and rainfall (flooding) events are expected to be exacerbated in the future, and that indirect effects of food-borne and water-borne diseases could also increase. The increasing climate risk of vector-borne diseases like malaria and dengue should be manageable through high priority continuing to be placed on prevention strategies.

In addition to impacts on physical health, there is increasing evidence of extreme events like drought impacting on the mental and social well-being of rural communities (for example, Gray *et al* [56]). Prolonged drought is found to threaten family cohesion and to undermine community well-being. If future droughts become more severe as discussed earlier, then these social factors may need additional management.

An extreme case of social disruption is the collapse of a whole community leading to the (nationally internal) migration of rural communities. This process occurred a century ago in South Australia when farms beyond the Goyder Line had to be abandoned. If the assessment of viability of a community were based purely on direct economic criteria, then continuing periods of dry and hot conditions could lead to some rural communities being assessed as not viable in the future.

Over the next century Australian society could be impacted if migration occurs from countries affected adversely by climate change. For example, one study [57] suggests that a 40-centimetre rise in sea level could increase the number of people annually flooded by storm surges from the current 13,000,000 to 94,000,000. Most of the regions affected are in southern and south-east Asia. Many islands in the Pacific are currently only a few metres above sea level. These islands are susceptible not only to storm surges but also to the invasion of salt water into their freshwater aquifers.

### 3.4.2 Natural ecosystems

Pittock [58] notes that a number of Australian ecosystems are vulnerable to climate change because their habitats are limited by orography (for example, alpine areas) or because their habitats have become fragmented due to land-use changes (for example, areas of south-west Western Australia). Thus they cannot simply migrate to neighbouring areas as their current habitats become unsuitable.

The coral reefs of Australia may be vulnerable to climate change, not only due to the direct effects of warming waters but also due to the indirect effect of the gradual acidification of the world's oceans. A report by the Royal Society [59] states that, as the ocean has absorbed about half of the anthropogenic

[53] Pittock, B. (ed.), *Climate Change: An Australian Guide to the Science and Potential Impacts*, Australian Greenhouse Office, 2003, 250pp.
[54] Allen Consulting Group, *Promoting an Efficient Adaptation Response in Australia*, Australian Greenhouse Office, March 2005, 159pp.
[55] McMichael, A., Woodruff, R., Whetton, P., Hennessy, K., Nicholls, N., Hales, S., Woodward, A., & Kjellstrom, T., *Human Health and Climate Change in Oceania: A Risk Assessment*, Department of Health and Ageing, Commonwealth Government, Canberra, 2003,126pp.
[56] Gray, I., Stehlik, D., Lawrence, G. & Bulis, H., *Community, Communion, and Drought in Rural Australia*, Journal of International Community Development Society, 29, 1998, pp.23-37.
[57] UK Meteorological Office, *Climate Change and its Impacts: Stabilisation of Carbon Dioxide in the Atmosphere*, UK Meteorological Office, October 1999, 27pp.
[58] Pittock, B. (ed.), *Climate Change: An Australian Guide to the Science and Potential Impacts*, Australian Greenhouse Office, 2003, 250pp.
[59] Royal Society, *Ocean Acidification Due to Increasing Atmospheric Carbon Dioxide*, Royal Society, June 2005, 68pp.

emissions of carbon dioxide over the past 200 years, it has become more acidic. Indeed the concentration of hydrogen ions has increased by 30 per cent (pH reduction of 0.1). It is estimated that by 2100 there will be a three-fold increase in the concentration of hydrogen ions (pH reduction of 0.5). Increasing acidification of sea water constrains the formation of calcium carbonate shells, and so the impact is focused on corals, molluscs and some plankton species.

### 3.4.3 Energy

Increasing temperatures are expected to impact on energy demand in Australia. An increase in demand for electricity for air conditioning in the summer may on average be balanced by a reduced demand for heating in the winter. However, the peak demand in summer is expected to continue to grow as the mean and extreme temperatures increase. Pittock [60] also notes that as the environmental temperature increases there may be increased costs for some energy-intensive industries due to a reduction in thermal efficiency of equipment.

### 3.4.4 Water availability

Drought has been a continuing feature of Australian climate. However, there is now evidence that the nature of Australian drought is changing [61]. While there appears to be no trend in the rainfall deficit during widespread droughts, there is an underlying upward trend in temperature. The rainfall deficit during the 2002 drought was comparable with that in the droughts of 1982 and 1994, but the maximum temperature was nearly a degree warmer. Indeed the temperature in each major drought in recent decades has been warmer than that in earlier droughts. A consequence of this trend is expected to be increased heat stress on humans, agriculture and ecosystems. Evaporation is also expected to be increased.

The Indian Ocean Climate Initiative [62] was established because of government concern about the reduced stream flow since the 1970s in the catchments serving Perth. Analysis of the climate record and climate modelling studies have led to the conclusion that the reduction in rainfall and hence stream flow are due to changes in the large-scale circulation and that the enhanced greenhouse effect is at least a contributing factor to the changes.

### 3.4.5 Agriculture

Agriculture is a significant source of export income for Australia, and so the potential impacts of climate change need to be considered in a global context. It is expected that the mid-latitude regions of the northern hemisphere will become more productive under climate change conditions which could reduce Australia's competitive edge in the global market [63].

Wheat is Australia's major crop. Analysis of wheat yield and climate fluctuations over 40 years from 1952 implies that 30-50 per cent of the increase in wheat yield over that period was due to climate trends, particularly due to increasing night-time minimum temperatures [64]. The increases in minimum temperatures have led to a widespread reduction in the frequency of frosts in much of eastern Australia. Other studies suggest that as the maximum temperature rises and water availability is reduced, the positive impacts of frost reduction and of $CO_2$ fertilisation will be offset.

The history of Australian crop production suggests that the industry can adapt to difficult climates. However, the changing nature of the climate will place an additional stress on agri-business in the future.

### 3.4.6 Natural disasters

Many natural disasters, such as storm surges or bushfires, are associated with extreme weather events, and so potential changes in the frequency and intensity of extreme events could impact on the nature of natural disasters in Australia in future decades. It has been noted that the upward trend in temperature may be

[60] Pittock, B. (ed.), *Climate Change: An Australian Guide to the Science and Potential Impacts*, Australian Greenhouse Office, 2003, 250pp.
[61] Nicholls, N., *The Changing Nature of Australian Droughts*, Climatic Change, 63, 2004, pp.323-336.
[62] Indian Ocean Climate Initiative. (www.ioci.org.au)
[63] Pittock, B. (ed.), *Climate Change: An Australian Guide to the Science and Potential Impacts*, Australian Greenhouse Office, 2003, 250pp.
[64] Nicholls, N., *Increased Australian Wheat Yield due to Recent Climate Trends*, Nature, 387, 1997, pp.484-485.

leading to an exacerbation of drought conditions in Australia. In turn, it is possible that bushfire conditions could become more frequent. Indeed Hennessy *et al* [65] find that the number of days each year with high or extreme fire danger may increase by 15-70 per cent in parts of south-east Australia by 2050.

Bushfires can have both short-term and medium-term impacts on runoff from burnt areas. In the short-term, the absence of vegetation can lead to the contamination of water due to an increase in sediments flushed into nearby rivers and catchments. As new vegetation starts to grow in burnt areas, it is likely that runoff will be reduced as the vegetation transpires water to support its growth. This process could lead to a reduction in water storage for human use during the medium-term revegetation period.

While it is difficult to discern any significant long-term trend in mean rainfall around the world, there is some evidence (for example, Manton *et al* [66]) that the proportion of annual rainfall from extreme events is increasing in the Asia-Pacific region. Webster *et al* [67] suggest that the intensity and frequency of severe tropical cyclones are increasing around the world, but these results (while consistent with some modelling studies of possible future changes) are under continuing discussion in the meteorological community. Taking into account the uncertainties associated with estimates of future rainfall, it is certainly possible that the frequency of extreme rainfall events could increase in the Australian region, leading to more flooding events from heavy rainfall and from storm surges in coastal areas.

## 3.5 POLICY ISSUES

As societies become increasingly averse to risk, governments continue to refine policies that attempt to manage societal vulnerability to various types of risk. For example, given the historical importance of agriculture to the Australian economy and the propensity of Australian climate for drought conditions, governments have had ever-evolving policies on drought management. The growing awareness of the potential risks to societies from global climate change is prompting governments to develop new climate-related policies. State governments are preparing greenhouse policies (for example, NSW Government [68], 2005 ; Victorian Government, 2005 [69]) which have at least three elements:

- raising of public awareness;
- mitigation of greenhouse gas emissions; and
- adaptation to climate change.

The Commonwealth Government [70] has prepared a paper outlining Australia's response to climate change, which covers:

- international action;
- managing emissions of greenhouse gases;
- adapting to change;
- monitoring greenhouse gas emissions; and
- science of climate change.

The enhanced greenhouse effect is global in scope: the sources of greenhouse gas emissions are closely related to economic development [71], and the long lifetime of greenhouse gases in the atmosphere means that they are uniformly mixed so that their effects on climate are global. It follows that international

[65] Hennessy, K., Lucas, C., Nicholls, N., Bathols, J., Suppiah, R. & Ricketts, J., *Climate Change Impacts on Fire-Weather in South-East Australia*, CSIRO, December 2005, 91pp.

[66] Manton, M.J., Della-Marta, P.M., Haylock, M.R., Hennessy, K.J., Nicholls, N., Chambers, L.E., Collins, D.A., Daw, G., Finet, A., Gunawan, D., Inape, K., Isobe, H., Kestin, T.S., Lefale, P., Leyu, C.H., Lwin, T., Maitrepierre, L., Ouprasitwong, N., Page, C.M., Pahalad, J., Plummer, N., Salinger, M.J., Suppiah, R., Tran, V.L., Trewin, B., Tibig, I. & Yee, D., *Trends in Extreme Daily Rainfall and Temperature in South-east Asia and the South Pacific: 1961-1998*, Int. J. Climatology, 21, 2001, pp.269-284.

[67] Webster, P.J., Holland, G.J., Curry, J.A. & Chang, H.R., *Changes in Tropical Cyclone Number, Duration and Intensity in a Warming Environment*, Science, Vol.309, Issue 5742, September 2005, pp.1844-1846.

[68] NSW Government, *NSW Greenhouse Plan*, NSW Government, November 2005, p.64.

[69] Victorian Government, *Victorian Greenhouse Action Plan Update*, Victorian Government, November 2005, p.64.

[70] Australian Greenhouse Office, *Australia's Response to Climate Change*, Commonwealth Government, 2005, p.12.

[71] Up until the oil crisis of the 1970s, there was an almost linear relationship between gross domestic product (GDP) and $CO_2$ emissions in many countries, IPCC, *Climate Change 2001: Synthesis Report*, Contribution of Working Groups I, II and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom, 2001, p.397.

cooperation must be an important element of any national policy.

Australia was active in the negotiations leading to the introduction of the UN Framework Convention of Climate Change (FCCC) in 1992. The Convention came into force in March 1994 after it was ratified by 50 countries, including Australia. The Convention provides a basis for international action "to protect the climate system for present and future generations". The objective of the Convention is to achieve "stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". Stabilisation is to be achieved "within a timeframe sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner". The Convention requires countries to "take precautionary measures to anticipate, prevent or minimise the causes of climate change and mitigate its adverse effects".

The objective of the FCCC requires the stabilisation of greenhouse gas concentrations in the atmosphere. Given the long lifetimes of greenhouse gases, stabilisation of concentrations occurs many decades after emission levels have been reduced. Thus, long-term polices are needed in order to mitigate the effects of global climate change. For example, in order to eventually stabilise $CO_2$ concentrations at about double the pre-industrial level of 280ppm, internationally-agreed policies to slow down emissions will need to have been implemented before 2050.

The stable concentration level required under the FCCC is not well defined, and it depends upon the definition of "dangerous anthropogenic interference". This issue of definition has been nicely avoided by both scientists and policymakers, but the science of climate change and its impacts is maturing to the stage where it is expected that policy-relevant advice will be developed over the next few years. Key science issues relate to the timeframe for ecosystems, agribusiness and societal systems to adapt to climate change.

While the FCCC provides a framework for action, it does not provide specific commitments of countries to manage greenhouse emissions or climate change. In December 1997, the Conference of the Parties (COP) to the Convention adopted the Kyoto Protocol, which provided more detailed commitments for industrialised countries. It is expected that the Protocol should lead to a reduction of at least five per cent in global emissions below the level in 1990. Australia was active in the development of the Protocol, successfully arguing for the inclusion of emissions associated with land use change (deforestation) and for a target for Australia above the baseline level of 1990 emissions.

Although Australia has decided not to ratify the Kyoto Protocol of the FCCC, it still aims to meet its Kyoto emissions target of 108 per cent of 1990 levels by 2008-12. As noted above, the Australian strategy has been based largely on reducing emissions associated with land use change by about 72 per cent, which has allowed energy-related emissions to increase by about 30 per cent since 1990. Such a strategy has a limited lifetime, and so there is now an increasing emphasis on technological means to reduce emissions. The Asia-Pacific Partnership on Clean Development and Climate aims to promote technological initiatives to reduce emissions in Australia, China, Japan, India, Korea and the US .

Mitigation is an important long-term strategy for all countries. On the other hand, as the impacts of climate change become apparent across the world, the development of adaptation strategies becomes important for each country in the short to medium term. Ideally, strategies would be developed for each of the sectors (noted above) that are susceptible to climate change in Australia – that is, at least covering the sectors of:

- human health and well-being;
- natural ecosystems;
- energy;
- water availability;
- agriculture; and
- natural disasters.

While recognising the regional differences in the impacts of climate change, there would be benefits from ensuring national consistency in the outcomes of adaptation strategies. Where the timeframe of the basic sector is small compared with the timeframe of climate change, the most obvious strategy is essentially "to do nothing" and to allow the sector to adjust naturally. However, some sectors have natural timeframes that are much longer than the expected rate of change due to global warming. For example, it would be appropriate (although difficult) for major infrastructure projects to account for the potential impacts of climate change over their lifetime.

The magnitude of climate change can also affect impacts in non-linear ways; in particular, impacts can occur in jumps or can change from beneficial to detrimental when the climate exceeds some threshold. For example, the beneficial impact on wheat yield from $CO_2$ fertilisation and from a reduction in frosts is expected to be lost as the temperature continues to rise. It will be important to understand such impacts and to devise strategies to ensure the affected sectors adjust to the changes.

The global nature of climate change means that Australian response strategies need to account for overseas developments. For example, it has been noted above [72] that Australia's competitive edge in crop production may be reduced if climate change leads to relatively greater productivity in mid-latitude regions of the northern hemisphere. It will be vital for these overseas developments to be understood when planning Australian agriculture policy for future decades.

There has been a range of estimates of the expected impact of sea-level rise on coastal areas over the next 50 years. As uncertainty in these impacts is reduced, strategies will be developed to ensure the safety of life and infrastructure along the Australian coastline. However, it is expected that some low-lying regions of the world will need to be abandoned and migration will be a necessary strategy. Internal migration could also be a policy option if water availability became a limiting factor to the viability of some inland regions of Australia. However, viability is a social and cultural, as well as an economic factor in an industrialised country, and so internal migration may be deemed to be unacceptable.

A key element of the FCCC is the support by countries for "international and intergovernmental efforts to strengthen systematic observation and national scientific and technical research". With its relative isolation in the southern hemisphere and its unique climate, Australia needs to continue to carry out appropriate research and systematic observation programs to ensure that climate change and its impacts in the region are understood and anticipated. These activities need to be conducted at the national level, but also within the key international frameworks so that Australia benefits from major overseas developments. In addition to research at the national level, regional studies within Australia provide a focus on specific and unique features of each climatic region. The Indian Ocean Climate Initiative (IOCI), involving collaboration across government agencies and research agencies as well as universities, provides an effective model for the organisation of such studies.

Economic instruments are not highlighted in the Commonwealth Government paper on Australia's response to climate change [73]. The Kyoto Protocol to the FCCC promotes economic measures and instruments for the "progressive reduction or phasing out of market imperfections, fiscal incentives, tax and duty exemptions and subsidies in all greenhouse gas emitting sectors that run counter to the objective of the Convention". One such instrument is the international trading of carbon emissions between developed countries. At present international carbon trading is not well established, and Australia has decided that it "will not impose significant new economy-wide costs, such as emissions trading, in its greenhouse response at this stage" [74]. However, regional (for example, European Union) and national (for example, New Zealand) schemes for carbon trading are being implemented. In order to maintain its international competitiveness in the future, it will be important for Australia to continue to monitor international developments of economic instruments and measures associated with the mitigation of climate change and to be prepared to act with the international community at the appropriate time.

It is expected that Australia will be able to develop and implement policies to manage climate variability and change as the population continues to grow over the next 50 years.

[72] Pittock, B. (ed.), *Climate Change: An Australian Guide to the Science and Potential Impacts*, Australian Greenhouse Office, 2003, 250pp.
[73] Australian Greenhouse Office, *Australia's Response to Climate Change*, Commonwealth Government, 2005, 12pp.
[74] Department of the Prime Minister & Cabinet, *Securing Australia's Energy Future*, Commonwealth Government, 2004, 104pp.

## 3.6 CONCLUSION

For a century it has been understood that Australia's climate constrains the population it can naturally support. European settlers took many decades to learn to manage the unusual variability of Australia's climate, which impacts on natural ecosystems and on many aspects of human endeavour. Global climate change is adding a further dimension to the uncertainties associated with Australian climate, and these uncertainties will need to be managed against the background of natural climate variability.

As in other parts of the world, there are indications of climate change and its impacts in Australia. For example, while there is not a clear trend in rainfall deficit during major droughts, there has been an underlying increase in temperature in recent decades so that droughts are becoming hotter and probably drier due to increased evaporation. The impacts of climate change will be felt in many sectors, and strategies will need to be developed to adapt to inevitable changes. Action will be most important in sectors where the inherent timeframe is long compared with the timeframe of climate change or where there are climate thresholds beyond which impacts have detrimental effects. There will also be sectors in which beneficial impacts should be exploited as quickly and efficiently as possible.

Global climate change could lead to a reduction in Australia's international competitive edge in crop production, and so it will be necessary to monitor and understand the global as well as regional aspects of climate change. Sea-level rise could cause some low-lying areas of the world, including some island states in the Pacific Ocean, to be abandoned leading to international migration which could affect Australia. It is also possible that some rural communities in the semi-arid regions of Australia could become marginally viable if rainfall deficiencies continued for long periods. By monitoring national and international trends, it should be feasible for Australia to adapt to such potential changes.

While adaptation to climate change and variability is essentially a national concern, the development of strategies for the mitigation of global climate change should be conducted in international forums. In the past, Australia has been active and effective in these forums, particularly in the Conference of the Parties (COP) to the UN Framework Convention on Climate Change (FCCC), and it will be appropriate to continue such participation.

There are inherent uncertainties in the nature of climate change and its impacts, and so there needs to be continuing research and systematic monitoring to ensure that these uncertainties are understood and reduced where possible. These activities should continue to be carried out at the national level, in conjunction with the relevant international organisations and programs to ensure that Australia benefits from overseas developments and influences international trends.

# CHAPTER 4
# Water

Water, water, everywhere,
Nor any drop to drink.

Samuel Taylor Coleridge, The Rime of the Ancient Mariner (1798)

## SYNOPSIS

**There appear to be no insurmountable engineering, health, scientific, economic or environmental barriers to providing water for 30 million people**. Following major infrastructure developments after World War II, interest in water supplies (and particularly urban water) waned in favour of social and environmental issues. However, since the early 1990s there has been renewed political and community interest in water – driven by global warming, recent droughts and consequent water restrictions.

This chapter addresses institutional arrangements, water resources, current supply and demand management issues, long-term planning and the use of new technology to diversify sources. Its main focus is urban water, since population growth is likely to be concentrated in existing cities. Responding to the challenge of providing adequate urban water supplies to meet future population growth is in the context that urban water (household, manufacturing and other) currently accounts for some 16 per cent of total water use, whereas agricultural use accounts for some 67 per cent of total water use.

While Australia is the driest continent – and is already seeing a drastic reduction in run-off over the past 32 years in the south-west of Western Australia due to climate change, and in the eastern states due to drought (which may be linked to climate change) – demand management techniques with customer co-operation have handled the current situation well.

In aggregate terms, Australia has a plentiful supply of water (a view supported by the World Bank and studies conducted by the Barton Group). However, much of the rainfall is in the under-populated north and it is currently uneconomical to transport water over thousands of kilometres from north to south. Many of the large water utilities have long-term planning in place (some for a 50-year period) and expect to meet future needs.

With the exception of Perth, Australia's major cities have added little new capacity since 1980 but this will need to change. Current long-term planning will need to be strengthened by drawing on a diversity of sources, including those that are independent of rainfall and run-off. There will be new surface and groundwater schemes, accessing water from agriculture, improved catchment management, more demand management including pricing strategies, increasing wastewater re-use (recycling) and sea water desalination.

It is important to realise that desalination is now more affordable and has become the "bench-mark" for economic comparisons with other proposals. At this stage, desalination has shown the economic frailty of schemes for north-south diversions and some of the large recycling proposals. Recycling (probably excluding direct potable re-use, which may not be needed) and desalination will undoubtedly both feature in the future and have similar high energy needs and similar cost projections. Generally all future sources will cost more, and have high energy needs as obviously the close, cheaper and cleaner sources have already been developed over the past 100 years.

There are obvious risks in such long-term planning when climate change uncertainties exist, and all planning will need revisiting every five years. Ongoing research into both technology and policy formation (particularly to encourage water trading) is necessary. Equally necessary is the extension of water education to ensure the community, politicians and other decision makers can differentiate between economic proposals and some of the populist solutions being proposed for future water supply.

## 4.1 INTRODUCTION

Samuel Coleridge (1772-1834) would have been well aware that most of the world's water was saline, and although British discovery and settlement of Australia took place in his lifetime, settlement proceeded in well-watered coastal environments and so he may not have been aware of just how dry the Great South Land is. In fact, Australia is often referred to as the driest inhabited continent, with only the Antarctic continent receiving lower precipitation. Certainly the availability of fresh water, an essential element of life, is often cited as one of the limiting factors to population growth.

Australians see on a daily basis the impact of supply shortages alongside growing water demands at a time of increasing uncertainty about the long-term impacts of global warming and climate change. They understand that inflows to rivers and streams have been significantly reduced and that recent severe and long droughts have led to reduced storage and ground-water levels. There are growing concerns about salinity, the capacity of land and water systems to support past patterns of primary industry and advancing desertification.

Climate change is predicted to lead, in some locations, to rising temperatures with consequential higher evaporation rates. All this makes planning and decision making more complex and uncertain and ready, low-cost and simple responses are not evident.

This chapter focuses on the way water is now managed and where that seems likely to lead. It explores some of the intergovernmental and institutional arrangements that can either foster or inhibit more effective water resource management, including in urban surrounds. It comments on some of the economic and commercial issues that face water managers in allocating water entitlements, getting pricing signals right and instituting water trading. In this context, it is imperative that the nation and the states continue to curb water demand and secure urban water supply if a growing population is to be accommodated, more than likely in existing cities, complemented by the further projected development of urban centres in south-eastern Queensland and south-western Western Australia. For that reason, the wider questions of catchment management and supply for rural populations and industry are often related back to the urban context. For example, when water trading becomes better established, there is, in principle, the possibility of some urban water needs being met through trades of water surplus to the needs of rural users.

Where the chapter addresses national issues, it often does so by reference to particular approaches adopted by states or cities in dealing with water resource management, including future availability of water and demand management. The text draws on several significant works including: *Testing the Water*[75], *Australian Water Roadmap*[76] and *Australian Infrastructure Report Card*[77]. Other documents that were used in the preparation of this chapter are listed in Section 4.12.

While planning by state and territory utilities occurs over greater and lesser timescales, the WSAA[78] report is based on extrapolation of present trends which would result in a population of approximately 25 million by 2030. This is consistent with a population of some 30 million by 2050, which figure is similar to that derived by Professor Peter McDonald, ANU, in a parallel study for the Scanlon Foundation (and included as Chapter 2).

## 4.2 THE CHANGING FACE OF WATER MANAGEMENT[79]

For the past 15 years there has been an increasing focus by government, water-using industry, academe, public interest groups and the community at large on gaining a better understanding of the nation's water resources and how to plan and manage in transparent and integrated ways to meet many diverse ecological,

[75] WSAA, *Testing the Water: Urban Water in Our Growing Cities – The Risks, Challenges, Innovation and Planning*, WSAA Position Paper No.01, Water Services Association of Australia, October 2005.
[76] *Australian Water Roadmap*, Barton Group (2005).
[77] Engineers Australia, *Australian Infrastructure Report Card*, Engineers Australia, 2005.
[78] WSAA, *Testing the Water: Urban Water in Our Growing Cities –The Risks, Challenges, Innovation and Planning*, WSAA Position Paper No.01, Water Services Association of Australia, October 2005.
[79] A glossary and a definition of terms are included as Section 4.13 and 4.14 respectively.

commercial, economic and social goals and needs. Essentially, the many interested parties are involved in balancing the needs of the natural systems against the needs of those who live, work and draw on these systems and resources. Of course, the central objective must be to manage critical natural systems and resource bases in ways that allow them to adapt to support the needs of present and future populations.

As a result of these collective efforts, including deep analysis and feedback from past reforms, as well as very wide-ranging public debate, governments have carried through substantial water reforms, at local, state and national levels. These major reforms can loosely be categorised around three themes, namely, improved and integrated catchment management, improved viability and sustainability of water using industry, and the securing of adequate water quantity and quality for future populations and their industries.

Governments worldwide have come to realise that catchments, rivers systems and their ecosystems and resources cannot be managed satisfactorily within traditional administrative and local government boundaries. Nor have efforts succeeded where issues, such as water pollution, or system elements such as soils or river banks, have been managed as if they were discrete and unrelated to the whole catchment system. In Australia the primary aim of government seeking sustainable management of catchments has been to:

- arrest the degradation of catchments, rivers and natural systems;
- put together the basic data and trends relating to water-based systems and resources. This spans catchment and river health, including stream flow, groundwater, lake and estuary conditions as well as the state of riparian land and vegetation, all of which are central to effective decision making on future water resource management;
- harness assessment, audit and modelling techniques to improve the feedback between the sustainability of biophysical outcomes and decisions taken and strategies implemented;
- develop a more systemic view and approach to water resource management by integrating the planning and management of surface run-off, river water, groundwater, lake, bay and estuarine water and by recognising variability in climate and predicted change;
- implement strategies that use a mix of standards, controls and economic instruments to overcome longstanding problems and to secure sustainable outcomes for catchments, people and industry;
- improve the prospects of access to water of sufficient quality and quantity to meet water supply, irrigation, farming and other industrial needs, by focusing on better land use management and better management of riparian vegetation, water quality and river flows; and
- introduce processes that hold those with significant responsibilities accountable for the state of water based systems at the end of each cycle of action and management.

A good deal of this effort has provided important underpinning for each of the other reform areas. In that regard, there has been a very considerable focus, particularly in the past five years, on improving the prospects, sustainability and confidence of major water using industry. That has been offset, at times, by the obvious concern to mediate the impact of outmoded land and water use practices or approaches that lead to unacceptable impacts on natural systems or other users. The aims of these efforts involving government and a variety of stakeholders have been to:

- foster improved efficiency and productivity in the way water is used, in order to maximise industry returns, to support rural communities and to achieve wider economic and social benefits. This has included some effort to provide incentives to primary producers and encouragement for sustainable farming;
- secure fair, transparent and comparable access rights for water users across regions, states and latterly the nation, based on sound assessments of available water, with variable recognition having been paid to date to community interest and rights in the resource. First-round allocations have largely occurred to meet environmental needs, and rights to use and re-use are progressively being conferred by legal process on those with or seeking entitlements;
- facilitate water trading within and across catchments and regions, in ways that build confidence and create operational flexibility in water-using industry, and that secure progress in advancing high value-added usage of available water resources. The process of establishing market structures and pre-

conditions is in its infancy and has only partially recognised the idiosyncrasies of river systems and how to respond to their needs in ways that lead to sustainable results;

- progressively replace myriad regulatory and administrative requirements on primary producers by broadly based land, water and vegetation cover plans, incentives or requirements. This recognises the farming community as wealth producers, resource stewards and potentially as agents of change in securing water reform outcomes; and
- remove institutional barriers to water reform to achieve both improved prospects for industry and improved river health. This calls for much more resolute review and action to target and streamline reforms and to remove impediments to agreed strategies, many of which barriers span a number of areas of government and the community.

Since World War II, interest in water supplies, particularly in urban surrounds can be divided into three distinct phases. The period 1945 to 1975 was one of high political interest and action as water was needed to support the rapid growth of population brought on by post-war migration, and the expansion of irrigated agriculture. This was the period during which significant progress was made in securing advances in both amenity and public health through the provision of high-quality drinking water and reticulated sewerage. While these programs continued, including the building of some new dams, from 1975 to the early 1990s, government and community concerns led progressively to priority attention in water resource management being given to the social and environmental impacts of the way water resources were managed and major water supply and sewerage services delivered.

In the 1990s, the management of water resources, the viability of water-using industry, present and future, and the challenge in determining how to secure adequate supply for both urban and rural users has become an issue of such national importance that water is once again at the forefront of politics, with responsibilities returning to more senior cabinet portfolios, as in the post-war era. The aims of reforms to the public water industry include:

- placing water authorities on a competitive footing by corporatising their operations, leading them to focus on what they do best, to harness competitive opportunities, to price their services to better reflect cost recovery, to provide for future assets, services and demands, and to pay a return on past public investment in their assets;
- separating water resource custodianship or ownership from policy setting and water distribution to gain greater efficiency and value for money, including in the delivery by councils of water, sewerage and drainage services to rural townships;
- containing public costs, giving higher priority to competitive pricing, and focusing on price impacts on users by setting or scrutinising water and service pricing independently of the water authorities or corporations, and by evaluating the cost-benefit of proposed supply and service standards; and
- introducing wide-ranging techniques to curb water demand, to promote re-use and recycling and to reduce per capita usage, thereby reducing pressure on existing storage capacity as population grows.

All these initiatives contribute to the extent to which a growing population is absorbed, the prosperity of future industry and the sustainability of jobs as well as the ability of the natural systems to adapt and adjust.

## 4.3 WATER REFORM: A NATIONAL PRIORITY

The process of Federation and the creation of an Australian Constitution maintained the responsibility for the control of water resources and the development of water services in the hands of the states, latterly including the territories. Commonwealth government involvement has been limited to those specific situations where its powers, including external affairs, corporations and interstate commerce, have underpinned legislation that has enabled or required its involvement. This has led to specific actions at state boundaries (Murray Darling), in matters of heritage (Franklin Dam, Great Barrier Reef) and where activities or development could impact on national biodiversity. The Commonwealth has also harnessed its power to provide conditional grants to advance what it considers to represent the national interest in this domain.

The Commonwealth Government has played an increasingly active role in setting national standards, seeking harmonisation of water resource management policy and approaches across the nation, in fostering major research into salinity, water saving and other vital long-term water-related issues, and in developing common approaches to water entitlements and approaches to water trading. Its use of the national competition framework and associated funding to drive competition throughout a largely state and local government public water industry has also been important in gaining efficiencies and reshaping that industry.

The Commonwealth Government has led examination of water resource management nationally in both the Council of Australian Governments (COAG) and various ministerial councils. Such councils have provided a way to agree on joint action, leading at times to the application of Commonwealth and/or state funding, in pursuit of national aims. Commonwealth involvement is continuing to grow through such initiatives as the COAG water and competition reforms, the Land and Water Audit, the National Water Initiative and the National Water Commission.

### 4.3.1 National Water Quality Management Strategy

The National Water Quality Management Strategy [80] was launched by the Ministerial Council of Water Ministers before the COAG framework encouraging overarching reforms was firmly in place. This process led to the development of national water-quality guidelines that are used as a reference tool and guide by health, environment and water regulators and managers and the Australian Water Industry (AWI). The guidelines were undertaken in partnership between the Councils of Water and Environment Ministers, with the National Health and Medical Research Council involved, where necessary, for example, in production of drinking water guidelines. The guidelines, already under revision, are beneficially influencing regulators as well as water utilities in their operational and service performance.

### 4.3.2 COAG gives impetus to wider national water reforms

Many of the reforms described in Section 4.2 above have been given impetus or strengthened as a result of the reforms adopted and agreed by the states and Commonwealth at COAG forums in the early 1990s. For example, the public water industry is more efficient and competitive, utilities have been corporatised, water pricing is more commercial, assets are being depreciated and provision made for replacement and new capital works, and reasonable returns are being achieved on equity invested. Assessment and audit of performance have in some cases been passed to government regulators. There has been widespread separation of policy setting from water distribution and service delivery, and in some states, the management of and exploration for water resources has passed from the state water utility to a government agency.

A number of these water policy initiatives were also incorporated into the National Competition Policy framework, where they have been directly linked to tranche payments by the Commonwealth Government for achievement of specified reform targets. This incorporation has driven the states to reform public monopolies in water supply and services, improve the oversight of public water enterprises, encourage better cost recovery and pricing reform, and to review critical legislation and some institutional arrangements

### 4.3.3 National Water Initiative (NWI)

The NWI was developed to refresh the COAG water reforms by taking actions to "increase the efficiency of water use, sustain rural and urban communities, and to ensure the health of river and groundwater systems [81]." The NWI places considerable emphasis on efforts to harmonise quite diverse water rights and entitlements so that they become more uniform and secure nationally and so that the traditional link between land and water rights is broken. The NWI is working to ensure that the right pre-market

[80] Department of Agriculture, Fisheries and Forestry, *Water Quality Management Strategy*, Natural Resource Management Ministerial Council, Commonwealth Government, 1993.
[81] AWA, *The Australian Water Directory 2005*, Australian Water Association, 2005.

conditions are in place to facilitate the development of water markets. A further initiative known as Water Smart is designed to speed the adoption of appropriate technologies, processes and practices to save water, including by mounting significant case studies, such as those already being funded in Adelaide and the Gold Coast. An independent National Water Commission has been appointed to report to COAG on NWI progress. Three Fellows of the Academy, Dr Wally Cox, Professor Peter Cullen and Dr John Radcliffe, are Commissioners of that body.

### 4.3.4 Linking water management and sustainable development

In much the same timeframe as the national water policy framework was being developed governments, experts and public interest groups turned their attention to ecologically sustainable development. The national and state approaches that emerged were destined to guide and inform much water reform from the early 1990s. It became clear that all those involved in managing the nation's water were bound to take account of the provisions of the National Strategy for Ecologically Sustainable Development. That strategy called on those involved in taking critical decisions to seek sustainable outcomes and to take precautions in situations of uncertainty, while continuing to strive for international competitiveness. At the heart of ESD lie the following principles:

- 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 processes and life-support systems.

### 4.3.5 Water Services Association of Australia (WSAA)

Australian capital city water utilities formed an association in the 1920s to exchange technical and policy information which continued to meet until 1995. Among its other achievements was the production in the 1980s of the first Australian guidelines for drinking water quality and re-use.

In 1995 WSAA was formed with its own staff to give utilities an independent voice in their newly corporatised and changed regulatory environment. WSAA now includes Australia's 28 largest water utilities, providing water services to 15 million people. The organisation plays a key role in policy development, research and utilising performance measurement and benchmarking.

Australia's water utilities continue to be publicly owned, mainly by state governments. These utilities have, as a result of extensive and continuing reform, become very competitive and commercial. This has led to innovative and wide-ranging use of contracts and to a variety of public-private partnerships and alliances, with private enterprise playing an ever increasing role. Since the 1990s most design and construction work in building water and sewerage facilities and infrastructure has been outsourced to private contractors.

More recently some operations have been outsourced, by harnessing Build, Own, Operate (BOO) and Build, Own, Operate and Transfer (BOOT) schemes, which arrangements are commonplace in the development of major infrastructure such as roads and tunnels.

Although, most new water infrastructure is presently built with public utility capital, the scale of the challenge in renewing, replacing and extending the existing systems and infrastructure associated with water distribution, sewerage and drainage is formidable. To that can be added the cost of introducing new technology and approaches to facilitate the recycling of very large quantities of waste water and storm water.

It is also important that new opportunities are seized to introduce less costly, innovative and more local approaches to meeting the water service needs of growing localities. It seems likely, therefore, that an increasing role for the private sector will progressively emerge in this arena, as current arrangements between the public and private sectors are expanded further to meet these very large challenges.

## 4.4 AUSTRALIAN WATER RESOURCES: AVAILABILITY AND ACCESSIBILITY

Water resources that can be drawn on for water supply and commercial use in Australia comprise surface water and groundwater. Surface water is measured by Mean Annual Run-off (MAR). Table 4.1 shows MARs for Australia in 2000.

### Table 4.1 – Surface Water Stocks – 2000 [82]

| | | Mean annual run-off | |
|---|---|---|---|
| **Drainage division** | **Area sq km** | **Gl** | **%** |
| North-East Coast | 451,000 | 73,411 | 19.0 |
| South-East Coast (a) | 274,000 | 42,390 | 10.9 |
| Tasmania (b) | 68,200 | 45,582 | 11.8 |
| Murray-Darling Basin (a) | 1,060,000 | 23,850 | 6.2 |
| South Australian Gulf( c) | 82,300 | 952 | 0.2 |
| South-West Coast | 315,000 | 6,785 | 1.8 |
| Indian Ocean | 519,000 | 4,609 | 1.2 |
| Timor Sea | 547,000 | 83,320 | 21.5 |
| Gulf of Carpentaria | 641,000 | 95,615 | 24.7 |
| Lake Eyre | 1,170,000 | 8,638 | 2.2 |
| Bulloo-Bancannia | 101,000 | 546 | 0.1 |
| Western Plateau | 2,450,000 | 1,486 | 0.4 |
| **Total** | **7,680,000** | **387,184** | **100.0** |

(a) South-East Coast and Murray-Darling Division. The volume diverted represents the sum of available data (NSW has not reported water use for unregulated surface water management areas).
(b) Tasmanian Division. Volume diverted does not include the hydro-electric scheme diversions.
(c) South Australian Gulf Division. Mean annual outflow includes the flow from surface water management areas Willochra Creek and Lake Torrens, which do not flow to the sea, but flow into the terminal lake, Lake Torrens.

About five per cent of MAR can be captured by existing infrastructure. While good resources exist near major population centres, the major underdeveloped resources are in the remote north of Australia.

There is less certainty about available and accessible groundwater resources. The figures in Table 4.2 are based on sustainable yield.

The table reports volumes, classified by salinity levels. The salinity of groundwater is an important determinant of water use. Thus, while the total sustainable yield is 29,173Gl, only water under 1500mg/l of salinity is useable for agriculture (20,980Gl), while only that below 1000mg/l (18,000Gl) is suitable for drinking water. The Australian Drinking Water Guidelines recommend less than 500mg/l for human consumption. Thus groundwater resources of higher salinities are only likely to be used where they can be diluted with lower salinity water.

At an International Water Supply conference in 1996 [83], Marks used a "water stress" indicator used in the World Bank and UN population estimates to compare fresh water availability in 1990 and 2050 in various countries. The indicator used – the level below which stress could be assumed – was 1700m$^3$/year. It showed six per cent of the world population was under water stress in 1990 and 44 per cent could be under stress by 2050. Per capita water for Australia was 20,300m$^3$ in 1990 and 11,500m$^3$ in 2050 (for 30 million people). This indicated no "water stress" for Australia, which was in better shape than many countries. It should be noted, however, that national figures can hide the availability, distribution and consumption patterns of water, which were not identical in countries, as well as regions of disadvantage in a country or continent that might otherwise be well-supplied.

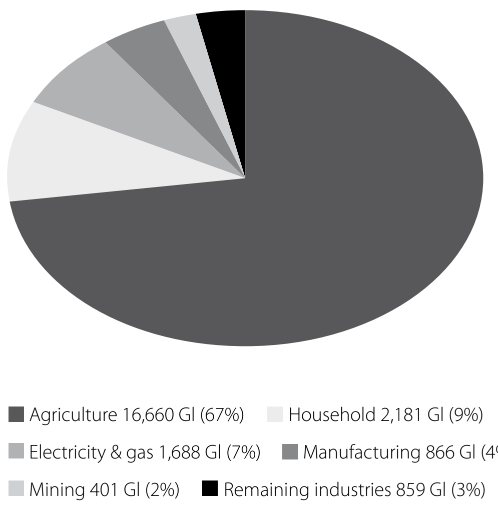
[82] ABS, *Year Book Australia 2005*, Australian Bureau of Statistics, 2005
[83] Marks, R., *Shrinking Water Resources in a Growing World*, International Water Supply Association/ASPAC Conference, Hong Kong, November 1996.

## Table 4.2 – Sustainable Yield of Groundwater, by Level of Salinity – 2000 [84]

| | NSW Gl | VIC Gl | QLD Gl | SA Gl | WA Gl | TAS Gl | NT Gl | AUST Gl |
|---|---|---|---|---|---|---|---|---|
| Less than 1,500 mg/l | | | | | | | | |
| <500 mg/l | 698 | 194 | 1,373 | 56 | 1,899 | 1,585 | 4,412 | 10,217 |
| 500-1,000 mg/l | 3,928 | 827 | 995 | 229 | 1,061 | 767 | 287 | 8,093 |
| 1,000-1,500 mg/l | 34 | 386 | 119 | 679 | 995 | - | 455 | 2,670 |
| Total | 4,660 | 1,407 | 2,487 | 964 | 3,955 | 2,353 | 5,154 | 20,980 |
| 1,500 mg/l and over | | | | | | | | |
| 1,500-3,000 mg/l | 812 | 244 | 113 | 253 | 1,468 | 178 | 139 | 3,208 |
| 3,000-5,000 mg/l | 2 | 707 | 30 | - | 588 | - | 183 | 1,510 |
| 5,000-14,000 mg/l | 440 | 201 | 63 | 762 | 841 | - | - | 2,307 |
| More than 14,000 mg/l | - | 797 | - | - | 371 | - | - | 1,168 |
| **Total** | **1,254** | **1,949** | **206** | **1,015** | **3,268** | **178** | **322** | **8,193** |
| Total sustainable yield | 5,914 | 3,356 | 2,693 | 1,979 | 7,223 | 2,531 | 5,476 | 29,173 |
| Proportion (%) | | | | | | | | |
| Less than 1,500 mg/l | 79 | 42 | 92 | 49 | 55 | 93 | 94 | 72 |
| 1,500 mg/l and over | 21 | 58 | 8 | 51 | 45 | 7 | 6 | 28 |

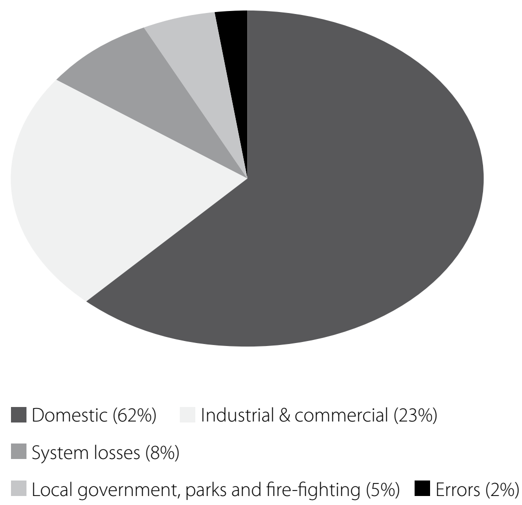
Given pressure on the quality and quantity of water resources and concerns about the sustainability of some patterns of groundwater use, there is continuing interest in harvesting the untapped water resources of the north of Australia and in diverting the waters of some of the major coastal rivers on the east coast for use by the primary producers of the plains of NSW. The broad alternatives are to encourage population growth and re-settlement northwards or water diversion southwards or to the west of NSW, in the latter case. Many schemes involving pipelines, ships, dams and recently canals have been considered to gain access to these resources for current and future users. Of course, each such proposal needs to be assessed in terms of future river health, energy consumption, greenhouse contribution and all round environmental impact and practicability – as well as financial viability. To date studies have shown that all these water diversion proposals do not meet first-order tests of financial viability, especially by

### Figure 4.1 – Water use in Australia[85]




**Source: Water Services Association of Australia, 2005**

### Figure 4.2 – Urban water consumption[86]




**Source: Water Services Association of Australia, 2005**

[84] ABS, *Year Book Australia 2005*, Australian Bureau of Statistics, 2005
[85] *Testing the Water, Urban water in our growing cities: the risks, challenges, innovation and planning.* Position Paper No. 1 Water Services Association of Australia, October 2005.
[86] *ibid*

comparison with other ways of securing water supply, such as recycling, improved efficiency of storage use, seawater desalination, and so on.

In the latter context, Australia's first major urban seawater desalination plant is now under construction in Perth and is expected to deliver drinking water for $1.16/Kl. When operational this plant will provide useful cost and energy consumption benchmarks against which to gauge alternatives. Sydney has also done some preliminary planning for the construction of such a facility, if the need should arise, and the Victorian Government has recently received a report on costs and options for various desalination technologies.

## 4.5 CURRENT WATER USE IN AUSTRALIA

### Table 4.3 – Industry and Household Water Consumption – 2000-2001 [87]

| | NSW Gl | VIC Gl | QLD Gl | SA Gl | WA Gl | TAS Gl | NT Gl | AUST Gl |
|---|---|---|---|---|---|---|---|---|
| Agriculture | 7,322 | 3,725 | 3,454 | 1,302 | 565 | 222 | 70 | 16,660 |
| Forestry and fishing (a) | 3 | 4 | 2 | 1 | 10 | 2 | 0 | 2 |
| Mining | 52 | 7 | 109 | 12 | 195 | 21 | 5 | 401 |
| Manufacturing | 179 | 249 | 181 | 86 | 83 | 79 | 9 | 866 |
| Electricity and gas supply | 59 | 1,536 | 71 | 2 | 19 | 0 | 1 | 1,688 |
| Water supply (b) | 676 | 745 | 216 | 24 | 114 | 10 | 9 | 1,794 |
| Other | 254 | 148 | 172 | 38 | 175 | 24 | 22 | 832 |
| Households | 679 | 472 | 501 | 181 | 245 | 59 | 45 | 2,181 |

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

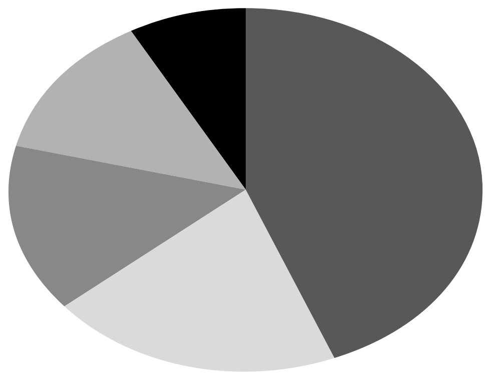
Total water use summarised in Figure 4.1, shows the dominant consumption sector as agriculture at 67 per cent. By contrast urban water use, (household, manufacturing and other) accounts for only about 16 per cent. Shown in Figure 4.2 is the proportion of urban water used by different sectors.

Household water use has been the subject of numerous authoritative studies. While most states and territories have undertaken such studies, those conducted in Perth in 1981 and 1999 give indications of the challenges faced elsewhere in the nation. Summaries of all studies are presented in Figure 4.3. It is important to note that the figures presented in such studies represent a snapshot and that the picture may change as pricing and demand management initiatives take hold (such as more widespread use of water efficient appliances and restrictions on water use), all of which can lead to significant changes in the pattern and scale of consumption. There are also distinct regional variations that arise from climate, soil type and lifestyle differences that can and do influence local snapshots and the rate of response to demand management. The foregoing data show that the major user of water in Australia is the agriculture sector – leading commentators to point out, from time to time, that diversion of a small proportion of that rural water to urban domestic uses would provide sustainable supplies to urban Australia, at what they argue are modest and sustainable costs to the primary industry base. This argument has not carried weight with either government or primary producers to date, although it will, in principle, become possible when water trading becomes more widespread.

Recent droughts and unpredictable and unreliable rainfall have threatened Australia's city supplies; all have been subject to water restrictions. In some cases the restrictions have been more severe, involving, inter alia, total bans on the use of sprinklers, while in others sprinklers have been restricted usually to night hours only. These droughts have coincided with growing public debate on global warming and climate change. It seems that the variability in present rainfall differs from the past, and augurs future

[87] ABS, *Year Book Australia 2005*, Australian Bureau of Statistics, 2005.

Figure 4.3 – Water use in Australian households[88]

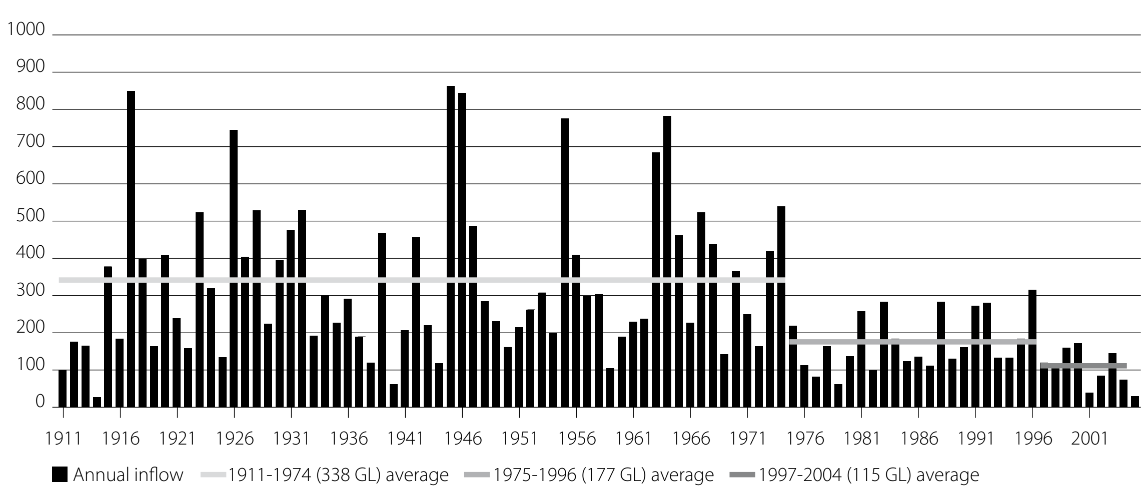



changes in rainfall patterns and therefore in access to adequate supplies of urban water.

There is increasing evidence that climate change is already here (see Chapter 3), with its greatest impact being felt in south-western Australia. Figure 4.4 shows inflows into Perth's major dams from 1911 to 2004 and reveals a dramatic change since 1974 with inflows over the past eight years being reduced by 64 per cent compared with those prior to 1974. "The evidence of climate change induced reduction in run-off to other cities around Australia is not clear [89]."

Drought or, more correctly, changing rainfall patterns affect regions differentially and have profound effects on runoff. These factors, increasing population and, in some cases, the failure to act have increased pressure on water supplies nationwide, with shortages of water occurring in some urban centres and many

Figure 4.4 – Climate effects on runoff, Perth 1911-2004[90]




* Year is taken as May to April and labelled year is beginning (winter) of year

** Inflow is simulated based on Perth dams in 2001 and 2005 is total until 3 August 2005

**Source: Water Corporation WA**

[88] WSAA, *Testing the Water: Urban Water in Our Growing Cities – The Risks, Challenges, Innovation and Planning*, WSAA Position Paper No.01, Water Services Association of Australia, October 2005.
[89] *ibid.*
[90] Water Corporation, Western Australia 2005.

rural areas and townships of Australia. In that regard, the report of the Water Services Association of Australia (WSAA)[91] notes that, "over the last 20 years, with the exception of Perth, no new water sources have been developed for our cities. At the same time, the urban population has increased dramatically". In the case of Perth, the region is favoured by substantial ground water resources in sandy soil. Perth has been able to more than double its source yield through an intensive capital works program since the early 1990s. Its strategy for coping with a drying climate, *Security through Diversity*, is set out in a recent convention paper[92].

## 4.6 MANAGING DEMAND FOR WATER

Throughout the nation governments have tried to manage demand for water in ways that diminish the need for and urgency of building new storages and finding new sources of supply, with all their potential social and environmental impacts. The intent is to curb or contain demand, while population grows and community lifestyle and standards remain high. Variable rainfall and drought have all contributed to added pressure on urban storages and to shortages which have been managed by a range of water conservation and demand management measures. A combination of these measures has already produced substantial savings. For example, Melbourne's per capita use is now 19 per cent lower than in the 1990s; Perth has reached its target of 155Kl/capita/year – down from well over 200 a few years ago; while Sydney has added 700,000 more people since 1985 without increasing overall water use. Water recycling within individual industries or properties as a form of demand management is discussed later in this chapter.

### 4.6.1 Restrictions

Restrictions, widely in place in recent times, have proved quite successful in achieving short-term reductions in urban consumption. They are generally directed at outside household use. In some cases, they seem likely to become permanent, as for example in Sydney by limiting the number of days where watering can occur and by further limiting garden watering to cooler night-time hours. The extent of community tolerance will be tested if restrictions start to impact too heavily on lifestyle or living standards..However, the degree of compliance in Australian communities under restriction is encouraging, and suggests that the seriousness of the problem, and the need for personal action, are both widely accepted. In fact, all major cities have had community awareness campaigns designed to foster water-saving cultures, to enlist assistance in curbing demand and to bring home to consumers the limitations and constraints on present and future supplies.

Of course, restrictions also impact on commercial activities such as nurseries, turf production and landscaping outlets, and substantial service industries, and have already led to some industry dislocation and restructuring.

### 4.6.2 Water-efficient appliances

Efficient appliances extend from dual and low-flush toilets to economiser shower and tap fittings up to dishwashers and washing machines. WSAA's voluntary labelling scheme gave way to the new Commonwealth mandatory scheme on 1 July 2006 as part of the National Water Initiative. A similar scheme for outdoor products and services has been developed by the AWI. Rainwater tanks can make only a modest contribution to demand management, the prospects being greater in climates that have year round rainfall such as Brisbane and Sydney. Rainfall storage on a regional, rather than an individual scale, which leads to the replenishing of aquifers in underlying sandy soils, by natural or artificial (pumped-storage) methods, can make a greater contribution to improved yield in a more economic way.

[91] WSAA, *Testing the Water: Urban Water in Our Growing Cities – The Risks, Challenges, Innovation and Planning*, WSAA Position Paper No.01, Water Services Association of Australia, October 2005.
[92] Gill, J., *Staying Ahead of a Drying Climate*, Paper No. 5319, Australian Water Association Convention, Brisbane, May 2005.

### 4.6.3 Pricing

Over the past 25 years pricing policy reform has played a significant part, along with other demand management measures, in reducing per capita water usage. Previously, urban water rates for consumers were frequently much more related to the value of land than to the price of water as a valuable resource. As well, some consumers lacked any metering of consumption and on the periphery of cities and towns much low-cost bulk or illicit abstraction occurred. Most urban utilities now use fixed service charges plus a consumption charge that sends the "right" signals. That charge can be increased further if usage seems likely to exceed potential supply.

Notwithstanding this progress, some studies show that water demand is relatively price inelastic, especially indoors – or has thus far proved to be so. That suggests that further increases in consumer prices for water will continue to contribute to reduced demand, but not to an extent commensurate with price rises.

## 4.7 LONG-TERM PLANNING FOR URBAN WATER

As Australian governments have come to understand the impacts of dams on river flows, people and catchment environments most have developed strategies aimed at maximising use of current water infrastructure and resources, with a conscious effort to avoid building new dams.

Water restrictions and climate change have led some commentators to claim that Australia has an urban water crisis. However, to quote the Barton Group [93], "Contrary to popular belief, we do not have a shortage of water in Australia." This statement echoes the previously mentioned World Bank/UN findings. It should be noted, however, that these findings are based on the acceptance of "stress" levels well below those to which Australians are accustomed and that such assessments include the water resources of northern Australia, remote from most consumers and demand pressures, thereby possibly contributing to a false impression of supply and demand options.

All states have water resource plans for major conurbations. These include new sources of water deriving from the application of advanced technology. This helps to provide source diversity, thereby spreading and diminishing natural supply risks. While plans are not as advanced for smaller regional populations, many are now receiving attention. Planning for the major conurbations extends to 50 years, with more detail provided for the first 20 to 25 years. WSAA has recently released a position paper [94] outlining plans for Australia's 10 major cities to about 2030. These cover population growth in these 10 cities from 12.8 million in the areas served by WSAA member organisations (out of about 20 million total population) to a projected 17.3 million (out of about 25 million). The paper indicates that public utilities must prepare for changes in policy, infrastructure and climate but, in so doing, notes that many water-using industries have abandoned long-term planning because of rapid natural and institutional change.

While these plans appear to be economically robust, 25-year planning involves obvious significant risk and requires regular revision, for example every five years, to allow for changing climate conditions, new assessments of social and environmental impacts and technological advances. For example, the Source Development Plan for Perth [95] spans 2005 to 2050 and is a revision of the 2001 plan, brought on by continuing dramatic reductions in stream flows.

## 4.8 PLANNING FOR DIVERSITY IN WATER SUPPLY

One key to long-term planning for security of future water supply lies in achieving diversity. The WSAA position paper reveals some of ways of diversifying, which have informed this text

[93] *Australian Water Industry Roadmap*, The Barton Group, May 2005.
[94] WSAA, *Testing the Water: Urban Water in Our Growing Cities – The Risks, Challenges, Innovation and Planning*, Position Paper No.01 Water Services Association of Australia, October 2005.
[95] Water Corporation, Western Australia, *Integrated Water Supply Scheme Source Development Plan 2005*, Planning Horizon 2005-2050, Water Corporation, Western Australia, April 2005.

### 4.8.1 New sources

New sources might include new surface and groundwater supplies, accessing and diverting water from agricultural use, re-commissioning out-of-use dams, improving catchment management and/or desalination. None involves water diversion from the north. A study prepared by GHD (September 2004) for the Water Corporation of WA on a proposal for a Kimberley-to-Perth pipeline indicated that water would cost over $6/Kl and use three times the energy of desalination. A further study including canals, tanker ships and towing water bags is in hand.

### 4.8.2 Improving the efficiency of existing systems

There are a number of techniques currently being applied or under investigation by water authorities that will lead to considerable improvements in access to existing water sources and improved distribution. This includes more efficient use of existing storages and improved and deeper water off-takes; changes in distribution systems to reduce unnecessary retention and diversion of water; covering canals and small storages: and reducing serious overflows and system leakages at various points in the distribution system. These efforts are being assisted by new technology, and changes driven by greater concern to contribute to water conservation.

### 4.8.3 Water trading

Formal water trading has occurred in the Murray Darling since the early 1980s and in a number of the states a few years later. Most often, it has involved arrangements between farmers and between farmers and irrigators in one river valley, but many local informal arrangements also exist. From this promising start we can expect to see more extensive trading as the system develops. Under the Australian Water Initiative there is significant potential for rural/environmental/urban trading and there is the prospect that agricultural sector trading could provide urban users with water from low economic value services.

Although there are producer and political sensitivities to overcome, such rural to urban reallocation could be carried out in ways that would not damage irrigated agriculture, given the order of magnitude of water use by agriculture compared to that used by cities. Thus, a five per cent improvement in agricultural water use efficiency could free up enough water for two to three million urban users. Examples already exist. SA Water recently purchased 16Gl from irrigators while the WA Water Corporation is paying to upgrade Harvey Irrigation assets so as to permanently free up 17Gl/year. For geographical reasons – mainly the location of water sources – the prospects for such water transfer would seem to be greatest in South Australia and Victoria.

Water trading is a useful tool to advance structural change in water using industry. It encourages the movement of water to sites, enterprises and users where higher value-added activity and more efficient uses are practical. It can, in such circumstances, improve industry viability and operational flexibility, while allowing farmers and irrigators the opportunity to relinquish water surplus to current needs. As trading becomes more commonplace between regions, those regions experiencing rapid development of population and associated services and industry may be able to benefit from market aided transfers, including, as noted above, by water utilities seeking to augment supply. Once the economic and environmental conditions under which water markets will operate have been established, the trading process will also help governments and the community to avoid having to make some difficult trade-offs between competing industries and their demands for available water resources.

The introduction of a better structured and formal trading system between catchments, regions and states still requires further research, analysis and political negotiation. The introduction of such water markets must bring about the national harmonization of water rights, entitlements and allocations that presently vary considerably between states. This work must also establish other pre-market conditions that take account of adequate environmental flows and other catchment management parameters as well as ensuring that there is an adequate return on public investment in established water infrastructure. Feedback loops will also need to be in place, prior to market operations, so that corrective action can be taken where necessary; to deal with teething problems in market operations or to protect river health from any unexpected impacts of trading. This task requires patience and skill because at its conclusion, water users must have confidence in the long-term operations and integrity of the market structures so-established.

### 4.8.4 Alternative sources

Alternatives to the present system for supply of reticulated water include reusing or recycling treated wastewater and storm water as a substitute for potable water. Such sources currently can supply industry, irrigation of open space, some produce and golf links and non-potable household uses. While re-use technologies are likely to play a major part in augmenting future supplies of water for various domestic uses, treatment to potable level is currently limited in Australia by economic, health and environmental perceptions. As proposals have come forward in recent years, the resistance to potable re-use is seen to depend more on non-technical factors, with cost a secondary but nonetheless important factor.

A project to supply recycled water to vegetable growers in Werribee, Victoria, encountered resistance (and unfavourable press coverage) until water of potable standard was promised - although such high quality was initially held to be unnecessary. It is understood that direct potable re-use has only occurred in one major city world-wide and it is unlikely to be adopted in Australia as other acceptable solutions are more viable.

Even indirect potable re-use is comparatively rare and usually needs ground water reservoirs under large sand areas to enable recharge with treated wastewater, storage, and then extraction at a distant point. Perth is the only major city with these conditions and intends to create a major new source by this method, subject to research currently underway.

Indirect potable re-use should be considered in terms of cost, practicability and health risk. Analysis of its potential contribution requires a more open-minded and professional approach than that to date. Recycled indirect potable water is already in use elsewhere in the world and, as technologies improve and confidence is gained, the same can and arguably should be expected in Australia.

Most states have set re-use targets and a number of schemes are planned or under way. These are discussed in the Developing Technologies section (Section 4.9).

### 4.8.5 Ongoing water efficiency measures (demand management)

Despite recent reliance on pricing reforms, water efficient appliances and practices, education and semi-permanent low-level restrictions, much more can be saved by the extension of such measures. All utilities are improving their efficiency programs. Pricing is a vital issue for demand management. If pricing could be made a more effective tool, it could contribute to considerable savings. Most utilities use some form of volume charging for reticulated water.

Considerations to start volumetric charging for large private extraction of groundwater around Perth, thereby freeing up water for other uses, and decisions to meter private users of reticulated water on the outskirts of Sydney, represent clear examples of the mood for change. In some regions, licenses for groundwater extraction for a range of uses specify maximum quantities to be extracted but compliance continues to be poor and over-extraction is common.

## 4.9 DEVELOPING TECHNOLOGIES

Technology continues to improve rapidly in the water industry. While many of the following are in use, most are developing further and receiving a wider application.

### 4.9.1 Water re-use and recycling

The terms *re-use* and *recycling* have become interchangeable and the community seems more comfortable with the latter. In this section *recycling* is used to describe the re-use of water within an industry or complex, and *re-use* to describe the more general re-use of treated community waste water. In 2004 the

Academy released its report on the status and technical aspects of water recycling [96] and while this survey was warmly welcomed by industry and government, subsequent development in the field indicates a need for the work to be updated.

Improvements in treatment systems for domestic and industrial wastes will increase industry recycling instead of sewer discharge, thus reducing potable water demand. Small efficient systems allow recycling of treated wastewater for non-potable purposes in new commercial and high density residential buildings, however recycling of grey water within individual lots is likely to be limited by economics in the absence of regulatory requirements.

There are many Australian schemes to re-use treated wastewater and/or storm water. The earliest schemes were inland where irrigation of playing fields, pastures, vineyards and tree lots also doubled as effluent disposal. Total flows re-used in Australian cities are modest, with the exception of Adelaide [97] and this is the case in cities world-wide. The comparatively low level of re-use in large cities has existed because of the poor economics, health risks and public perceptions associated with reusing large flows within or close to major urban centres. The number of successful schemes is however growing, as detailed in the Academy's 2004 report. Most states are selling treated wastewater to industry and some schemes are already in operation, such as Brisbane's Luggage Point Wastewater Plant that provides water to a BP refinery and the new re-use plant in Kwinana (WA) providing water to a number of industries. Other examples are to be found in all state capitals [98]. Third pipe schemes in new housing developments are becoming more common, and substitution of potable water by recycled water of slightly lower quality is seen as a desirable development. State governments are now establishing utility, industry and council targets to increase re-use. Potable re-use is discussed above.

Australian cities will continue to develop non-potable water re-use in new subdivisions. These can be cost effective and quite safe, provided that misuse is prevented. Eventually high quality treated effluent could also be used for environmental flows, thereby freeing up existing potable water for higher level use. Progress in the treatment and re-use of wastewater re-use is well summarised in the following extract from a recent AWA Journal paper [99].

> "Recycled water is advocated by some proponents as being the answer to the water challenges confronting our cities. The arguments for recycled water are often put without understanding the costs, risks and energy implications of such schemes (consider Greenhouse Gas Emissions). With the exception of Canberra, all of Australia's capital cities are on the coast which means that the source of the recycled water can be some distance from where it can be used in large quantities. Given the lack of national and international guidelines, indirect potable re-use on a large scale is considered to be premature. Recycled water via third pipe systems will play an important role in commercial/industrial precincts and green field suburbs, but these applications are at the margin. Furthermore, some 80 per cent of the asset base of urban water relates to the distribution system and contemplating duplication of it, even to a minor extent, is economic nonsense. We should not use drought as an excuse to forget fiscal discipline!"

### 4.9.2 Use of membrane technology

The improvement in quality and reduction in cost of membranes has significantly reduced the cost of high quality treatment of effluent, waste water and seawater virtually to drinking water standard. Although large scale indirect potable re-use is still some way off, non-potable and industrial use is now possible with much reduced health risk, given adequate means of containing overall costs and energy consumption.

While desalination by thermal means is still appropriate in some circumstances, the improvement in membranes has steadily reduced the cost of desalination to the point where it is becoming competitive with other water sources, where high degrees of treatment and/or moving water over large distances is involved.

96 *Water Recycling in Australia*, Australian Academy of Technological Sciences and Engineering, 2004.
97 AWA, *The Australian Water Directory 2005*, Australian Water Association, 2005.
98 *ibid*
99 Young, R., *Water Markets – Let the Water Begin to Flow*, Water, Journal of the Australian Water Association, November 2005.

Seawater presents an unlimited raw resource for conversion to potable water, although high energy consumption and environmental concern about the disposal of super-saline waste present some significant challenges. Similar energy issues exist in treating brackish water or augmenting supply from distant sources.

Membrane technology development is advancing so steadily, with such wide-ranging prospects for its cost effective use that more extensive investigation of its applications is called for.

## 4.10 SUSTAINABILITY

As outlined earlier the concept of sustainable development has changed the way water is managed nation-wide. Legislation and priorities have been changed; trade-offs have been made more transparent; and decisions affecting water supply and management now occur in a quite different context. Thus the managers of water supply catchments must focus on river health, effective land and water conservation, water quantity and quality as well as stream flows. The managers of those rivers and streams that receive effluent must focus on the release location, the quantity and quality of effluent, the changes in river flow, nutrient load and water quality. More sustainable outcomes for catchments, rivers and water use must go wider still, calling for better coordination between timber and agricultural industries, mining, environmental and water regulators, urban planners and the major water and power utilities.

The urban water industry must avoid environmental damage, maintain environmental flows, utilise groundwater resources only to the extent that they are being replaced and develop sources and manage delivery systems in ways that impact least on greenhouse production – while providing basic water needs at affordable cost. Australian water utilities are committed to sustainability and have made good progress in these areas as well as improving citizen awareness and customer education. Some measure their greenhouse gas emissions and are taking steps to reduce these through efficiency and process improvements.

It is clear that new and diverse ways of augmenting water supplies must be developed for increasing populations. As most cheap and easy sources have been developed over the past 100 years, nearly all sources of augmented supply will be further away, harder to access and/or require more treatment. This means the Australian water industry will use more energy, remembering that it is already one of the major electricity users amongst Australian industries. Some argue that, as water is an essential element of life, the problem of greenhouse gases associated with its production should be borne by the power production industry. For similar reasons others hold that it would be reasonable to expect a water utility developing a large, stand alone source with high energy use, to buy its power from an environmentally friendly source and pass the cost differential (if any) on to the water customers. This is what the WA Water Corporation is doing by sourcing the power for its new desalination plant from a wind farm. Supporters of desalination point out that desalination has been developed to augment water supply elsewhere in the world and that it could be applied in many coastal situations where augmented water supplies are needed, driven by significant and increasing population densities.

Considerable work is under way involving Commonwealth and state agencies and research institutions, as well as some academic and private institutions into the sustainability of rural industries, townships and populations. This work is usually being carried out against parallel assessments of the sustainability of significant rural land and water systems. This work aims to:

- halt further degradation of significant land, vegetation and water systems, by driving significant change in land and water use practices, including improved water conservation, and by finding ways to encourage primary producers to become custodians of local ecosystems and natural resources, for example, by payments for so-called environmental services;
- find ways of rendering existing farming more sustainable by supporting pilot studies, for example, into different patterns of rotation, conservation tillage, revegetation including in riparian zones, off-site watering of stock, perennial crops;
- understand the changes in rural communities as small farms continue to lose economic competitiveness,

leading to greater dependence on off-farm income and to their absorption into larger farms, and as large scale agricultural enterprise keeps innovating and adapting, growing in size through aggregation and investing to remain competitive in the global economy;

- involve governments in industry restructuring where that represents the most effective way of speeding the advance of future ecological sustainability and economic viability of regions; and
- mobilise long-term private investment in the repair and more sustainable management of rural land and water systems and in regional renewal, thereby supporting and encouraging changed management practices, improved water infrastructure and the emergence of modified and different industries – eg: forestry (including a more widely based system of carbon credits), honey production, local processing plants, deep-rooted perennial trees, shrubs and plants.

## 4.11 CONCLUSION

Much of the effort described in this chapter to reform water management should be viewed as work in progress, although the reform of urban water authorities, their roles, management and planning is well advanced. Across the whole reform arena, there are some early signs of success, some initiatives that have failed to meet expectations, and a variety of actions that will only be able to be evaluated at a later time. To make such evaluations calls for better water accounting and improved measurement of the performance of water managers, water users and the success of major reforms. We can, however, already state unequivocally that the very broad approach described in this chapter, which has engaged government, water using industry, academe, many interest groups as well as water agencies, authorities, commissions and utilities, represents a much more cohesive and strategic approach than previously to this matter of critical national urgency.

Of course much remains to be done. There are outmoded water supply and distribution systems and infrastructure to replace and extend, and sewerage and drainage infrastructure requiring augmentation, renewal and replacement. This is critical if water saving and efficiency targets are to be achieved and advanced recycling of waste water and storm water is to make a cost effective and significant contribution. That suggests that private investment must play a greater part in meeting these challenges alongside traditional public investment by public water utilities. Where supply and service augmentation are called for, local needs could at times be better met by local cost-effective solutions, rather than the customary process of making expensive and complex additions to large existing systems. Innovative funding, innovative technology and innovative administrative arrangements can and should play a part.

At the same time, new approaches are needed to confront and remove the many existing administrative and regulatory obstacles to advanced water reform, to the development of next generation primary industry and to the wider application of path breaking technologies. National water reforms currently pay little attention to this issue which can represent an obstacle to both more commercial and efficient water management and improved catchment and river health.

Nonetheless, it remains essential to get the priorities right and to avoid "quick fixes" driven by understandable impatience and the desire to try unduly to simplify many complex economic, social and environmental problems. It is also imperative that all stakeholders remain resolute and hold the course if lasting and systemic rather that piecemeal change is to be achieved.

This chapter focuses on current management and future planning in those major urban situations likely to accommodate much of the future population growth. The chapter shows that substantial reductions in per capita usage have been achieved through a combination of pricing reform, community education, demand management and water restrictions. As part of this analysis it explores the part that re-use and recycling have played to date and the further opportunities offered, especially when advanced membrane technology can be harnessed to produce high quality water from waste water, storm water and sea water. That said, the chapter demonstrates just how difficult and costly it will be to secure further improvements.

The nation has limited accessible and useable freshwater resources to meet future urban demand. For this reason this chapter explores the many ways of both augmenting existing supplies and reducing pressure on those supplies, from improved pricing to water trading, from system efficiencies to recycling. New technologies offer good prospects for more widespread re-use of waste water and desalination, where that proves to be the best route to augmenting supply. If the various other measures are introduced in optimal ways, innovative techniques are encouraged and if efforts are well integrated, the need for high-tech and high energy use desalination of sea water may be avoided, in some situations, though there is no technical barrier to its implementation. Curiously, if desalination of sea water makes any more than a modest contribution to the whole, Coleridge's Ancient Mariner, looking back, will find us turning to the sea for our 'drop to drink'.

This chapter also points out that the Australian people and their lifestyles and industries, now and in future, depend heavily on the health of major catchments, river systems and the quality and quantity of their water resources. Some of those issues that link water management and demand to growing population which are introduced briefly here are described in greater detail elsewhere, because they create significant future policy challenges as discussed in Chapter 9.

The Academy has previously tackled these issues in a number of symposia and reports, most recently in its 2003 Symposium Water – The Australian Dilemma. The report containing the proceedings of this symposium highlights the importance to the nation of government, community and industry working together to gain a better understanding of how catchments function and how they have been modified. If sound and sustainable decisions are to be made, they must be supported by improved understanding, science and data and better targeting of technology. Then interventions can be made in ways that both recognise and overturn those past arrangements that block effective action and can be crafted to better meet the needs of catchments and rivers as well as those of land and water users.

There are many significant economic, social and environmental forces impacting on the health and prosperity of the nation's agriculture, rural regions, their people and their lifestyles. Yet, these regions and industries, and their produce and services support existing towns and whole regions. As the population grows these towns, regions and industries seem destined to continue to play their part in the process of successful absorption and assimilation of more people. Unsurprisingly, efforts are increasing to find the keys to future viability of these and modified industries, how to support and encourage the development of new industries that are likely to be more ecologically and economically sustainable in the long-term, how to cope better with economic, social and environmental change in rural regions and how to introduce more sustainable patterns of water use, particularly in irrigation.

This chapter points to a number of initiatives that are designed to improve sustainability of industry, from better-defined water allocations and rights, to more widespread water trading, from the use of property plans to meet economic and ecological tests to reduced emphasis on regulation. Private investment in the long-term repair of rural lands and sustainable water use and targeted government support for critical industry restructuring are both under active consideration. Case studies show that some forms of "sustainable farming", including provision of off-site stock watering and rotational cropping and grazing, can reduce production costs and improve water conservation and local stream quality. Such initiatives could be accelerated and adopted more widely if greater incentives were provided to primary producers so that they could play a part as custodians of some natural systems and resources.

Now is the right time to redouble all of the above efforts because global warming, recent droughts and water shortages have all contributed to renewed political and community interest in investing in and saving water, in securing urban and rural water supplies, and in promoting secure and water friendly primary production. There is widespread recognition of the need to invest in the nation's "water future" and to accept both community restrictions and personal restraint.

This chapter shows that advanced technologies, the introduction of modified and new water using industries, changed water management practices, continued water saving by the community as well as wide ranging institutional change, all have a part to play in ensuring that some 30 million Australians are adequately supplied with fresh water in 2050.

## 4.12 INFORMATION SOURCES

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## 4.13 GLOSSARY

| | |
|---|---|
| ATSE | Australian Academy of Technological Sciences and Engineering |
| AWA | Australian Water Association |
| AWI | Australian Water Industry |
| BOO | Build, Own, Operate |
| BOOT | Build, Own, Operate and Transfer |
| COAG | Council of Australian Governments |
| MAR | Mean Annual Run-off |
| NH & MRC | National Health and Medical Research Council |
| NWC | National Water Commission |
| NWI | National Water Initiative |
| NWQMS | National Water Quality Management Strategy |
| WSAA | Water Services Association of Australia |

## 4.14 UNITS

| | |
|---|---|
| Kl | Kilolitre = 1,000 litres (or 1 cubic metre) |
| Ml | Megalitre = 1,000,000 litres |
| Gl | Gigalitre = 1,000,000,000 litres |
| mg/l | = Milligrams per litre |

## 4.15 DEFINITIONS OF TERMS USED IN WATER USE APPLICATIONS

| | |
|---|---|
| Water recycling | The use of wastewater that is captured and redirected back into the same water use scheme. Recycling is practiced predominantly in industries such as manufacturing, and normally involves only one industrial plant or one user. |
| Water re-use | The use of treated wastewater for a beneficial use, such as agricultural irrigation and industrial cooling. |
| Planned re-use | Deliberate, direct or indirect, use of reclaimed water, without relinquishing control over the water during its delivery. |
| Unplanned re-use | Re-use of treated wastewater following discharge, where control is relinquished, such as in the diversion of water from a river downstream of a discharge of treated wastewater. |
| Direct potable re-use | A form of re-use by the incorporation of reclaimed water directly into potable water supply system, often implying the blending of reclaimed water with potable water. |

| | |
|---|---|
| Indirect potable use | Potable re-use by incorporation of reclaimed water into a raw water supply, allowing mixing and assimilation by discharge into an impoundment or natural body of water, such as in a domestic water supply reservoir or groundwater. |

# CHAPTER 5
# Energy in Australia

"The most abundant source of energy on earth is sunlight, but because it is spread out in time and space, it is low in quality compared with the many other forms of energy on earth derived from it."

**Odum and Odum, Energy 31, 2005, 21-32**

## SYNOPSIS

**The review of Australia's energy resources and applications to the year 2050 confirms that the nation is well endowed to respond to the projected population increase to 30 million.** However, energy security issues could arise especially in liquid fuels for transport, where indigenous resources are insufficient and reliance must be placed on imports and/or on more costly conversion technologies.

The following observations are drawn from the overview of energy in Australia as it applies to stationary power – essentially the generation, transmission and distribution of electricity and related exports of Australian coal and natural gas:

- Australia has adequate primary energy resources and reserves (apart from oil) to serve the projected Australian population to 2050 and beyond;
- moreover Australia will continue to derive growing export income from these resources, principally black coal (and its "clean" application technologies), natural gas and uranium;
- climate change and the pressures both for short-term adaptation and effective long-term response is likely to see growing reliance on lower carbon resources, including nuclear energy and, to a lesser extent, renewable energy;
- Australia's abundant primary energy resources are, in the main, adequate for national energy security;
- the potential for improvement in end-user efficiency in industry, commerce, the domestic sector and transport remains hugely significant. Present and emerging technologies – driven by increasing energy costs, largely in overseas economies, and by climate concerns – offer dramatic reductions. However the extraordinarily low-cost of energy in developed economies, especially Australia, still constrains their more widespread acceptance;
- developing economies, with vastly lower but rapidly growing per capita demands for energy, will offer both opportunities and threats to developed economies, including Australia. Opportunities include the provision of both resources and technologies with the development of productive partnerships. Threats could include the unbridled growth of unconstrained energy pollution, negating the progress made by developed economies; and
- Australian energy research, development and demonstration are world class and strongly focused on long-term sustainability. CSIRO, industry research centres and research universities attract international recognition and are an enduring, albeit still-undervalued, national resource.

World oil production is at, or close to, current capacity and there is considerable uncertainty as to whether capacity can be expanded to meet burgeoning demand at current prices or even whether current production levels can be sustained in the longer term. Furthermore, Australia continues to be exposed to the international oil market simply because the composition of Australian oils does not allow the full range of petroleum products to be produced. In addition, Australia's oil production is falling due to depletion of reserves with the rate of discovery of new oil reserves not keeping up with production.

Accordingly, Australia must adopt a number of strategies. Industry must be encouraged to explore for remaining Australian oil deposits (particularly in new frontier areas), diversify sources of liquid fuel supply as a buffer to the uncertainties of the international oil trade and/or attempt to mitigate demand. These strategies are fundamentally driven by price and the market, to some extent, will provide a response.

The development of alternative sources requires very long lead times, at least in the order of a decade or more for hydrocarbon fuels and much longer for alternative sources of transportation power. This is where government can play a significant role.

In the case of petroleum-based transport fuels, it will be necessary to manage a transition to a larger, mixed economy in which liquid fuels are derived from a number of sources. This transition is not expected to present problems for fuel technologies.

Gas-fuelled vehicles are already common and biofuel use is increasing, especially as the price of petroleum has risen steeply. The production of synthetic hydrocarbon-based liquid fuels will develop in step with the pre-combustion technologies required to facilitate carbon dioxide sequestration. There will be a need to provide versatile engines for the different fuels and fuel mixtures that become available, and to establish fuel standards and labelling protocols to ensure their appropriate use.

The area in which the transition will be most difficult will be in aircraft fuels, which have the most demanding specifications, and so what petroleum is available could be applied to such uses as a priority.

Changes can also be expected in vehicle design that will help ameliorate the demand pressures for transport fuels. These include improved consumption and environmental efficiencies for internal combustion engines and the use of smaller cars and mopeds that will have intrinsically lower fuel consumption requirements.

## 5.1 INTRODUCTION

Australia is a semi-arid continent with a relatively small population concentrated in urban and agricultural areas, mainly in the south-east. It has abundant energy resources and reserves except for hydro power. It is ranked in the top six countries for economic demonstrated resources (EDR) of black and brown coal and has the highest EDR for uranium. It has significant reserves of natural gas, though is more modestly endowed for crude oil.

As foreshadowed in the opening quotation for the chapter, Australia's vast land mass and low population density offer potential for harvesting abundant solar and wind energy. Hot dry rocks too have their place but, like many natural resources, and especially renewable energy resources, are remote from their markets. Australia's energy reserves are nevertheless more than adequate for the expected 2050 population, provided certain conditions are observed.

Australia's readily won, low-cost energy resources support major export industries, contributing significantly to the growing quality of life of all Australians. In 2001-02, energy exports earned $24.6 billion, some 20 per cent of total merchandise export earnings. Around two-thirds of all energy resources recovered each year is exported, with only a third used domestically. The relevant figures are shown in Table 5.1.

### Table 5.1 – Energy Supply and Use in Australia 2001–02 (PJ)[100]

| | |
|---|---:|
| Imported energy products | 1,222 |
| Primary energy production | 14,788 |
| Total energy input | 16,010 |
| Less: Energy products exported | 10,601 |
| Net energy input | 5,409 |
| Domestic energy use | 4,346 |
| Conversion and transmission losses | 1,747 |
| Derived energy production | 2,599 |
| End-use of derived and primary energy | 3,307 |
| Stock change and statistical differences | 353 |

[100] ABS, *Year Book Australia 2005*, Table 17.1, Australian Bureau of Statistics, 2005. (www.abs.gov.au)

The above table shows clearly the relevance of both domestic energy use and exports. Any review of Australia's energy future necessarily includes both these components. Domestic energy use is dealt with first followed by energy exports and their impact on Australian quality of life.

Australia's vast energy reserves are shown in Table 5.2 which clearly justifies the strong allocation to exports, at least for the immediate future. Table 5.3 shows the relatively modest rate of resource depletion for the national electricity market (NEM), the major domestic user.

Oil is the exception to the picture of near-unlimited resources at present extraction rates. Australia has limited reserves and few new fields have been developed recently. This worrying energy security scenario is compounded as world demand moves ahead of crude availability and processing capacity with the resource politics well beyond Australia's control. The emerging oil deficiency may yet be mitigated by successful exploration or, more likely, by employing available technologies to convert non-exportable fossil resources into transport fuels. Conversion of natural gas to liquid fuel and the exploitation of biofuels are also part of Australia's future liquid fuels portfolio.

### Table 5.2 – Economic Demonstrated Primary Energy Resources – 2002 [101]

| Resource | Unit | Quantity |
|---|---|---|
| Black coal | Gt | 40.8 |
| Brown coal | Gt | 37.7 |
| Crude oil | GL | 227.0 |
| Condensate | GL | 282.0 |
| LPG | GL | 262.0 |
| Natural gas | bm3 | 2219.0 |
| Uranium | kt | 648.0 |

### Table 5.3 – Energy Resources for NEM Power Generation – 2002 [102]

| Resource | Unit | Quantity |
|---|---|---|
| Black coal | Mt | 51.7 |
| Brown coal | Mt | 67.1 |
| Natural gas | TJ | 160,000 |

These tables do not quantify other available Australian natural or renewable energy resources including biomass, solar radiation, sea-derived energy and wind, which are addressed later in the chapter. However their availability and value are tempered by the present state of technology development, their diffuseness and variability and the still limited availability of economic large scale storage technologies. The energy export industry is a significant employer and a valuable proportion of export income remains in Australia, contributing to quality of life. A small percentage only is used in the transport of energy exports.

## 5.2 ENERGY IN AUSTRALIA − 2005

Electric power generation and distribution and energy for the transport of goods and people are between them the major users of primary energy. This section examines the electric power industry, by far the largest Australian primary user.

### 5.2.1 Stationary energy for power generation

The largest and economically most important stationary energy system in Australia is the interconnected electric power grid supplying Eastern Australia's National Electricity Market (NEM). A lesser but geographically extended grid supplies the Southwest of Western Australia (SWIS) with small, more localised grids throughout Australia. In general, energy resources and large scale generation are located

[101] ABS, *Year Book Australia 2005*, Australian Bureau of Statistics, 2005. (www.abs.gov.au)
[102] Energy Supply Association of Australia, *Electricity Australia*, Energy Supply Association of Australia, 2004. (www.esaa.com.au)

far from major load centres, requiring high-voltage transmission to bring electricity to where it is needed. About 92 per cent of Australia's population is served by the 4,500 km power system, extending from North Queensland to South Australia and, more recently, Tasmania.

Major power systems depend on heavy rotating generators based on hydro, coal, oil (or nuclear in some countries) as the primary energy resources which contribute to system electrical stability. Gas turbine generators are lighter, providing limited stability contribution while most renewable energy resources add little. In South Australia, for example, the growing proportion of wind generation could give rise to stability implications unless advanced energy storage technology is employed. Tables 5.4 and 5.5 set out the present generating plant and energy resource mix within the NEM. In 2004 annual generation was just over 200,000GWh.

### Table 5.4 – Principal NEM Generation Plant Mix – 2004 [103]

| Technology | Proportion % |
|---|---|
| Hydro | 13 |
| Pumped-storage | 3 |
| Coal | 63 |
| Gas-fired steam | 4 |
| Other steam | 3 |
| Gas turbine | 10 |
| Wind | Low |

### Table 5.5 – Australian Generation Plant Mix – 2004 [104]

| Technology | Proportion % |
|---|---|
| Hydro | 8 |
| Steam, coal + gas | 87 |
| Gas turbine | 5 |
| Renewable energy | Low |

Figures 5.1 and 5.2 illustrate the extent of electricity and gas grids in Australia.

## 5.3 AUSTRALIAN ENERGY RESOURCES

Energy resources suitable for power generation in Australia include fossil (coal, oil, gas and shale), water (for hydro power), renewable energy (solar, wind, biomass and oceans) and, in the future, nuclear.

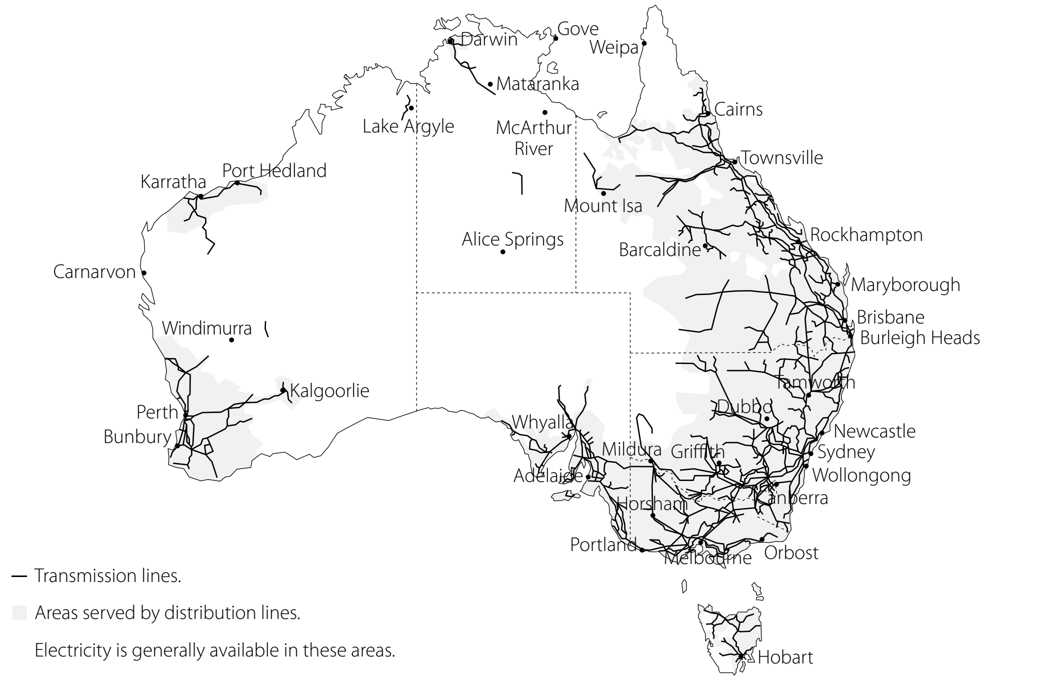
All can attract a range of taxes and charges on the one hand and subsidies and grants on the other, reflecting the essentially non-market and, to some extent, subjective externalities associated with their use. Externalities, which include factors such as air pollution, climate change and human safety on the one hand and subsidies and grants for emergent industries on the other, continue to be the subject of world-wide study. The European Union's ExternE project is one of the more mature, but is naturally slanted to European values and conditions.

Some say that such economic distortion is unwarranted and that open markets should determine resource allocations. Others believe that longer-term intangible issues, which may span generations, need to be recognised in current-day market structures if the appropriate economic drivers for long-term sustainability are to be put in place. The debate has significant commercial and political overtones. An evolutionary approach, reflecting perceived community values of the time rather than a clear-cut transition to a new market structure, is the more likely outcome.

The key attributes of each of these resources, together with the implications for their relative contribution to the generation of power over the next 50 years, are set out below.

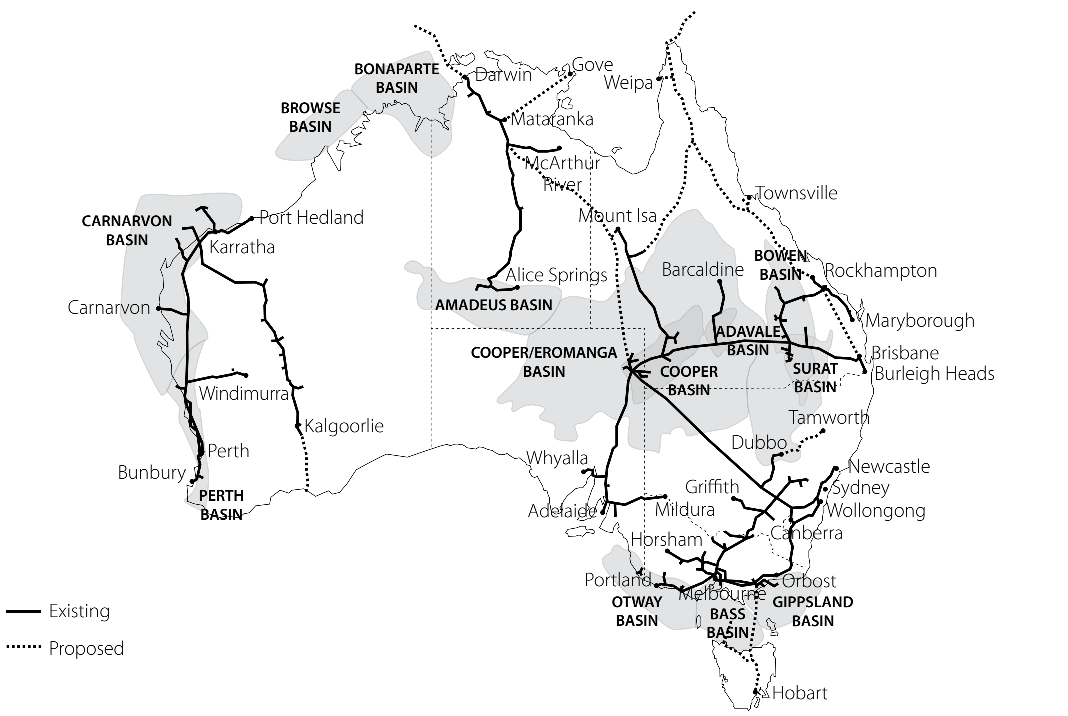
[103] Energy Supply Association of Australia, *Electricity Australia*, Energy Supply Association of Australia, 2004. (www.esaa.com.au)
[104] *ibid*

Figure 5.1 – Australian electricity supply system




Source: Electricity Supply Association of Australia

Figure 5.2 – Australia's natural gas transmission pipelines




Source: Australian Gas Association

## 5.3.1 Fossil resources

### Coal

Fossil energy sources represent high-density stored solar energy. Coal, which is Australia's most abundant fossil resource, provides nearly 85 per cent of Australia's present electric power generation and can be expected to remain a major source to 2050 and beyond. Coal has given Australia some of the world's cheapest power, underpinning globally competitive energy intensive industries and contributing to significant employment and national income. Coal mines and associated power stations are generally located well away from population and load centres. Potentially polluting air and water emissions are controlled and their impacts minimised.

However fossil fuels release carbon dioxide on combustion, so adding to greenhouse gases (GHG) and consequent climate change potential - as discussed earlier in Chapter 3. Nevertheless the International Energy Agency (IEA) and other authorities predict, despite the significant GHG contribution, demand for cheap primary energy is such that fossil energy resources cannot be eliminated by 2050. Coal will still be a major energy source at that time.

Accordingly there is a growing technology push worldwide to minimise carbon dioxide release to the atmosphere. Coal-fired power stations have increased their efficiency and will continue to do so. In New South Wales, for instance, efficiency in 1950 was 16.5 per cent, increasing to 35 per cent by 2000 and with the expectation of significant further improvement by 2050.

In addition to these important initiatives, the potential for the economic collection and subsequent underground permanent sequestration of carbon dioxide in geological formations is under active study. Queensland, Victoria and Western Australia all appear to have relatively good geological storage potential.

Integrated gasification combined cycle (IGCC) technology has been demonstrated internationally for 10 years and commercial plants are now being assessed. In this process coal is gasified with limited oxygen. The resulting 'syngas' can be used in a gas turbine, promising even higher power generation efficiencies, or converted to hydrogen or transport liquid fuels. IGCC also produces a concentrated stream of carbon dioxide well suited to more economic sequestration.

A Victorian plant, now in design, will use brown coal in a 500MW IGCC plant which will also produce 50,000bbl/day of low-sulphur diesel fuel. Exhaust carbon dioxide can be injected into depleted Bass Strait oil or gas wells using conventional technology. To assist this greenhouse-friendly low-emission technology the Australian Government is providing $500 million and the Victorian Government $83 million towards commercial application.

It is therefore not unreasonable to conclude that, as ageing coal-fired plants retire over the next 50 years, they will be replaced by more efficient power technologies which will also provide transport fuels while having a far lower carbon dioxide release. Increased generation capacity can be located at existing sites, with preference to those which avoid possible sea level problems.

## Oil

Australia has never had significant oil-fired power generation apart from small but generally highly efficient diesel sets. Most are at remote community or mining locations with a few units over 5MW, some of which employ sophisticated heat-recovery systems for desalination or process purposes. With Australia's declining oil reserves there is little likelihood, apart from special circumstances, of further large-scale diesel generation over the next 50 years. The IEA expects world oil production to peak after 2025 and then start to decline unless recovery costs for more exotic sources can be made more economic.

## Natural gas

Conventional natural gas and coal-bed methane are competitive resources for peak-load applications that can be expected to grow. Natural gas-fired, simple-cycle and combined-cycle units can be expected if competition brings down the price of natural gas. This could provide much needed new capacity for intermediate and base-load operation.

Importantly natural gas combustion releases less carbon dioxide than coal for equivalent power generation. However the IEA expects that natural gas may become less available after 2025 as recovery costs increase. Australia has major internationally significant gas reserves in the north-west of Western Australia where there is little present demand for power. Export gas to international markets is providing valuable foreign earnings and is expected to increase considerably.

## Shale

Australia has massive reserves of easily won oil-bearing shale, mainly in Queensland. World oil prices are however not yet high enough to warrant the major capital investment needed to establish the industry. Furthermore, the environmental impact of this source requires close study.

### 5.3.2 Hydro power

Australia's main dams and hydro power facilities, especially the Snowy Mountains Scheme, were generally installed for agricultural and flood-control purposes, to be paid for by electricity sales. The Snowy Scheme has a capacity factor of about three per cent, making it suitable for peak and emergency loads only – in general the reverse of similar installations in other economies. Snowy capacity has been reduced in recent years to provide enhanced environmental flows, especially to the Murray and Snowy Rivers. Hydro power in Tasmania is the dominant source of electricity.

Further large-scale Australian hydro development is unlikely for three reasons. Firstly the lack of high mountains is not conducive to economic application; secondly growing evidence suggests that rainfall, already below average, could (with predicted climate change trends) decrease further; and thirdly community resistance to such projects is unlikely to be overcome. Despite this prediction it is nevertheless likely that existing plants will continue to be upgraded while several relatively small schemes, strategically located to supply high value NEM niche markets, will attract private investment.

### 5.3.3 Renewable resources

Apart from biomass and energy from hot dry rocks, renewable energy resources have two significant deficiencies which mitigate against large-scale power generation. Primary energy density, namely the sun or wind, is low and, given the vagaries of weather patterns, power predictability is poor. Low energy density requires expensive and extensive collection plant, be it solar or wind, generally in comparatively small unit sizes. Low plant-capacity factors, inevitable without inexpensive energy storage, compare poorly with central generation. Thus the cost of delivered renewable energy, although free at source, is relatively high.

Renewable energy resources do not as yet offer the plant scale or reliability essential for grid supply. Nevertheless inherently low pollution levels make them very attractive to the growing population having environmental concerns, many of whom are prepared to pay a premium for "green" energy in recognition of the implicit negative externalities.

The IEA estimates the likely contribution of all renewable energy resources at 2050, including large-scale hydro, as less than 30 per cent of primary energy needs. To many this appears an unrealistically high figure, given the enormous generating capacity already in place at 2005 and the new capacity, expected to well exceed the 2005 figure that will be installed worldwide by 2050. To others the challenge of this immense growth lies in capitalising on one of the world's fastest growing business sectors. Allowing for the low density of renewable resources, it is inconceivable that there will not be steady progress in renewable energy and its supporting technologies by 2050.

At present, however, renewable energy generation relies on the grid and its other participants to provide effective storage and to manage the mismatch between renewable energy availability and system demand.

Given Australia's strong reliance on abundant low-cost coal and the emerging potential for cleaner technologies and effective carbon sequestration, it is believed that a more realistic figure for the uptake of renewable energy in Australia, including hydro, is unlikely to exceed 20 per cent of primary energy supplies by 2050. More detailed discussion of individual renewable resources follows.

## Energy storage

Apart from the grid, pumped-storage is the only large-scale technology currently used in Australia for energy storage. Water is pumped into a suitably elevated reservoir during light system demand, effectively absorbing electricity, while in peak periods it flows back to the low reservoir, generating electricity and recovering a reasonable proportion of the energy stored. Australia has only a few pumped-storage installations with limited potential for more.

A number of electrochemical batteries using flowing electrolytes with ratings per MWh storage capacity and MW power rating are now entering commercial service.

Responding to system needs, these batteries can both absorb and deliver power on a near-continuous basis, meeting system demand peaks, absorbing renewable supply peaks and covering electricity supply shortages. Smaller energy storage batteries, broadly in the kWh capacity and kW power range, are well developed for small remote area applications.

Considerable further development, critical to the parallel commercial success of renewable energy generation systems, is needed in this important technology domain.

## Wind energy

Recent intense wind generation activity reflects the Australian Government's Mandated Renewable Energy Target (MRET) scheme. This places liability on wholesale electricity purchasers to contribute proportionally towards generation of an additional 9,500 GWh of renewable energy per year by 2010. Liable parties are required to surrender renewable energy certificates (RECs) against the liability. This has provided, to a degree, subsidised certainty for investment in wind generation and, to some extent, to the onshore development of manufacturing facilities and associated employment. It is argued by renewable energy advocates that the MRET premium represents a reasonable market valuation of the externalities attributable to higher carbon technologies. However, despite strong lobbying from the renewable energy industry, there are no plans in place to extend the MRET scheme beyond 9,500 GWh.

There are a few very good wind sites in Australia with the potential to support plant-capacity factors up to 40 per cent, although the majority of sites developed or under investigation offer factors nearer 20-25 per cent. Wind generators of 1-2MW each, of either synchronous or induction design, are typically installed in groups of up to 50. Most Australian generators are induction machines which do little to stabilise the local grid.

Generators installed and proposed for South Australia will bring the proportion of wind generation system to around 20 per cent, approaching practical maximum without substantial energy storage. This could raise questions of the ability of interconnected thermal plant to compensate for wind generation swings and Australia is in the vanguard of managing such variability in a competitive power system. However in Tasmania, where wind energy is also well exploited, the hydro system with its massive storage capacity and ability to change load rapidly responds far better to such generation swings.

## Solar energy

Australia has an enviable reputation in photovoltaic (PV) power generation. Several noteworthy industry leaders and numerous world class research and development achievements stand to its credit. In parallel the world market for PV continues to grow at near exponential rates, albeit from a low base. Accordingly the cost benefits of increasing production rates are becoming more evident. The crossover, from PV being a relatively high-cost technology in all of its several forms to becoming a commodity item, is yet to be reached but is within the sights of some major players. Already small PV systems are in widespread personal and community use although its application for on grid generation is unlikely.

Large PV farms are not uncommon and provide "green" energy under encouragement from the MRET scheme. Perhaps the more pervasive application will however become the integrated PV roof where generation is located adjacent to and can be matched with domestic load. Such installations can help relieve existing distribution systems from impending overload as household loads are increasing rapidly with the uptake of low-cost domestic air conditioning.

Larger-scale PV applications trend towards concentrating systems. These employ relatively low-cost parabolic or paraboloidal collection mirrors to track and concentrate the solar radiation (up to several hundred times in some technologies) onto the high-cost PV elements. Conversion efficiencies more than 40 per cent have been obtained in development trials. Their cost-effectiveness is promising, especially for remote (off-grid) applications where the cost of conventional alternatives is very high.

A solar thermal technology with grid-scale generation potential is that of the solar tower planned for southern New South Wales, near Buronga. Originally designed for 200 MW, further technical and economic improvements have suggested 50 MW for the prototype Australian installation. Added large-scale thermal storage will make this unit fully dispatchable [105], a world first for solar power generation. Some existing coal-fired power stations are also considering solar thermal additions for feed-water pre-heating and trial systems have been installed.

### Hot dry rocks

There are a few commercial sites in Australia where hot dry rock technology may flourish. Present initiatives in South Australia and Queensland are however at a considerable distance from major load centres. In South Australia demonstration wells have been drilled 4km into granite where residual nuclear radiation sources raise the rock temperature, enabling it to act effectively as a natural boiler. Hot dry rock technology is based on water pumped down one well circulating through the hot fractured rock (HFR) and returning up the adjacent well to the low-temperature Kalina cycle generating plant.

Claims of eventual economic power generation have been made. The resource is vast and is available continuously. The potential is high and theoretically such power could be an added source of supply for the Olympic Dam copper/uranium mine and, in the future, the NEM.

### Biomass

Around 30 small Australian installations use biomass in various forms, most notably sugarcane bagasse, with claims of lower net GHG emission power generation. The primary issue with biomass is its generally seasonal supply and low energy density, limiting the economic collection radius to between 50 and 100 km from the power station. The limitation of cooling water supplies and the possibility of further climate change-driven reduction renders the likelihood of large scale on-grid biomass generation remote. Small scale off-grid installations using local agricultural wastes offer some potential.

### 5.3.4 Nuclear resources and desalination

Australia has the largest EDR (economic demonstrated resources) of uranium with approaching 40 per cent of the world's economically recoverable reserves. However nuclear power generation is not yet deployed in Australia and is still regarded by many, including the incumbent political parties, as unacceptable. There is however growing political and community support for informed public debate on the issue.

Nuclear power offers excellent base-load characteristics and, like coal, its large generators contribute to power system stability. Nuclear power technology is now available in large units (up to 1600 MWe) but smaller-capacity modular plants are in development. The most recent generation of reactors are regarded as intrinsically safe, unlike some earlier designs of which Chernobyl is a tragic, albeit isolated, case. Nuclear energy in Australia would provide additional base-load power to replace old fossil fuelled stations and for growth, with little pollution or contribution to climate change. Australia's uranium could readily be used for domestic nuclear power plants in addition to the international nuclear power generation markets it now serves.

Currently some 18 per cent of the world's electricity is derived from nuclear energy. New reactors are under construction, many to serve rapidly expanding Asian economies. New reactor designs are becoming available that provide greater safety levels than earlier designs. These facts point to the need for a balanced and sensible review of the potential role for nuclear power in Australia's energy mix by 2050. As concern for climate change intensifies, the potential for major nuclear installations becomes more pressing. The IEA supports this general contention in its analysis of energy to 2050 [106].

The issue of safe permanent disposal of nuclear wastes attracts considerable debate and some concern. Technologies for such disposal, including the Australian development Synroc, are already available, as are deep geologically stable sites. The problem is essentially that of "not in my backyard". This is being overcome

[105] This means electricity can be bid into the market and delivered as a bid.
[106] International Energy Agency, *Energy to 2050 – Scenarios for a Sustainable Future*. OECD Publishing, 2003. (www.iea.org/textbase/nppdf/free/2000/2050_2003.pdf)

slowly but will be facilitated by an increasing number of deep disposal sites either operational or planned.

Much has been made recently of long-term potable water shortages throughout Australia. A recent desalination plant proposal for New South Wales has met with significant resistance, although a comparable plant is now under construction in Western Australia. Nuclear desalination plants have operated successfully in Russia for more than 25 years, including the Aktu plant in Kazakhstan. Both nuclear power generation and thermal desalination share the common characteristic of optimal performance of stable base-load operation; thus they are a natural "fit". High-grade energy is used for power generation while the inevitable waste or low-grade energy, otherwise discharged to the environment, is ideal for desalination.

### 5.3.5 Demand management

Electricity supply comprises continuous or base-load, less-frequent intermediate or shoulder load and short-term peak load. Significant investment is necessary for peaking plant, which is intermittently used. Solutions include some form of demand management, including artificially reducing customer demand at critical times. Various control initiatives are being considered but success is still limited. Unfortunately this can be expected to continue without effective end-user price signals, most retail electricity being sold at a flat marginal rate regardless of time of day or system load.

The economically unfettered drive for end-use customer comfort and convenience is an ongoing hurdle to the effectiveness of enforced customer demand management aimed at reducing investment in the power system peaking capacity. A potential solution lies in aggressive time of day or real time electricity pricing, now readily available with modern meters. This is made difficult in a competitive market with retailers seeking to retain and increase customer numbers. Current initiatives include both "pricing carrot" and "regulatory stick" approaches but without serious intervention it will be a long time before rational market forces and appropriate light handed regulatory instruments are in place.

## 5.4 ENERGY TRANSPORT TO LOAD CENTRES

Australia is vast; distances between population centres are great. Power stations are usually located near energy sources with energy transmission to load centres. Two large-scale systems for energy transport compete – high voltage power transmission and natural gas pipelines.

While not yet commercially viable, hydrogen is a candidate clean-energy bulk carrier. Case analysis may prove otherwise but it is expected, at least in the early years of the hydrogen economy, that hydrogen will serve short pipelines in areas of dense usage rather than extended-energy transmission systems.

### 5.4.1 High voltage electricity transmission

Large tranches of energy are generally carried on high voltage (HV) overhead transmission lines over the long distances between power stations and load centres as the basis of the NEM system. Figure 5.1 shows the relevant Australian HV systems.

The backbone voltage in New South Wales and Victoria is 500kV, with 275kV in Queensland. Before 2050 there will be a case to extend the 500kV lines into Queensland to form a robust NEM backbone, probably with both AC and DC components. This would reduce transmission losses and so minimise wasted generation with consequent environmental advantages. The HV DC "Basslink" from Tasmania to mainland Australia will link more than 90 per cent of the population of south-eastern Australia into the backbone system. Western Australia's SWIS distribution uses 330kV and will probably retain this.

Distributed generation, the combination of small-scale local generation, often with the advantages of useful heat recovery, and using lower transmission voltages is attractive for domestic and light industry, especially with commercially appropriate electricity pricing, but is inappropriate for large-scale power demands.

### 5.4.2 Gas pipeline transmission

High-pressure gas pipelines are an alternative for large-scale energy transmission. Figure 5.2 shows the

Australian gas pipeline grid. Presently the system is relatively limited with a less developed competitive market than the NEM. Investment in pipeline infrastructure is proceeding but is somewhat constrained by the need to sign up major clients for many years ahead. The level of competition is low in many regions.

The contribution of coal-bed methane as an alternative resource, particularly in Queensland, has provided welcome competition and new regional pipelines.

Natural gas import from PNG or East Timor has been on the horizon for some time but awaits committed customers to underwrite secure construction of the long distance pipelines.

### 5.4.3 Hydrogen pipeline transmission

Hydrogen pipelines offer a possible future path for energy transmission. Hydrogen, unlike coal, oil or wind, is not an energy resource but a potential energy-transport medium. Hydrogen pipelines, similar to those for natural gas, operate at much higher pressures involving thicker-walled pipes and thus higher installation costs. A number of such pipelines in the US link hydrogen generation plants with chemical plants needing hydrogen as a raw material.

Hydrogen could become the fuel of choice for both stationary and vehicle fuel cells. Although still very expensive, major development projects are in hand to bring their cost and reliability to levels that could provide serious competition for existing stationary generators and motor vehicle engines. Should hydrogen become a preferred transport fuel, at least for urban use, its generation and short-distribution pipeline systems would develop quickly in population centres.

## 5.5 FORECASTING ENERGY NEEDS

Several internationally recognised organisations have prepared long-term energy scenarios extending to 2100, generally including all world economies, while narrow studies cover single economies. Most have been of the explorative type with a lesser number of the normative type. The former seek to set assumptions to see what scenarios evolve while the latter impose policies driving towards a desired outcome.

The IEA [107] has reviewed a number of these scenarios and developed studies of both explorative and normative types. In general the scenarios encapsulate political rather than market driven directions, covering credible developments to 2050. None was specific to Australia although the Academy study has used characteristics of the IEA report, for deriving Australian energy scenarios to 2050.

The scenario studies generally do not address the balance of likely energy technologies or the orderly development of new technologies, being confined essentially to the proportion and use of primary resources. In particular they do not allow for both the timing and impact of disruptive technologies or discontinuities. A number of authoritative Australian studies, noted in Table 5.6 below, offer predictions over the next 10 to 15 years.

Table 5.6 – Energy Predictions

| **International** | **Year** |
|---|---|
| IEA | 2025 |
| IEA | 2050 |
| IEA, (for Australia) | 2020 |
| **Australian** | **Year** |
| NEMMCO | 2014 |
| Commonwealth | 2020 |
| ABARE | 2020 |
| Powergrid | 2015 |
| Western Power | 2015 |
| Transgrid | 2015 |

[107] International Energy Agency, *Renewables for Power Generation – Status and Prospects*. OECD Publishing, 2003. (www.iea.org/textbase/nppdf/free/2000/renewpower_2003.pdf)

Most Australian predictions are essentially short-term (10-year) straight-line "business as usual" extensions. Electricity predictions to 2015 from the major electricity grid managers, NEMMCO and Western Power, are set out in Table 5.7. The average growth rates should be compared with the IEA predictions to 2050 which include developing economies.

Table 5.7 Electricity Predictions (Medium Scenario) of Average Growth Rates

| Grid | 2004/5 GWh | 2014/5 GWh | Av. Growth% | 2050 GWh Av. Growth% |
|---|---|---|---|---|
| NEM | 172,080 | 228,616 | 2.2 | - |
| SWIS | 14,372 | 19,287 | 3.3 | - |
| World (IEA) | | | | 3.5 |

## 5.6 ENERGY IN AUSTRALIA TO 2050

The foregoing international and Australian energy forecasts were taken into account in developing this section on likely energy initiatives and changes by 2050 and their potential impact on the then population.

### 5.6.1 Stationary energy for power generation

The Australian 'business as usual' predictions to 2015 have been extended to 2050 with due consideration of the critical changes in energy mix to achieve desired goals. Energy resources are reviewed in turn below.

Unless climate change results in far greater precipitation over the Snowy or Tasmania there is little potential for increase in large-scale hydro power. This is expected to remain effectively static, apart from efficiency improvements and marginal new catchments, becoming a reducing proportion of the overall primary energy mix.

The potential for renewable energy and large-scale storage to add significantly to primary generation by 2050 is still limited. Numerous small clusters of wind generators and a few larger solar thermal units appear to offer the greatest potential at this time. The development of effective large scale low-cost energy storage may change this and some prospective technologies are under intense development world-wide. The IEA makes similar world projections to 2050.

Renewable energy resources are nevertheless expected to make a growing contribution in small scale on-grid generation, especially, in the area of solar PV building materials for roofing and building cladding, and in off-grid generation; for example, small remote communities, where their costs are much more competitive.

Natural gas has significant potential to increase its share of generation if major new sources are located linked to market opportunities. Imports from PNG and East Timor are a growing probability. Coal-bed methane availability from New South Wales and Queensland is also growing. An increasing proportion has therefore been allocated for natural gas contribution to the overall energy mix.

Major new primary generation will therefore come from other resources. The two most likely are coal, using IGCC and sequestering the carbon dioxide, and uranium using the latest modular and fundamentally safe reactor designs and assured secure long-term waste disposal facilities. These technologies can be deployed in large-scale unit sizes but will contribute relatively little to climate change. However, it must be appreciated that carbon dioxide sequestration, while the subject of intense research and development, especially in CSIRO and CRCs, is still to be demonstrated as economic and practical. At the least it will add significantly to electricity costs and, possibly, allow other resources to compare more successfully.

In its study of energy to 2050 the IEA used a notional annual world energy growth figure of 3.5 per cent, including for the developing world, which would be expected to be much higher than for Australia. The IEA reviewed a number of scenarios from reputable organisations and compared their outcomes. Australia, as a relatively small player, was not directly included.

For many years Australia's annual electricity demand growth has been between two and four per cent. The 2005 NEM Statement of Opportunities estimated annual demand growth at two per cent for the

10 years to 2014 under a medium-growth scenario. Western Power's prediction for the south western grid (SWIS) is estimated at 3.3 per cent. These figures allow for population growth.

This analysis uses two per cent for Australian energy growth for the following reasons:

- two per cent is the figure presently used in the NEM Statement of Opportunities;
- previous predictions include for population increase ;
- two per cent assumes a demand management contribution;
- Australia as a developed economy, would expect a lower growth rate than the IEA global figures; and
- industrial energy intensity will decline as electricity costs rise.

In the absence of other predictions, and appreciating that demand will be more constrained once price signals are the norm, 2014 to 2050 growth rates of two per cent for the NEM and three per cent for the SWIS, appears realistic. These result in the notional values for power generation in 2050 in Table 5.8.

Table 5.8 – Predictions of electricity requirement in 2050

| Grid | Factor % | Electricity GWh/a |
|---|---|---|
| NEM | 2 | 457,000 |
| SWIS | 3 | 54,000 |

### 5.6.2 Energy transport

From the above figures NEM generation will approximately double by 2050. Most existing power stations will have ceased operation and a new generation of coal-resourced IGCC power stations using carbon dioxide sequestration will be operating in Queensland, Victoria and Western Australia. They will probably be located on existing power station sites already connected to the HV transmission system, close to fuel and cooling water resources and protected from possible sea level change. They will also produce liquid fuels and hydrogen as needed by the market.

A number of modular new-generation nuclear power stations may be operating, perhaps with desalination and/or hydrogen production as an added facility and with secure waste disposal.

Clusters of wind generators will be located in remote areas with adequate wind resources. A few large solar towers could also be operating while concentrating PV installations and building PV systems, especially roofing systems, should be commonplace.

The existing high-voltage transmission system will have a north/south backbone operating at 500kV using a mix of AC and DC to provide a strong, stable power system with minimum transmission losses. Distributed generation systems will be linked to the grid for smaller-scale local operation including heat recovery. Nevertheless substantial transmission and distribution system enhancement can be expected over the review period.

The natural gas pipeline system will cover Australia's south-east more effectively than at present, with the possibility of a corresponding gas price reduction leading towards a more competitive position. A transcontinental east/west pipeline, which has been evaluated several times, is not within the horizon of current planning but remains a technologically feasible possibility.

Hydrogen could be produced in bulk at coal IGCC or nuclear power stations with small pipelines conveying it to local centres. More generally, hydrogen would be produced less efficiently for local supply from electrolysis of water by electric power.

### 5.6.3 Energy resource mix

The energy resource mix for any economy can be modified only slowly because of the longevity of power generation installations. Australia's 2050 energy resource mix will be somewhat different from the present. From the above discussion, little additional hydro will be available, thus reducing its proportion from eight per cent to about five per cent. Natural gas can be expected to double capacity from five per cent to 10 per cent, and perhaps reach 15 per cent if additional competitive gas resources become available for base-load. Total renewable resources could reach 10 to 15 per cent, but a higher figure is believed unlikely.

Time delays to accept and build nuclear units would probably limit the uptake to the five to15 per cent range. The balance of demand will need to be provided by coal IGCC/sequestration units capable of poly-generation to produce transport fuels or hydrogen as well as electricity, provided the relevant technologies prove economic. The notional proportions below are less important than their implications.

Table 5.9 Energy mix for power generation in Australia 2050

| Technology | Range % | Notional % |
|---|---|---|
| Hydro | 5 | 5 |
| Coal, IGCC | 60-70 | 63 |
| Gas | 10-15 | 12 |
| Nuclear | 5-15 | 10 |
| Renewable energy | 10-15 | 10 |

## 5.7 ENERGY ISSUES TO 2050

Between 2005 and 2050 there will be many issues on the energy needs of an expanding population. Some of the more important are reviewed below.

### 5.7.1 Security of energy resources

Australia exports annually about two-thirds of its recovered energy resources, bringing substantial national earnings.

Development of Australia's mineral energy resources interacts with complex regulations at every level of government. These presently facilitate recovery and export. While acceptable now, governments will need to institute major changes well before 2050.

There is no evident coordinated government policy framework on energy reserves and the portion that needs to be reserved for long-term domestic use. Policies will need to be in place well before the need arises so that exporters and their customers have a clear understanding and can plan with certainty. Additionally, complex industry regulations need to be simplified to reduce domestic and export costs and Commonwealth Government intervention is essential.

### 5.7.2 Security of electricity supply

Previously society functioned reasonably successfully with, in some cases, an unreliable electricity supply. Business now depends far more on high quality electricity and supply security. Supply interruptions have major economic and personal consequences.

The NEM structure is still in transition. Some state governments retain responsibility for adequate generation while others transfer this role to the electricity market. On formation of the NEM, Victoria and South Australia sold their stationary energy infrastructure and ceded responsibility to the market while New South Wales and Queensland maintained their ownership roles. To date this has been successful for peak-power provision but has yet to be tested for new base-load capacity. The situation is complicated by the continuing strong intrastate transmission interconnections but weak to very weak interstate connections.

Consequently there is still market confusion over responsibility for new generation and transmission infrastructure. With the long lead times for new plant there is a real possibility that generation capacity may lag demand. This must be resolved soon to ensure adequate base-load power is available. The agreement between Australian governments to appoint a single regulator will assist in overcoming the existing federal/state constitutional nexus but further coordinated policy action is needed.

### 5.7.3 Ownership of energy infrastructure

Ten years ago all power system infrastructure was substantially owned by the states. Ownership is now in transition being part-private and part-state. Much of Australia's generation and related infrastructure capability is now owned by international organisations with their own agendas.

Initially the major new owners were from the United States and the United Kingdom. More recent transfers have been to Asian interests from China, Hong Kong, Malaysia, New Zealand and Singapore. So far only additional peak-load plant has been needed and the international owners have committed to provide this new plant in good time. To what extent they will commit to new base-load plant or major transmission system augmentation is still unknown. This is an added cause for concern for the long-term viability of the NEM.

Where assets have remained state-owned the response is varied. Some have committed to new base and peaking plant while others show little apparent response to perceived need.

### 5.7.4 Energy convenience versus demand management

Ideally the use of most products can be controlled by simple limiting mechanisms. Unfortunately this is not so for electric power. Australians are accustomed to highly reliable but extraordinarily low-cost electricity, valued as a component of quality of life. This contributes to conflict between two facets of that life – convenience and sustainability.

Convenience technology has undoubtedly captured the populace. Conventional cameras have been discarded for digital. CDs and DVDs have transformed recording and playing music and video. Domestic air conditioning and powerful home computers are pervasive. Electricity, still almost of the cheapest in the world, is demanded "at the flick of a switch".

Parallel with this, community knowledge and awareness of the need for long-term sustainability has grown quickly, leading to increasing emphasis on energy conservation and the minimisation of pollution and greenhouse gas emissions.

Power system investment could be significantly reduced, without loss of convenience or reliability but with enhanced sustainability, with effective peak-demand management. This involves reducing demand at times of system peak. Investment in peaking capacity is however unattractive at present retail prices. Thus reducing peak demand is critical for limiting poor infrastructure investment as well as conserving energy.

However it is difficult to see, in a fixed-retail-price regime, just how the purchaser of a low-cost convenience air conditioner can be convinced to not use it, regardless of system demand stresses, short of draconian regulation or realistic price signals. Encouragingly, time-of-day or real-time retail charging initiatives are now being trialled and can be expected to become adopted progressively.

### 5.7.5 Technology development

Likely technologies for the next 50 years are already available, with the possibility always of as yet-unknown disruptive technological advances. In the meantime, development must be accelerated in the following areas to meet community imperatives:

- effective permanent sequestration of carbon dioxide in geological formations;
- improved efficiency and cost reduction of renewable energy technologies;
- cost reduction of emerging large scale electricity storage technologies;
- improved conversion technologies from fossil to transport fuels; and
- development of non-exportable resources to fill niche energy needs.

### 5.7.6 Climate change – taxation effects

A climate-change tax, in some form, that would act to minimise the use of fossil energy and consequent carbon dioxide release to the atmosphere, is the subject of intense national and international debate. The objective of such a tax is to create a market driver to favour energy from lower or carbon-free sources. Some believe that any such impost should include all other "externalities" associated with delivery of energy to consumers.

Tentative taxation and emission trading systems have been developed in some economies. Some wisely direct the proceeds to promotion and support of sustainable energy supplies. However in other cases receipts have gone to consolidated revenue with little other beneficial effect. If taxation or trading systems are to become universal they must support and encourage sustainable energy delivery and end-use.

### 5.7.7 Relative price of oil and transport fuels

World crude oil prices have risen with the increase in demand over supply as well as security concerns. China's transport fuel demand has increased to the point where excess crude oil capacity is near its limit without new recovery and refining facilities. Meantime Australia has a declining oil resource with only limited prospecting for new reserves.

These factors are unlikely to disappear in the short-term leading to progressively more costly transport fuel, which is a significant cost component in the economy.

As prices rise, the development of a transport fuels industry based on a range of sources including small isolated natural gas fields, gasifying brown coal, exploiting shale oil and developing biofuels become more viable. All are in plentiful supply and the mix will ensure that adequate, albeit more expensive, fuels will become available as their production becomes economic. However the economy will need to factor in a higher cost for transport.

### 5.7.8 Energy price and quality of life

Australia, by world standards, has exceptionally cheap electricity. This has underpinned the development of highly energy-intensive industries such as refined aluminium, sometimes called frozen energy. However electricity prices will inevitably rise as resources become harder to recover and environmental sustainability costs are factored in. It is believed that such increases will not unduly affect or constrain the quality of life of the population up to 2050. Depending on world energy price comparisons they could, however, inhibit new energy-intensive industries in Australia.

## 5.8 PROSPECTIVE ENERGY PATHWAYS TO 2050

The pathway and energy mix to 2050 believed most likely is shown in Section 5.7 and Tables 5.8 and 5.9 and differs somewhat from the present power generation mix. Each component has a number of possible pathways towards a sustainable economic goal.

The key to an economically effective pathway lies in the constructive and progressive modification of the energy resource mix over the next 50 years. This was a simple process 20 years ago, when all Australian generation lay with state governments, but is now far more complex with diverse ownership and a competitive electricity market.

Changes, previously made by government-to-government agreement, must now be achieved through regulation. This is a relatively blunt instrument to achieve an economically tuned transition in overall energy mix over many years. Different outcomes can be expected from alternative forms of carbon tax; emission trading and greenhouse offsets legislated to achieve a desired outcome. Five evolutionary pathways (or energy scenarios) appear realistic. All can be justified. They are described very briefly below.

### First pathway

The simplest pathway continues with existing generation technology, paying carbon tax in whatever form it manifests itself. Power prices rise but, as these are relatively low in world terms, they are unlikely to neither reduce quality of life nor significantly change the resource mix. This pathway may however make an excessive contribution to climate change due to its unmodified CO2 emissions.

### Second pathway

This pathway postulates the use of advanced coal technologies and carbon dioxide sequestration. Sequestration technology has been used selectively for at least 30 years in the oil industry for injection of carbon dioxide into depleted oil and /or gas wells. Geologically suitable sites have been identified in Queensland, Victoria and Western Australia. There is, however, again little change to the resource mix.

### Third pathway

The third pathway assumes that nuclear energy becomes part of the resource mix. Nuclear power now provides about 18 per cent of the world's electricity. Developing economies, especially China and India, are committed to a significant proportion of nuclear power generation. Australia has nearly 40 per cent of the world's uranium reserves and exports are significant. Australia will need to consider nuclear technology as the need to limit greenhouse gases inevitably becomes even more pressing.

### Fourth pathway

The renewable energy pathway, attractive to many of the lay public, is however less well-developed. Its primary sources – while free, extraordinarily abundant and absolutely unlimited – are generally of low energy density. Uncertainty of supply due to the changing seasons, weather patterns and the passage of day to night place a premium on the development of economic storage technologies. While renewable energy resources are highly unlikely to be the major energy source by 2050 as many would hope, they will nevertheless be a robust business sector, providing employment and export income, but working within a more eclectic resource mix.

### Fifth pathway

The final pathway, and perhaps the most likely, is a strategic hybrid of all the foregoing. It will intelligently take into account total primary reserves, the necessary energy security levels, long-term sustainability (and the impact of externalities) and the export potential (without compromising any of the foregoing) of every energy resource available to Australia. Energy policy and the price for electricity, subject to often variable market forces, will derive from optimisation of all the above outcomes.

The energy conversion and delivery mix will not, however, change quickly. Generation and transmission facilities are very significant investments which have long lives over which their substantial costs have to be amortised. In other words the optimisation equations are moderated by major time constants. It is therefore essential to develop long-term national strategic plans to move the energy mix in the desired direction, using government regulation as may be needed to achieve policy outcomes where market forces alone would trend towards short-term optimisation. This warrants a far more substantial policy and planning framework, based on national agreements, similar to that negotiated for the single-energy regulator, to overcome constitutional difficulties between state and federal jurisdictions.

## 5.9 ENERGY EXPORTS

As two-thirds of Australia's recovered energy resources are currently exported, the implications of serving long-term and growing export markets must be considered in any review of energy output in Australia to 2050.

### 5.9.1 Energy resources

Australia has a broad range of energy resources, only some of which can be exported, as indicated in Table 5.10.

Table 5.10 – National Energy Resources

| Exportable | Domestic (Local) Use Only | |
|---|---|---|
| Black coal | Brown coal | Ocean energy (waves and tides) |
| Oil (limited) | Biomass | Non-exportable gas |
| Natural gas | Wind | Hot dry rocks |
| Uranium | Solar radiation | |

A proportion of exportable resources and associated application technologies and expertise will continue to be used to assist economies less fortunate than Australia and to provide export income, local jobs and joint venture associations. Safeguards may be needed to maintain adequate domestic reserves.

Non-exportable resources need to be developed, together with their application technologies, to fill any gaps in the national energy resource portfolio. For instance, with the depletion of Australia's oil resources, the extensive Victorian brown coal reserves could be used to produce transport fuels. Brown coal can be gasified to synthetic gas (syngas) and used for power generation and liquefaction to a diesel fuel. A prototype poly-generation plant is planned for commissioning in 2008 with outputs of 500MW of electricity and 50,000 bbl/day of low-sulphur diesel fuel, ideal for transport. Such a plant could also produce hydrogen if required.

Both wind and/or solar energy could be used to electrolyse water to produce hydrogen, converting a variable natural resource into one that can be transported and stored.

### 5.9.2 Export income

Energy exports provide national jobs, income, royalties and income tax receipts while national road, rail and port infrastructure assets are developed. In 2001-2002 energy export income amounted to $24.6 billion, equivalent to about $1,200 per capita. Present government policy is to facilitate export where profitable and strategic to do so. Approaching 2050 serious consideration will be needed to develop a clear-cut and rational reserves policy, even if this leads to curtailment of potential export income.

## 5.10 CONCLUSION

Australia has adequate energy resources to support a population of more than 30 million with no less than the amenity enjoyed at present. However, to achieve such a position, it will need to plan and develop clearer long-term policies for the management and use of Australia's abundant energy resources, keeping in mind the long time scales required to develop most energy related infrastructure.

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## 5.12 Glossary

| | |
|---|---|
| ABARE | Australian Bureau of Agricultural and Resource Economics |
| ANTS | Annual National Transmission Statement |
| EDR | Economic Demonstrated Resource |
| EIA | Energy Information Administration |
| IEA | International Energy Agency |
| LRMC | Long-run Marginal Cost |
| MRET | Mandatory Renewable Energy Target |
| NEM | National Electricity Market |
| NEMMCO | National Electricity Market Management Company |
| PNG | Papua New Guinea |
| REC | Renewable Energy Certificates |
| SOO | Statement of Opportunities |
| SRMC | Short-run Marginal Cost |
| SWIS | South West Interconnected System |

# ADDENDUM Oil Supply and Transport Fuels

## A.1 OIL SUPPLY [108]

### A.1.1 Forecasts

In recent years there has been considerable debate as to how long the world's oil supplies will last. This issue has been prominent in the popular media, given the recent surge in the price of crude oil and its key role in the world economy. Several estimates suggest world production has peaked or will peak in the next 10 years (see www.peakoil.com/index.php and associated links). Other estimates push the date out to beyond 2020 or even to the mid-century, depending on the certainty of the resource estimates and the assumed demand (for example, refer to reports that are available from the US Energy Information Administration [109]).

It is important to focus on when production will peak rather than how long reserves will last because it is the point at which the supply-demand pressure commences, prices begin to surge, conservation and substitution become economically attractive. Similarly at the national scale, the point at which local production peaks is the point at which petroleum imports begin to affect the trade balance and security of supply issues become increasingly important particularly if global supply is under pressure.

Australia's ability to predict local production is much more certain because through long-standing policies at Commonwealth and state level, geological and petroleum resources information is freely available – nationally through Geoscience Australia and through the state resource departments. Geoscience Australia publishes annually the national reserves and for each producing area and provides forecasts of future production (for example, *Oil and Gas Resources of Australia* 2003 [110]). The following observations are based on these published figures. However, it must be emphasised that any decision making relating to petroleum supply and transport fuels is being made in an increasingly uncertain environment as to the ongoing availability of crude oil.

Australia's oil production comes from two types of petroleum fields – a crude oil fields where the hydrocarbons exist in a liquid phase; and gas fields where "liquid" hydrocarbons exist in the gaseous phase in the reservoir and condense out of the gas stream as condensate or "light oil" in the surface facilities upon production. Both contribute to Australia's oil production.

During the past 30 years Australia has enjoyed a high level of oil self-sufficiency. However it should be noted that a large proportion of Australia's oil production, particularly from the north-west, is light in character – feedstock for gasoline – and is exported, while heavier crude oil (suitable for the production of the full range of petroleum products) is imported. Oil self sufficiency in this case is on a net basis. Australia therefore has been, and continues to be, exposed to the international oil market simply because the composition of Australian oils does not allow the full range of petroleum products to be produced and substantial amounts of oil must be imported to meet this need.

Australia's remaining crude oil reserves peaked in 1995 at two billion barrels and have declined to 1.58 billion barrels at 1 January 2004 (latest figures available) of which 0.8 billion barrels are in currently commercial fields. Condensate reserves are close to an all time high of 2.42 billion barrels of which 0.66 billion barrels are in currently commercial fields. The balance is largely stranded in gas fields yet to be developed off north-west Australia. Crude oil and condensate production in 2005 was 194 million barrels, of which about one-third was condensate. Note the unsuitability of condensate for the refining of many petroleum products. This compares with the situation in 2000, when total oil and condensate production was at a maximum of 264 million barrels, of which 21 per cent was condensate. Through time

[108] This text is based on an ASTE submission to the Senate Inquiry into Australia's Future Oil Supply and Alternative Transport Fuels, March 2006
[109] Energy Information Administration, Petroleum Navigator, All Petroleum Analysis. (tonto.eia.doe.gov/dnav/pet/pet_pub_analysis_all.asp)
[110] Geoscience Australia, *Oil and Gas Resources of Australia (OGRA) 2003 Summary*, Commonwealth Government, 2005.

condensate is becoming a more important source for oil production in Australia. The peak in production occurred five years after the peak in oil reserves was recorded

The ratio of annual crude oil production to "Economically Demonstrated Resources" is currently around six to seven compared with an historical figure of around 10 during the 80s and 90s. A boost to levels of crude oil production is anticipated in the next couple of years as crude oil reserves discovered earlier in this decade in the offshore Exmouth Sub-Basin of Western Australia is brought into production. Production decline is anticipated to continue in the absence of the discovery of major new reserves.

### A.1.2 Exploration

Successful exploration and full development of the identified resources is a necessary part of a sustainable oil production at a national scale. Future oil production will come from remaining reserves in:

- identified and currently commercial petroleum fields;
- identified but non-commercial petroleum fields which could become commercial over the forecast period;
- petroleum fields which will be discovered and made commercial in the forecast period;
- extensions to identified commercial petroleum fields (growth in reserves); and
- non-conventional sources of crude oil such oil shales, the conversion of some of our abundant natural gas and coal reserves into synthetic fuels and the conversion of biomass into ethanol.

Any forecast must therefore consider the technical issues associated with these sources as well as the assumption of an ongoing and vigorous petroleum industry in Australia capable carrying out ongoing exploration and development in frequently more challenging circumstances such as deep water and distance from land.

The anticipated decline in Australian oil production will only be arrested if substantial new sources of crude oil are found. It is worth noting that the basins (geological entities) that sustain current production were all found to be hydrocarbon-bearing by 1972. The history of hydrocarbon exploration in Australia over the past 30 years has been predominantly one of exploring the full potential of these basins. The latest extension to the Carnarvon oil province in the Exmouth sub-basin is considered to be one of the last major new oil opportunities in the established basins.

However there remain many Australian Basins that, to date, have remained substantially unexplored, many of them in deep water and in difficult environmental conditions. Geoscience Australia [111] has a geological research program aimed at opening up some of these areas for petroleum exploration. Only by continuing to encourage petroleum exploration in these frontier areas can we maximise the opportunity to find a new oil province. However the lead times are considerable – a discovery today in a frontier would be unlikely to yield any production for a least six years. The release and preliminary exploration of new acreage has a lead time of around four years. A decision to commence exploration in a new area would be unlikely to yield production under the most optimistic scenario would be around a decade. This emphasises the need to facilitate exploration in frontier areas whilst fully exploring the potential of existing producing areas where lead time are much shorter because of the knowledge of the geology and the existing infrastructure. Future exploration success for oil in Australia will have significant research and development issues and problems unique to Australia.

The above processes will produce significant quantities of greenhouse gases which will require mitigation. Hydrogen as a fuel source is a possible longer-term alternative as an energy source including for use in transportation. Significant issues remain and further research is required.

## A.2 TRANSPORT FUELS

### A.2.1 Petroleum fuels

By far the greatest part of Australia's car and truck fleet, and vehicles such as tractors mowers, recreational

[111] Geoscience Australia, Big New Oil Program (www.ga.gov.au/oceans/og_BigNewOil.jsp)

vehicles and construction machinery, uses liquid fuels derived from petroleum. This is also the case with aircraft, trains (outside the electrified urban networks) and ships. Smaller proportions of the vehicle fleet rely on gases such as natural gas and liquid petroleum gas (although LPG is distributed as pressurised liquid).

There are small but growing contributions from ethanol and biodiesel, and a tiny proportion of the vehicle fleet operates on electric motors supplied by on-board batteries. In all but these last cases, there is a national system of production and distribution and the key attributes are handling of the fuel by non-experts and mobility of the vehicle between fuel replenishments. Petroleum-based fuels meet 97 per cent of Australia's transport needs.

At the turn of the century, road transport accounted for 76 per cent of the energy consumed as transport fuels, air 16 per cent, water 14 per cent, and rail two per cent. Data from ABARE suggest that all are expected to grow at more than two per cent a year in coming years, leading to totals 50 per cent greater by the year 2020 and much higher by 2050. The view of the writers of the Australian Government June 2004 report *Securing Australia's Energy Future* [112] was that petroleum would remain the main source of liquid fuels at least to 2020, but two factors combine to suggest that alternatives could become cost-competitive and thus make a significant contribution by then and become more significant than petroleum within a few years.

Firstly, the rapid growth of industry in China and India has resulted and will result in increased competition for petroleum supplies, probably outrunning supply by 2015 or 2020. Secondly, that petroleum production will peak within a decade – the current prediction being 2006, although such dates are frequently extended. Even if oil production is maintained, it is likely to be at greatly increased cost, partly because of increased competition for the resource and partly because less accessible sources such as oil sands and shales will be brought into production.

### A.2.2 Alternative fossil fuels

At present, LPG accounts for just over five per cent of transport fuels and, because Australia's reserves are expected to last for several decades even at increased rates of extraction, its use is being promoted by the Australian Government. Further policy changes could occur over the decades ahead to increase the use of alternative fuels. At present, excise on LPG and some other alternative fuels is foregone by the government (current cost over $800 million/year) and new LPG vehicles delivered between July 2011 and June 2014 attract a grant of $1000.

There has been extensive research by CSIRO and Australian universities into the production of liquid fuels from coal, both brown and black, of which Australia has abundant reserves. World-wide, the lifetime of known coal reserves is estimated to be at least 250 years. The technology involved in coal conversion, as it is known, has drawn heavily on that developed by coal-rich but oil-poor countries that were isolated from petroleum supplies – Germany and later, South Africa. Some work in Australia has been funded by Japanese interests. So far, products of these technologies have not been cost-competitive in Australia and so they may be regarded as being held in reserve until the rising price of petroleum brings these alternatives into play.

Development is also underway of known processes to convert petroleum-derived gases into liquid fuels. Most of the gas will be sourced from Australia's North West Shelf and there are plans to undertake the necessary chemical engineering close to source and then ship liquid fuels to major distribution points, mainly south eastern Australia and overseas. Technical details for such processes were set out in an article by Professor David Trimm AM FTSE [113].

As indicated above for petroleum, these gas- and coal-derived liquid fuels will be readily available in future but prices (both actual and relative prices) will be higher than today's.

### A.2.3 Biofuels

The Australian Government announced its intention to promote the production and use of biofuels with

[112] Department of Prime Minister and Cabinet, *Securing Australia's Energy Future*, Commonwealth Government Report, June 2004.
[113] Trimm, D., ATSE Focus No.124, November-December 2004, pp.13-22.

a December 2003 report entitled *Appropriateness of a 350 Million Litre Biofuels Target* [114]. Once again, technology is not limiting since known (and even simpler) chemical engineering is involved, but price and the provision of suitable biomass could hinder the large-scale development of these technologies. Biofuel production and use is projected to rise unaided from the present 60Ml/year to 115Ml/year, but government stimulus is directed to ensuring the production of a further 205Ml of ethanol (sourced from molasses 60Ml and grains 145Ml) and biodiesel (30Ml from waste cooking oil and tallow) for the 350Ml target to be reached. In the long term, given likely price rises of petroleum products, these biofuels will be price-competitive even when excise is restored.

Arguments about the detrimental impacts of ethanol on present automobile engines have been over-drawn but in any case will be obviated by pending changes in engine design and operation. Such fuel mixtures are widely used in other countries. A co-product of biodiesel formation from vegetable oils or tallow is glycerol (glycerine), the market for which is already depressed by new product coming onto the market in North America, but it is expected that new uses will be found for this material so that biodiesel production is not hindered by loss of potential income from sale of the co-product.There are small gains to be made in greenhouse gas and other emissions from biofuel-powered vehicles, but these are marginal compared to the resource conservation benefits offered by moving to renewable fuel sources.

The Biofuels Action Plan released in late 2005 suggests that the 350Ml target will be easily reached by 2010, with industry projections for that year falling in the band 403-532Ml. New production facilities can be supported from the $37.6 million Biofuels Capital Grants Program, and the use of E10 (10 per cent ethanol blend in gasoline) will be mandated for Commonwealth fleet vehicles. This mandating is a further example of how government policy can be used to drive technological change and consumer behaviour. It is impossible to predict which policies will be devised and implemented over the next 45 years, but it would be wrong to believe that governments will not act to ensure the provision of adequate transport fuel (and other resources) in coming decades.

### A.2.4 Hydrogen fuel

Despite the enthusiasm in the research and technology communities for what is optimistically labelled "the hydrogen economy", it seems unlikely that hydrogen fuels will contribute significantly to transport before at least 2020. Beyond that time, however, the prospects should improve, at least relative to other energy sources. Much current R&D is directed towards the large-scale production of hydrogen from coal and water, and use of the gas as fuel in a "combined-cycle" power station where electricity is generated first by the hot gases from combustion of the hydrogen and then (in a second and more conventional step) by steam generated by the heat of combustion. The ancillary product of coal treatment, carbon dioxide, can be separated from the hydrogen and sequestered in deep aquifers. Plans to test this technology in Australia are already well advanced, under the leadership of Dr Peter Cook FTSE and the Cooperative Research Centre for Carbon Dioxide Capture and Storage. The concept of geosequestration of carbon dioxide enjoys wide support, especially in countries like Australia and the United States that have not signed the Kyoto Protocol and others who have joined with them in the Asia Pacific Consortium (AP6). It has the ability to reduce major greenhouse gas emissions that are believed to be responsible for climate change.

Hydrogen is already produced from coal and from natural gas for use in the chemical industry, for example for the synthesis of ammonia, but its use as a transport fuel will probably be allied with large-scale development in the stationary power sector. While some engine manufacturers are looking to hydrogen combustion in a more-or-less conventional engine, the alternative technology involves the use of hydrogen in fuel cells to generate electricity which can be used to power the vehicle by means of a number of electric motors strategically placed where motive power is required. Australia is a leader in fuel cell technology and also in the field of electricity storage in supercapacitors, which are likely to be used in electric vehicles to store excess charge, for example during regenerative braking, and release it when required. Trials of buses fuelled with hydrogen working in fuel cells have been under way for some time in Perth. In the report *Securing*

[114] Department of Industry, Tourism and Resources, *Appropriateness of a 350 Million Litre Biofuels Target Report*, Commonwealth Government, Feb 2004

*Australia's Energy Future* [115], the use of hydrogen as an energy source was placed in the "reserve" category, behind the "world leader"“and "fast follower" categories, so major funding is unlikely to be allocated to hydrogen development in Australia, at least for some years. In Europe and North America, however, trials have taken place of distribution of liquid hydrogen at service centres in much the same way as liquid natural gas is dispensed to private vehicles. It is unclear whether any of these developments will succeed in becoming the preferred way to make use of hydrogen as a transport fuel, but whatever the case hydrogen is likely to remain subsidiary to other liquid fuels for vehicle transport for many decades to come.

Production of hydrogen without the use of fossil fuels is also under investigation but is expected to take longer to bring to commercial success. Suggested methods involve high-temperature splitting of water to hydrogen and oxygen (possibly using sunlight), and electrolytic generation of hydrogen from water using power generated by wind, tides or sunlight. Since storage of the hydrogen product of such technology chains is a simple matter, it could aid the development of intermittent power sources such as those listed above by providing a buffer to even out the fluctuations in their output. A detailed account of hydrogen R&D activity in Australia may be found in the report *Australian Hydrogen Activity* [116].

### A.2.5 Overview

Managing a slow transition from petroleum-based fuels to a larger, mixed economy in which transport liquid fuels are derived from a number of sources does not present problems for fuel technologies. The area in which the transition will be most difficult will be in aircraft fuels, which have the most demanding specifications, and so what petroleum is available could be applied to such uses as a priority. There will be a need to produce versatile engines for the different fuels and fuel mixtures that become available, and to establish fuel standards and labelling protocols to ensure their appropriate use.

A good overview of Australia's energy situation, with pertinent remarks on transport liquid fuels, is contained in the CSIRO technical report *Future Dilemmas* [117] which was prepared for the Commonwealth Department of Immigration and Multicultural and Indigenous Affairs. In their summary of the larger report, *Dilemmas Distilled*, the authors predict that, unless there is a "revolution in energy production" by solar, nuclear means or the advent of the hydrogen economy, increases in population and increasing affluence by 2050 will increase energy use by 25 to 70 per cent. "Possible oil constraints in the transport sector", they note, "can be moderated by a transition to natural gas for transport fuel. However, this also constrains natural gas self-sufficiency and lessens export income towards the end of the simulation period".

It seems likely that the CSIRO authors were unduly pessimistic about the prospects for the "revolution" they felt would be necessary, since as shown above there is already considerable change in the three years since their report appeared. Continued attention from government to the fine-tuning of policy, and recognition by government, industry and the community that energy from all sources is likely to be more expensive, remain the watchwords of the liquid fuels industry.

The "business as usual" totals for traditional fuels predicted by ABARE are as follows:

#### Table 5.11– Predicted Traditional Fuel Use

| | Petrol Ml | Diesel Ml | LPG Ml | NG Ml |
|---|---|---|---|---|
| 2005-2006 | 20,300 | 8,000 | 2,400 | 100 |
| 2009-2010 | 21,200 | 9,000 | 2,700 | 150 |
| 2019-2020 | 21,700 | 11,700 | 3,450 | 650 |

These figures back up the statement that petroleum fuels will fade only slowly from the scene, and put the 350Ml biofuel (by 2010) total into perspective.

[115] Department of the Prime Minister and Cabinet, *Securing Australia's Energy Future*, Commonwealth Government Report, June 2004.
[116] Rand, D.A.J. and Badwal, S. (eds), *Australian Hydrogen Activity*, prepared for the Department of Industry, Tourism and Resources, 2005.
[117] CSIRO technical report, *Future Dilemmas*, (eds), Foran, B.and Poldy, F., prepared for the Department of Immigration and Multicultural and Indigenous Affairs, Commonwealth Government, October 2002

# CHAPTER 6
# Transport in Australia

The World runs on Wheels

J.Taylor, The Water Poet, (1623)

## SYNOPSIS

**There are no significant insurmountable or uneconomic engineering, scientific or environmental barriers to providing adequate transport for an Australian population of 30 million in 2050.** Nevertheless, to achieve this outcome will require Australia to invest continually in its transport systems. This will require effort within Australia at urban, regional and national levels. It will also require a great deal of international co-operation as many of Australia's key transport tasks will relate to transport to and from the rest of the world.

By 2050 successful cities and nations will be seamless parts of international transport. The fact that international trade and alliances will be key components of Australia's policymaking over each of the intervening 50 years will ensure that Australia's international transport systems develop at the appropriate incremental pace. As Australia is not an economic island, under-investment in our international transport systems would significantly diminish our trading ability in any population scenario.

Within Australia, population increases will have different transport impacts in urban and rural areas. Patronage levels are particularly important for Australian urban "public" transport, and currently are often too low to ensure that suitable systems develop via normal market pressures. Investment will move from the current era of subsidised operating systems to alternate systems (as is already happening with toll roads).

Outside the cities, the increased transport patronage will lead to improvements in travel services, as many routes currently operate at below optimum usage levels. However, market forces will not be so evident and investments in these systems need to be made by government, and with strategic rather than political intent. Good long-term infrastructure planning will be essential.

This will mean a change from the current transport planning and development systems, which are often driven by political imperatives, operating on a short-term basis with little policy transparency and more than a hint of the pork-barrel. Effective plans will need to be cast beyond the lifetimes of current governments and be divorced from the traditional overly-reactive government approaches. In addition, transport planning will not able to be divorced from a consideration of regional economics, social trends, and land-use planning, so a whole-of-government approach will be needed.

The required transport facilities will not only require good planning but will also require a continuing funding commitment. While the funding levels will not differ greatly from those currently required, they will need to be ongoing and continuous as Australia's current facilities are already less than optimum and there is no leeway to accommodate investment shortfalls over the next half-century.

The largest transport problems will arise in urban areas where the existing transport services are already struggling. Increased and continued major investment will be needed in relevant transport facilities. In particular, arterial public transport routes will need to be upgraded and new road infrastructure built, but to less spatially-demanding urban standards.

It is most likely that the bulk of the population increase will occur in urban fringes. This will need to be managed by careful planning controls to prevent the creation of a new set of transport and land-use problems. Many of Australia's current transport challenges are due to past poor land-use management. As land choices become more marginal and as demand increases, there will need to be an increasing alignment of land-use and transport policies. For instance, methods must be put in place to ensure that changes in land use are accompanied by – or even preceded by – the appropriate changes in transport provisions.

Road vehicles will continue to play a major transport role. Private vehicles will be smaller (perhaps mopeds) and more fuel-efficient, and travel speeds will be much lower. This change will be partly be driven by market forces, but will need to be accompanied by government regulations and incentives to ensure that fuel-efficient vehicles are also safe and to allow purchasers' decisions to align with the needs of national policy. It is probable that the future vehicle fleet used for personal travel will become a rental fleet of fit-for-purpose vehicles and so alternative ways will need to be developed to provide the secure and private personal space offered by today's motor car.

In the outer urban fringes where the demands of increased population will be greatest, the bus will be the dominant transport mode with the bus operations much improved by the use of telecommunications and onboard electronics. Indeed, initially bus operations will show the greatest beneficial change of all the transport modes and provide the largest transport response to major population increases.

Beyond the bus, planning will also be needed for systems where private, personal vehicles lock electronically into "buses" when operating on high demand routes. The core of such bus and rental systems will be the outgrowth of today's embryonic intelligent transport systems, allowing individual travel choices to be managed, operated and modified in accord with an overall strategic intent for travel in any given area.

A particular challenge will be with urban freight movement. Major capital expenditure and alternative technologies will be needed to provide good regional freight links to urban distribution centres. Australia's relatively large urban areas, with mixtures of housing and industry, are inefficient systems for freight distribution. Tunnelling is relatively straight-forward in Australian cities and so future solutions might well involve a greater use of tunnels carrying autonomous delivery vehicles.

## 6.1 INTRODUCTION

Transport is a vital component of urban, regional and national development. It influences and facilitates the flows of people and goods within and between cities, nationally and internationally. It links cities and towns into a national (and global) system.

Transport is a derived demand and it is therefore impossible to discuss it without understanding and discussing the size, desires and locations of those people and producers who would use it. For both people and freight, these underlying factors are mainly determined by economic activity, social desires and land-use patterns. When the economy booms, transport booms. When the shape and size of cities change and their land use forms alter, transport alters. When origins and destinations are reoriented, transport needs and costs are modified.

A discussion of transport therefore cannot be divorced from a consideration of regional economics, social trends, and land-use planning. Of course, such a discussion must also consider the available and future transport technologies. Thus the following discussion will address all these factors.

It is convenient to consider transport in Australia in two categories: regional (or long-distance) and urban (or short-distance). The discussion of long-distance transport is simpler and so will be presented first.

## 6.2 REGIONAL, LONG DISTANCE, TRANSPORT

It is not expected that trends in long-distance transport in Australia will differ from those in the rest of the world, nor will they be much influenced by population increases.

### 6.2.1 Air travel

Travel by air will follow world trends and even the largest expected population increases will not create pressures on airspace or airport capacity which are anywhere near as severe as those which are already commonplace in other countries. Normal investment patterns will at least maintain systems at acceptable levels.

Similar remarks can be made about changes in sea transport and shipping. In both these modes, continuing infrastructure investment will be needed, but will not be exceptional. These transport modes will only suffer if other factors diminish these investment flows. As Australia is not an economic island, under-investment in our international transport systems would significantly diminish our trading ability in any population scenario.

### 6.2.2 Land surface travel

Long distance land transport within Australia is by road and rail. There is no reason why population increases should adversely affect either mode when operating outside urban areas. Many routes currently operate at below optimum usage levels. Indeed, considering current European travel patterns, an increased population might raise travel patronage to levels where more and better travel options at improved levels of service are offered as a matter of sound investment policy.

Thus, outside the cities, the increased patronage due to a population increase will probably lead to improvements in travel services, as systems become economically self sufficient.

### 6.2.3 Rail

The provision of long-distance rail has frequently been seen as a popular panacea for many of the ills of this large, sparsely populated country. However, in our 150 years of rail transport history there is little or no evidence of such schemes being successful and numerous examples of their failure. This excludes the immensely successful freight rail systems serving the large mining sites.

Outside of mining areas, our regional rail systems suffered from continuing neglect during the 20th century. Track was poorly maintained and rolling stock became antiquated. Rail demands gentle grades and generous curves and little was done to improve these as, for example, with the problems associated with the major lines into Sydney. The majority of the rural rail systems built in the boom years of the 19th century are now closed or in terminal decay. Few of the remaining major routes can operate at anything even approaching international levels of service.

In addition, and often more seriously, the urban track lengths at the ends of long-distance journeys are shared with busy urban commuter traffic. Examples would be the tracks into Melbourne from Sydney, Gippsland and Geelong. Similarly, many freight terminals are increasingly poorly located as urban development has encroached around them.

Growing population pressures will further exacerbate these problems, and major capital expenditure will be needed to provide good regional freight links to urban distribution centres. For example, the cost of the necessary third (express and passing) rail track from Melbourne to Dandenong has been estimated at close to a billion dollars.

It is hoped that the recent AUSLINK processes introduced by the Commonwealth Government will put future rail funding on a stronger basis and will improve our key long distance rail routes. AUSLINK certainly represents an encouraging start. Nevertheless, there remains a tendency for major projects to be seen as part of a political pork-barrel. Projects are advocated for questionable reasons and without being part of a transparent forward plan. Most recently the Alice Springs to Darwin railway which opened in 2004 was touted as providing a major freight artery. After it opened, shipping companies quickly undercut its charges and its major role now is as an iconic tourist railway.

### 6.2.4 Road

Australia's long-distance road system is far less developed than the equivalent US system. This is due to a lack of funds and patronage rather than to any physical constraints. It is difficult to see how the ongoing development of the road network, given a normal flow of investment funds, could be impeded by population increases.

Long-distance passenger travel is relatively minor and often for recreational purposes. Despite popular perceptions, most car travel on our major inter-city routes is local rather than long-distance.

The road freight industry is strong and self-sufficient and takes advantage of most market opportunities. It will not be a restraint on population increases.

In an information and logistics sense, the technology used in road freight is still quite primitive and relatively inefficient, with each vehicle operating as an independent unit. Over the predictive period embraced by this report, it is probable that a combination of IT and telecommunications technology (intelligent transport systems – ITS) [118] will see road freight vehicles operate more in a remote-controlled convoy mode, leading to even greater efficiencies. Logistics technologies and management principles will also be interwoven into the ITS systems.

Regional road freight often handles the urban distribution by distribution centres at urban fringes. These are serviced by smaller delivery trucks. Similar arrangements are needed for regional rail freight, but there is little sign of the systematic planning needed to put this in place. This problem will worsen as population increases continue and therefore appropriate planning measures should take place.

## 6.3 THE URBAN FRINGES

The planning issues at urban fringes are discussed elsewhere, but the topic cannot be avoided here as such issues intimately influence the population/transport interaction.

Since cities began to expand during the industrial revolution [119], such expansion has always occurred at the city fringes. There the land is cheap, there are ready sellers, and no need (if the seller is quick) to worry about providing supporting infrastructure [120]. And beyond the cheap land, are the desirable woods and dales and beaches sought by the wealthy for their weekend pursuits. Planning interventions inevitably bow to such market pressures and political influences. The view is as true today as it was 250 years ago.

The expansion of our cities is often blamed on the motor vehicle, but a careful examination shows that, even in "new" cities like Melbourne, that expansion was occurring before the car and fuelled by the factors listed above [121]. Of course, it was subsequently abetted by the car, but in Melbourne the rail-based extensions were so great that the role of the car was to allow the infill of the undeveloped wedges between the radial rail routes.

The expansion continues. Research in 2004 showed that young people were then buying into property on the urban fringes, with about half the purchasers aged 18 to 34 and 90 per cent under 50. Almost 80 per cent of these households owned two or more cars, with about two-thirds of residents happy to travel more than 10 kilometres to get to work, and 95 per cent of them drove to work [122].

A related concern is that these urban fringe developments often meet the market needs of the current generation of high spenders. Hence, recent data has a majority of London professionals, and many of their New York counterparts, making daily commuting trips of well over an hour each way as they live in idyllic villages and work in grand offices, with who cares what in between. Such continued trends would produce the worst of outcomes but there is little evidence of the ability of land use planners to control the phenomenon.

Despite this pessimistic view, there must be sustained efforts to achieve urban consolidation and land infill within existing urban areas. There have been some notable successes in this area - for example, Crows Nest and the extended use of railway land in Sydney – and there is no reason why they cannot be repeated in the future. These measures often appeal to people who wish to reduce their private car usage in and around city centres. The main issue with such measures is that the properties often become highly priced and therefore only available to a sector of the population.

[118] Lay, M.G., et al., in Sayeg, P. and Charles, P. (eds) *Transport Innovation – A New Era for Australia*, CL Creations, Sydney, 2005.
[119] Lay, M.G., *Ways of the World*, Rutgers, University Press, New Brunswick, New Jersey, 1992.
[120] In Melbourne Tommy Bent put a different complexion on this approach (Lay, M.G., *Melbourne Miles*, Australian Scholarly Press, 2003).
[121] Lay, M.G., *Ways of the World*, Rutgers, University Press, New Brunswick, New Jersey, 1992, and *ibid*.
[122] Bernard Salt reported in *Herald Sun*, 26 December 2004.

A local example occurred in Melbourne in 1995-96 when the Victorian Government spent $70 million electrifying the Cranbourne railway line and making other improvements between Cranbourne and Dandenong. Patronage increased by 20 per cent and commuter car-parking at Cranbourne by 80 per cent. Cranbourne is 45 km from the centre of Melbourne, so the merit of the provision and of giving priority to enabling Cranbourne residents to work in central Melbourne is questionable. Ten years later the government is discussing spending a billion dollars to add a third track to the Dandenong line to accommodate demands on the route.

Thus, population changes will inevitably create transport problems at urban fringes. We will deal with the urban aspects later. At the fringes, key problems are that self-contained activity in the urban fringe will:

- restrict development of the radial transport corridors;
- not naturally create any circumferential corridors; and
- compete with the regional traffic for use of the radial corridors.

Any measures to improve travel from the urban fringes to the city centre will directly encourage further fringe development.

## 6.4 URBAN TRANSPORT

The world of the future will be very much an urban world. Even today in Europe, 75 per cent of the population lives in urban areas and yet Europe is more than self-sufficient in the task of providing itself with a high standard of living.

For Australia, the transport issues associated with an increasing population are very much those of the urban areas. Our cities and towns are by any measure cities with low population densities. From 300 people/km$^2$ in the suburbs to 3,000 people/km$^2$ in the city centre, we fall well below the 16,000 in Seoul, 24,000 in Paris, 40,000 in Manilla, 100,000 in Cairo and over a million people/km$^2$ in a small part of Kowloon.

The transport practicalities of high population densities are obvious. Large numbers of people wish to travel short distances. Hence we see the high patronage levels in the “subways” in cities like New York, Paris and London. At the other extreme, a Melbourne suburban population-density at the low end of 300 people/km2 would provide little more than 100 travellers per peak period [123] and could never justify an “intense” urban transport system. It would barely support a low frequency bus service. However, the average Melbourne figure of about 1600 people/km$^2$ would support a 15 minute-headway [124] bus service. Thus we must not expect too much of rail outside its existing corridors. In those areas, buses must be high on our list of transport priorities.

A critical point is that Australian cities (with Sydney as a partial exception) do not currently have the infrastructure that could readily provide dense urban transport. London, Paris and New York had exceptional civil engineering circumstances (respectively clay, wide boulevards and an island geography) that made their systems initially feasible and New York also had a long-term commitment to subway building. None of these circumstances, and no economic imperatives, apply in Australia and it is inconceivable that intricate urban transport systems will develop in our cities.

If we were able to encourage higher urban population densities, rather than a continuation of the urban sprawl, the first signs of transport problems would be demand exceeding capacity on existing services during peak hours. This would be because of two factors:

- First, as discussed earlier, we have the competing longer distance travel demands on the same facilities; and
- Second, people needing to travel by transport – come what may – would locate themselves on existing transport corridors. The land market would be working and would place a price on accessibility to

[123] Some people will stay at home; others will be self-sufficient in their travel.
[124] For example, a bus would arrive every 15 minutes.

quality transport.

Most of these radial corridors in a land-sense date back over a century and we have already discussed how the 20th century was marked by a lack of any investment in or development of these corridors. Only the road corridors were developed, partly because of the incessant and more attention-worthy demands of owners and operators internal combustion vehicles, and partly because the new roads administrations saw strategy and long-term planning as key parts of their portfolios [125]. Such was not the case for the increasingly quiescent rail administrations.

The magnitude of the task can be seen from the fact that in Australian cities people make about four trips a day. Surprisingly, for Sydney "trips for social and recreational purposes" are the single most common reason for people making a trip. This is followed by shopping and trips to drop off/pick up (or accompany) someone. Contrary to popular opinion only 15 per cent of trips made on an average weekday are for the purpose of travelling to or from work. Even during the morning peak only 27 per cent of those travelling are commuting to work [126]."

Every new citizen generates four new trips. This simple statistic requires more than a passive planning response.

## 6.5 URBAN TRANSPORT MODES

The discussion is now best pursued by focusing on each of the transport modes in turn. Much of the preceding discussion has laid the groundwork for this Section.

Today 80 per cent of Melbourne's office space, but only 25 per cent of its jobs, are in the city centre. Cities of tomorrow will be increasingly multi-centred and therefore not easily served by a radial system. Strong centres such as Chatswood, Parramatta, Ringwood and Dandenong are all on busy radial routes, but draw on a population from a catchment far wider than that served by the radial route.

The situation is exacerbated when, as in most Australian cities, the radial services to the original centre are not adequate and workers are forced to seek employment away from that centre.

### 6.5.1 Rail

To service even the existing population, urban rail systems require major investments in third tracks and extra platforms at station, upgraded rolling stock and modern signalling. It is unlikely that the limited growth in demand for travel to and from the city centre will see the commitment of the very large investments needed. In the feed-back situation that will occur, major increases in population growth will not be associated with correspondingly large job growth in the city centres.

### 6.5.2 Tram

This mode operates mostly on-street and with frequent stops. It is therefore ideally suited to shorter suburban trips, particularly by those travellers who cannot drive cars (for example, students, disabled people). Some trams could also operate as feeder services to the rail system, but this is rarely the case with existing operations.

The land market has also accommodated to this travel facility, with people desiring tram travel seeking land serviced by the tram system. As with rail, this drives housing prices up and results in transport-disadvantage being particularly common among low-income earners.

Thus today, much of the useful rail and tram systems serve the wealthier portion of the community. Large increases in population will probably not fall into this category so new residents will be forced to live in areas which have relatively poor rail- and tram-based public transport.

Therefore new living areas will require disproportionately large investments to provide transport equivalent to the existing systems.

[125] See a review for Melbourne in Lay, M.G., *Melbourne Miles*, Australian Scholarly Press, 2003.
[126] Transport and Population Data Centre, NSW Government. (www.planning.nsw.gov.au)

### 6.5.3 Bus

The bus in many ways is the perceived poor cousin of public transport, but it is also the solution to many of our future travel needs.

The bus' poor image is despite the fact that it can often match the comfort, speed and convenience of the rail and tram alternatives. Some of this attitudinal problem has been explained in almost Freudian terms. At the least, many people lack confidence that a bus will appear around the corner – there is not the physical certainty provided by the steel tracks of train and tram.

Moves to allay this attitudinal fear are slowly being applied. Substantial bus stops and waiting areas with a strong public presence, dynamic signs telling when the next bus is coming and where it is going, clearer iconic route identification symbols and bus-only lanes are typical measures now being used.

Nevertheless the bus is still a very underdeveloped transport mode. It has the potential for numerous relatively low-cost but very useful enhancements. For example:

- guaranteeing bus frequency – a bus every 15 minutes on a signed route – rather than complex timetables beyond the comprehension of many travellers;
- real-time bus arrival signs;
- on-board advice to travellers on arrival times; and
- guaranteed interchanges with other transport services.

The bus is also able to take full advantage of the good arterial road systems provided in the newer parts of our cities. These systems often exist in areas which are transport poor with respect to rail and tram. Finally, the bus has route flexibility allowing it to service the range of destinations that will arise as cities expand and become more polycentric in their operations. Routes can also change as demand changes.

In the future:

- the use of intelligent transport systems [127] will aid the swift passage of buses through the urban road network;
- on-demand door-to-door pick-up and delivery will raise levels of service and passenger security; and
- buses will operate as electronically coupled and closely linked convoys:
    - these would separate at either end of the journey allowing diverse trip origins and destinations to be satisfied, without the traffic jams that occur at each end of car-dominated freeways; and
    - passengers would change between destination modules whilst the journey is in progress.

Up to the present, much urban development – although increasing housing density – has not seen a population density increase due to a social move to smaller household size. In the future, the urban consolidation potential in the outer suburbs is large and the transport needs of such areas could readily be met by the next generation of buses operating on the generous outer suburban streets.

For these reasons, it is expected that the bus will be a major and successful transport provider in high population-growth scenarios. It will provide most of the new transport capacity. There is only one serious impediment to this prediction, and that is fuel.

### 6.5.4 Fuel

Fuel prices have risen rapidly in recent times, reflecting perceived and real oil shortages. In addition, global warming concerns are beginning to create greenhouse targets that will have discernible transport impacts. Most commentators see this as a serious portend for the future.

The economic rationalist's response is that rising prices will attract industry to develop and offer alternative power sources. The pessimistic response is that the world has now been using the same fuel and power generating method (petroleum and piston engines) for over a century – a very long Krondatieff cycle. Does a better technology exist?

It has been predicted that [128], unless there is a "revolution in energy production by solar, nuclear means or the advent of the hydrogen economy, increases in population and increasing affluence by

[127] Lay, M.G., *et al.*, in Sayeg, P. and Charles, P. (eds), *Transport Innovation – A New Era for Australia*, CL Creations, Sydney, 2005.
[128] Foran, B. and Poldy, F. (eds), *Future Dilemmas*, CSIRO Technical Report prepared for the Department of Immigration and Multicultural and Indigenous Affairs, Commonwealth Government, October 2002.

2050 will increase energy use by 25 to 70 per cent. Possible oil constraints in the transport sector can be moderated by a transition to natural gas for transport fuel. However, this also constrains our natural gas self-sufficiency and lessens export income."

If we assume therefore that fuel costs will increase in both relative and absolute terms, this will have a major impact on our travel patterns. However, the response in Australian cities may not be as dramatic as is sometimes suggested, for the following reason. The typical fuel consumption data for various vehicle types are:

- large cars and four-wheel drives 16l/100 km
- medium cars 10l/100 km
- small cars and motorcycles 5l/100 km
- super-efficient cars & mopeds 2l/100 km

Thus an incredible eight times improvement in fuel consumption could be achieved by a simple change in existing vehicle types. It is sometimes argued that smaller vehicles are inherently unsafe, however if all vehicles were small and speed limits were dropped, safety would actually increase. The other important aspect in considering such a change in on-road vehicles is that the road space that already exists was provided for large vehicles. Dropping vehicle size and speed would therefore also increase traffic capacity.

In respect to this argument, it is useful to see the dramatic improvement in vehicle fuel and environmental performance in Europe during the past decade under the strong pressures of EEC regulations. The development has not yet finished and the rest of the world has yet to take up the many of the European advances.

Patronage levels are particularly important for the fuel efficiency of Australian "public" transport. Whilst it is easy to produce figures showing how relatively efficient various modes are, if they are operating with low loading levels they become very inefficient. For example, a fully loaded train consumes about 0.3 kJ/passenger-m where as a typical commuter car uses 1.1 kJ/passenger-m, making the train four times more efficient. But if the train is only 20 percent occupied, its energy usage rises to 1.6 kJ/passenger-m, completely changing the relative efficiency of the two modes [129].

Outside cities, the increased patronage will probably lead to improvements in travel services as many routes currently operate at below optimum usage levels.

### 6.5.5 Road vehicles

The preceding Section has suggested that the most likely future change in the vehicle fleet would be towards smaller and more efficient vehicles, requiring less fuel and less road space and operating in a lower-speed environment.

The further dispersion of intelligent transport systems [130] into the vehicle population will see car used in a more efficient way as drivers become better informed of the circumstances associated with their trip and their trip decisions. It may well be that some of the convoy-style operations described in Section 6.5.3 for buses will also be applied to peak hour travel.

The car rental market will also become more accessible and more travellers will hire specific cars for particular occasions, rather than purchase a single vehicle to meet all needs.

One inevitable major change will be the widespread use of automatic road pricing which will allow road-system administrators to charge travellers for using certain roads or for travelling at particular times. Road pricing is already used in Singapore and London. Increased parking charges can also be used to provide a blunter form of road pricing.

Thus the market place will be used to control congestion, make motorists experience the real cost of motoring, and therefore enhancing rational decision-making with respect to car usage. The technology to do this already exists in the electronic toll tags used by most urban motorists, surveillance videos, mobile phone networks, and the GPS systems already fitted in many cars for mapping and security.

[129] Lay, M.G. Handbook of Road Technology, Gordon & Breach, NY, Vol.2, 3rd Edition, Chap.30, 1998, p.1077.
[130] Lay, M.G. *et al.*, in Sayeg, P. and Charles, P. (eds), *Transport Innovation – A New Era for Australia*, CL Creations, Sydney, 2005.

Indeed, the ability of GPS to accurately monitor the location and movement of any vehicle will lead to widespread improvements in vehicle management, despite a growing number of vehicles.

Incidentally, for some decades it has been argued that information and communication technologies will impact on transport needs and demands, by substituting telecommuting and regional and global conferencing for travel, and – more recently – by harnessing internet supply portals to provide lower supply costs. These impacts have stubbornly refused to come to pass for two main reasons:

- people value the social side of work and the "feeling and touching" side of shopping; and
- the majority of trips are not work trips.

Similar technological (positive) impacts in the freight area are coming from the growing application of logistics theory and the pressures of just-in-time delivery and supply-chain management. The growth of companies devoted to transport as a total task, rather than mode based operations will lead to further freight efficiencies.

### 6.5.6 Modern roads

Japan gives us an inkling of how future urban roads might evolve.

After World War II, the US began building its famous Interstate system of freeways lacing the nation together. They were originally conceived as roads through the countryside, coincidentally linking cities together. The design standards were those appropriate to high speed rural travel – wide reservations and large (for example 1000 metre or more) curve radii. These rural freeways were, somewhat thoughtlessly, extended into the cities. Their spatial demands then devastated the downtown areas in many US cities.

Subsequently Japan showed that very effective urban motorways could be built with much lower design speeds, narrow reservations and tight (for example, 100 metre rather than 1000 metre) curve radii. They showed that appropriate road transport facilities can be provided without extending or replicating "traditional" land-hungry freeway system.

This argument for lower urban road design standards is supported by the fact that actual travel speeds have little relevance in urban areas – the difference in time to make a 10 km trip at 60 km/h rather than 100 km/h is only four minutes. More time that that can be spent at traffic signals at either end of the freeway.

The other key aspect of speed is the well-known empirical observation that people budget a fixed amount of time for daily commuter travel, say one hour [131]. If transport speeds are increased, then people simply travel further in a manner that is counter to most planning objectives. They flee the in-between lands, leaving them to the very wealthy or the very poor.

Thus there is ample scope to use speed management as a tool to assist in accommodating larger populations in our urban areas.

## 6.6 SUMMARY

As a general summary, there are no transport issues which will be insurmountable barriers to population growth in Australia. However, we need to continue to continually invest in our transport systems, if we are to be able to support larger populations.

Population increases in Australia will have different transport impacts in rural and urban areas. Patronage levels are particularly important for Australian "public" transport. Outside cities, the increased patronage will probably lead to improvements in travel services as many routes currently operate at below optimum usage levels. However, investments in these systems need to be made, and with strategic rather than political intent. Good long-term infrastructure planning will be essential.

Larger problems will arise in urban areas where the existing transport services are already struggling. Continued major investment will be needed in these transport facilities. Arterial public transport routes must be upgraded and new road infrastructure should be built to less spatially-demanding urban standards.

[131] Lay, M.G., *Handbook of Road Technology*, Gordon & Breach, NY, Vol.2, 3rd Edition, Chap.30, 1998, pp.1109-1110.

It is most likely that the bulk of the population increase will occur in urban fringes. This will need to be managed by careful planning controls to prevent the creation of a new set of transport and land-use problems.

Road vehicles will continue to play a major transport role. Private vehicles will be smaller (perhaps, mopeds) and more fuel efficient, and travel speeds will be much lower.

In the outer urban fringes where the demands of increased population will be greatest, the bus will be the dominant transport mode with the bus operations much improved by the use of telecommunications and onboard electronics. Indeed, bus operations will show the greatest beneficial change of all the transport modes and provide the major transport response to major population increases.

# CHAPTER 7
# Waste disposal

It is bad enough to see one's own good things fathered on other people, but it is worse to have other people's rubbish fathered upon oneself.

**Samuel Butler notebooks (c1890)**

From the foregoing survey of conspicuous leisure and consumption, it appears that the utility of both alike for the purposes of reputability lies in the element of waste that is common to both. In the one case it is a waste of time and effort, in the other it is a waste of goods.

**Thorstein Veblen, *Theory of the Leisure Class* (1899) ch4.**

## SYNOPSIS

**With continued improvements to the management of waste, there is no reason why waste should impose a limit to population growth of at least 30 million people by the year 2050.** Currently, with improved waste management, society is reducing the volume of waste, even from a growing population. Furthermore, Australia has the space and resources necessary for the effective management of waste. However, should problems start to emerge with the management of waste in Australia, incineration can always be introduced as is the case in most of the world's larger cities.

Any study of the growth of population must take into account the possible increasing impact on the environment from energy and resource generation, and also the disposal of all of society's waste.

Australians generate more waste per capita than in most other developed countries and this comes about from relatively low-density populations and comparatively abundant space for landfill disposal. Currently there are changes to waste management which encompass urban waste reduction, recovery and recycling. With acceleration of these programs, there is opportunity for Australia to produce less waste in the future than it does today.

The collection, sorting and recycling of materials is not driven by the economics of the recovered materials. The combined cost to collect, sort, process and deliver most glass, plastic, paper, and metals in our waste streams to a user is seldom less than the selling price of the recovered materials – yet recovery and recycling is supported at all levels in society. These actions may not save money but they definitely reduce the demand for landfill, make a financial contribution and lessen the environmental impact.

Schemes in some cities collect and extract putrescible materials then process them to make available commercial quantities of compost. These schemes however are impacted by some plastic (bags) and broken glass being entrapped in the compost, making it unsuitable for some crops.

The waste has no commercial value and is generally delivered free of cost to the accepting agricultural area. Growers do however claim that productivity is increased due to its use.

Most city municipalities have multi-bin waste collection systems. Some areas have as many as four separate containers (greens, plastic, paper and metals). Others have two bins and apply a factory style of sorting to separate each recyclable component. The growth in factory separation has been slow.

The Chapter gives a description of the application of the laws of science to the disposal of waste and four derivative laws – (1) all processes produce waste; (2) all waste becomes part of the earth, particularly part of the biosphere; (3) all waste changes biologically, physically or chemically with time, and then usually dilutes and disperses without becoming a hazard to life or environment; (4) the management of waste is a matter of providing a mechanism for its containment for sufficient time to allow for the process outlined in (3).

## 7.1 INTRODUCTION

Australians are among the highest producers of waste in the world (OECD 2002). Perhaps they illustrate Veblen's conspicuous leisure and consumption. They generate waste at a rate of 2.25 kilograms per person per day (820kg per person year), the majority of which ends up in landfill (AGO 2004). During 2002-03 more than 17 million tonnes of waste was disposed of at landfills in Australia. More than 30 per cent of this was domestic or municipal waste.

If present waste management processes continue to be applied to an increasing quantity of waste, an increasing land-fill volume per year would be required – against current environmental and political objectives. To maintain the preferred quality of environment near cities and regional centres, this may manifest itself in increased disposal and transport of waste over greater distances, with attendant environmental, cost and road safety issues.

However this trend can be modified if Australia further endorses waste minimisation, re-use and recycling. Secondary waste treatment (factory) sorting and then composting of all accessible putrescible organic wastes further reduces the volume to landfill. This concept is known as Urban Waste Reduction, Recovery and Recycling (UR-3R) and is discussed later. Densely populated parts of some developed countries, such as Japan, the US and the UK, generate greater volumes of waste and yet have significantly less space. This has forced those areas to include incineration for waste disposal. Those societies have developed waste collection, sorting and incineration methods that meet their space and environmental constraints. If Australia's waste volumes increase significantly then it may become necessary to adopt some of the systems used in more densely populated areas. Therefore with waste reduction, sorting and composting, and incineration if necessary, it appears that the disposal of waste will not be a barrier to the population growth envisaged by the Scanlon Foundation.

Australian authorities are working with industry to make inroads into waste minimisation in several areas, including packaging, paper, organics, construction and demolition, finance, automotive and electrical industries. For example, the reduction of organic waste from waste streams is important because it could reduce Australia's greenhouse gas emissions and significantly reduce the volume of landfill (Department of the Environment and Heritage 2004a). In addition, the adoption of the National Packaging Covenant in 1999 is a significant initiative aimed at improving the management of used package materials (Department of the Environment and Heritage 2004b) (both references are taken from Nolan ITU, Global Renewables, National Benefits of Implementation of UR-3R Process©).

## 7.2 HOUSEHOLD AND BUSINESS WASTE MANAGEMENT

Waste management systems include the collection, transport, sorting and disposal of recovered materials and refuse generated by Australian households and businesses. The structure and economics of these services varies greatly from municipality to municipality. These systems are not driven by the value of the materials derived from the waste streams, although at times this is an economic component. In the more densely populated areas, the value of recovered paper, cardboard, glass, plastics and metal impacts positively on the overall economics of the system. Municipalities are driven by the need to minimise the annual volume to landfill and the environmental impact of their operations. The reduction of putrescible waste into landfill is consistent with these ambitions. As the total cost to ratepayers for the waste system is just part of the overall rate, there is normally little public concern for that particular cost.

Municipalities vary greatly as to the method and frequency of waste collection, sorting and disposal. Areas can have one, two, three or four bins in an attempt to pre-sort and selectively collect wastes. Multi-bin systems, known as "at source recycling", have the disabilities of cost for collection and house-to-house inconsistencies as to the quality of that sorting. There can be "pollution at sorting" and therefore subsequent treatment is based on the lowest common denominator, reducing the effectiveness of primary sorting. Some have communal depots for the collection of glass, iron and aluminium containers. South Australia has effective refund policies for all containers and this appears to be successful. There is a possibility that other states may adopt this policy as a means of lifting the quality control and consistency of primary sorting. States are contemplating the ban of plastic bags in retail stores. This would assist in the quality of compost and material for landfill but there will always be some contamination from bags in the stream.

Tables 7.1 and 7.2 illustrate the amount of waste to landfill by states and the quantities of 'other' wastes.

### Table 7.1 – Solid Landfill Waste Quantities (a) (b), By waste type – 2002-03 [132]

| | NSW | VIC | QLD | SA | WA | TAS | NT | ACT |
|---|---|---|---|---|---|---|---|---|
| | '000 tonne | '000 tonne | '000 tonne | '000 tonne | '000 tonne | '000 tonne | '000 tonne | '000 tonne |
| Domestic and municipal | 1,657 | 2,132 | 1,108 | na | 741 | na | na | 82 |
| Commercial, industrial, construction, demolition | | | | | | | | |
| Commercial and industrial | 2,358 | na | 522 | na | 420 | na | na | 98 |
| Construction and demolition | 1,193 | na | 200 | na | 1,535 | na | na | 27 |
| Total | 3,551 | 2,790 | 722 | na | 1,955 | na | na | 125 |
| Other | - | 545 | 986 | na | - | na | na | - |
| **Total** | **5,208** | **5,467** | **2,816** | **1,252** | **2,696** | **na** | **na** | **207** |

(a) Received by private and public trading sector waste management businesses.
(b) Data as reported by state and territory government departments and Environment Protection Authorities across all industries. Refer to Technical Notes in 'Waste Management Services, Australia, 2002-03' (8698.0) for more details about the data, including differences in scope across states and territories.

### Table 7.2 – Waste Quantities Other Than Landfill (a) – 2002-03 [133]

| | NSW | VIC | QLD | SA | WA | TAS | NT | ACT | AUST |
|---|---|---|---|---|---|---|---|---|---|
| | '000 tonne | '000 tonne | '000 tonne | '000 tonne | '000 tonne | '000 tonne | '000 tonne | '000 tonne | '000 tonne |
| Received at liquid treatment plants (b) | *263.6 | 166.9 | 172.3 | np | np | np | np | np | 698.1 |
| Received for disposal at other facilities (c) | 41.5 | 41.3 | 24.5 | np | np | np | np | np | 123.5 |

(a) Received by private and public trading sector waste management businesses.
(b) Excludes waste received at sewage treatment plants, landfills and transfer stations.
(c) Excludes waste not handled by waste management services businesses and waste disposed of at landfills.

The separation and composting of putrescible household, business and garden waste is currently undertaken in secondary waste treatment plants in some cities. These waste factories are operating in Perth, WA; Port Stephens, NSW; Cairns, Qld; Wollongong, NSW and Eastern Creek, NSW (currently under construction). The move to factory sorting has been slow with these plants currently handling less than five per cent of Australia's domestic and commercial waste. The resultant compost is trucked to an accepting agricultural user. This material, when added to the soil, improves soil quality and obviates, at least in part, the need for fertilizer and wetting agents. Crop improvement has been recorded. At this stage in the development of a market to agriculture, the compost has no saleable value and in most cases must be delivered to the farm free of charge. The compost often carries disabilities, such as plastics (usually from plastic bags) and broken glass; the latter making it unacceptable for root crops. Any agricultural area dressed with this compost cannot qualify as an "organic" source due to the possibility of fertilisers

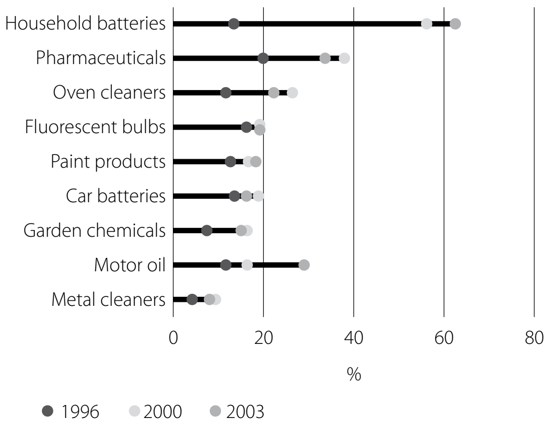
[132] ABS, Waste Management Services, Australia, Australian Bureau of Statistics Cat.No.8698.0, 2002-03.
[133] *ibid*

and chemicals (household, industrial, medical and agricultural) in the original waste.

By far the greatest volume of waste is deemed to be non-hazardous and is destined for composting, recovery or finally landfill. The more hazardous chemical and radioactive wastes should not be ignored. These are comparatively small in volume and require a specialist approach. All developed societies produce a range of toxic wastes, the disposal of which requires special management. The hazardous waste materials disposed by households, as shown in Figure 7.1, illustrates this point.

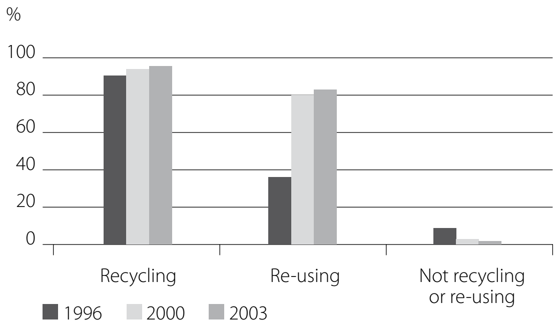
An increase in population will not necessarily increase the range of hazardous wastes and therefore disposal is only a matter of having intent and space, both of which Australia appears to have. Evolution in materials used by society however could expand the range of wastes. Australia will also need to accommodate additional radioactive waste if nuclear power is adopted [134]. Changes in waste management are not dependent on population growth, but more on societal and technical developments.

Figure 7.1 – Hazardous waste materials disposed by households[135]




Source: *Environmental issues: People's views and practices,* 2004

Figure 7.2 – Waste recycling/re-use by households[136]




Source: *Environmental issues: People's views and practices,* 2004

While multi-bin systems are well entrenched in most areas, there are signs in others of one bin collection and factory sorting being adopted. There are both financial and environmental savings in collection with the one bin system but an added cost for sorting and processing. Rate payers carry the cost of waste management and are usually oblivious to that part of the overall rates charged. Offsetting the cost of a more sophisticated waste system is the potential reduction in the volume and cost of landfill and hopefully an improved environment. The collection of one bin versus multi bins is, in itself, a large saving in fuel usage and environmental impact in the collection process. It does however add to the complexity of separation.

The material derived from sorted waste collection or the processing of waste often has little or no net monetary value. Compost has to be delivered free of charge to an accepting farm. At times bales of cardboard, paper and plastics await a willing consumer but finally generate some revenue, although this is usually less than the cost to recover. Recovered metal containers similarly have little or no net value at the point of collection but surely serve for the betterment of the environment and add some revenue from the process.

Glass is manually sorted by colour. It is then crushed and becomes an important component in subsequent glass production. At the point of transfer to a glass plant it has value and is competitive with virgin raw materials. The process of collection and sorting may however need to be subsidised by councils.

The management of wastes is an important health and environmental issue. Some wastes are toxic and can harm living organisms and their disposal is of particular importance. Other wastes, while not

[134] Duncan, I. J., *Dealing with Australia's Nuclear Waste*, ATSE Focus, No.140, March 2006.
[135] ABS, *Environmental Issues: People's Views and Practices*, Australian Bureau of Statistics, Cat.No.4602.0, 2004.
[136] *ibid*

directly toxic, can harm the environment biologically, physically, chemically and aesthetically. Sites that are used to store waste (for example, tips, landfills) can also impact on the environment visually, emit odours and attract vermin. As Australia's economy improves and with developing scientific awareness of the environment, it could be expected that the overall impact of waste disposal will decrease with time.

Additionally there is the discharge of waste through sewage systems. The recovery of nutrients and water from such systems is being applied to agriculture in some areas. Adelaide's sewage strategy allows for the return of such nutrients and water to agriculture and seems to be successful.

The guiding principles of waste management strategies in Australia are represented by the waste minimisation hierarchy – reduce, re-use and recycle. This strategy embraces a life-cycle approach whereby re-US ble and recyclable waste may be used as an alternative to traditional source inputs, not only reducing waste but alleviating pressures on the natural resources. Active programs that encourage the phase-out of plastic bags are evident in many localities. All states and territories have set ambitious waste minimisation goals to meet or exceed national targets. Available information indicates that although waste reduction has occurred, mostly through recycling, the original targets have not been met (Australian State of the Environment Committee 2001).

## 7.3 WASTE RECYCLING AND RE-USE BY HOUSEHOLDS

Recycling generally refers to the use of recovered like materials being used as a secondary source of raw material for further manufacture. The recovery of metals for iron and steel production and copper wire production are traditional. The recovery of plastics and aluminium is a more recent phenomenon but now certainly part of society. With recycling and re-use of glass, iron and aluminium, less energy is consumed, less virgin material is needed, potentially less damage is caused to the environment and landfill space is saved.

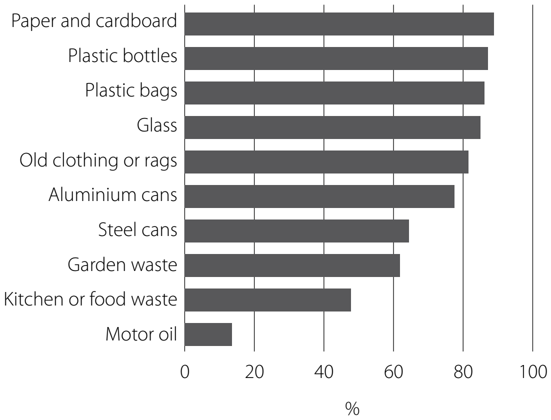
Almost all households in Australia engage in some form of recycling and/or re-use of waste, and the level of participation continues to increase over time. This may be attributed to the success of kerbside collection programs of various state governments and councils that deal with domestic and commercial wastes, garden refuse, plastic, paper, cardboard and glass.

In March 2003 about 95 per cent of Australian households recycled waste, 83 per cent re-used waste, while Figure 7.2 shows only two per cent did not recycle or re-use at all . Figure 7.3 shows the proportions of items recycled or re-used for households range from approximately 90 percent for paper to as low as 10 per cent for motor oil. Households in Victoria, the Australian Capital Territory and South Australia had the highest rates (99 per cent) of recycling and/or re-using waste. The percentage of households not recycling was highest in the Northern Territory (seven per cent of households). The methods used for recycling by households are shown in Figure 7.4.

From all processes and consumption, waste is inevitable. Wastes can be gaseous, liquid or solid and invariably are disposed of into the biosphere. There are several countervailing elements. Society tends to produce more waste per capita, populations grow but re-use and recycling is becoming more extensive. Separation and use of compostible materials will also reduce the amount for land-fill. As there are many examples of cities larger that Sydney in countries smaller that New South Wales not being restricted for growth, it can be assumed that waste disposal will not be a constraint on the growth of Australia's population, nor the population of any one place.

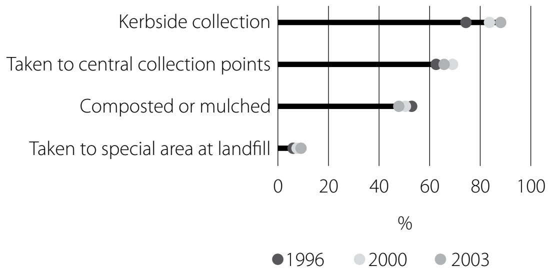
Re-use of waste can save material, energy and space. At times the saving of space carries such a bonus that the re-use of material can have a higher comparative cost. Take for example the demolition of a reinforced concrete structure, its break-up, separation of concrete chips from all reinforcing steel and the re-use, recycling of the components. The purchase of new steel and concrete would probably be less expensive but the reduction in waste carries a space and environmental bonus. Re-use and recycling is tempered by environmental and economic reality. If there is more environmental impact arising from the process of waste collection, processing and re-use than arises from the use of new material, then the process is questionable, save for the saving of space.

Figure 7.3 – Items recycled/re-used by households, March 2003[137]




Source: ***Environmental issues: People's views and practices,*** **2004**

Figure 7.4 – Methods of recycling by households[138]




Source: ***Environmental issues: People's views and practices,*** **2004**

## 7.4 THE 'DERIVED LAWS' OF WASTE DISPOSAL

Waste can change biologically, physically and chemically with the passage of time. Of course, all of the laws of nature apply to waste disposal as they do to all other matters. It therefore seems that four derivatives of these laws are relevant[134]:

1. All processes produce energy and/or material waste.
2. All waste becomes part of the Earth, particularly part of the biosphere, that part of air, water and rock that supports life.
3. All wastes change with time, and then usually dilute and disperse without becoming a hazard to life or environment.
4. The management of waste is not just a matter of finding a place to put it. It also requires a time trap to allow it to change from being potentially hazardous to benign.

With awareness of these laws and the necessary resources, developed society should be able to sustainably manage its waste.

## 7.5 CONCLUSION

Australians generate solid waste at a high rate, compared with most other OECD countries. Technologies and processes to avoid, reduce and recover waste are generally not used as extensively in Australia as in some other OECD countries, although there are signs of greater use. The economics of waste collection, processing and disposal are not driven solely by the value of material recovered from the waste stream, but largely by the minimisation of the space and costs of landfill.

The elements in waste disposal are moving from the resolution of just finding a place to put it, to a matter of quality, environment and economics. As Australia has the space and resources, there is no reason to limit the management philosophy short of a sustainable and economic system – even for a growing population.

[137] ABS, *Environmental Issues: People's Views and Practices*, Australian Bureau of Statistics, Cat.No.4602.0, 2004.
[138] *ibid*

# ADDENDUM Waste Management – Future Policy and Planning Issues

There are significant policy and associated planning issues relevant to the future management of waste. Such issues were the subject of a recent Productivity Commission inquiry [139] into waste generation and resource efficiency. The focus was on solid, non-hazardous wastes including: municipal waste; commercial and industrial waste; and construction and demolition waste.

In essence, the Commission was asked to provide advice on strategies to address market failures (including externalities) associated with the generation and disposal of waste.

[Externalities are the unaccounted costs and benefits of an activity that are experienced by people or organisations other than those directly involved in that activity. For example, a landfill may leak, causing damage (a negative externality) to a valued environment.]

The Commission's charter and the terms of reference required that a community-wide approach be taken which considered all of the financial, environmental and social costs and benefits of different strategies. This approach necessarily challenges notions of waste being inherently bad and recycling being inherently good. Policies that minimise waste are not costless and more recycling is not always a better thing. As society tries to recycle more and more waste, diminishing returns set in, costs rise, and the potential for perverse environmental outcomes increases.

The Commission concluded that future waste management policy should primarily be focused on reducing social and environmental risks from waste collection and disposal to acceptable levels. The Commission considers that policy makers have become distracted by the pursuit of other, waste-hierarchy inspired, objectives – such as minimising waste and conserving resources – and given insufficient regard to whether their interventions would actually lead to net benefits to the community.

Directly addressing relevant market failures and distortions throughout product life cycles will assist markets to determine the right balance between waste avoidance, resource recovery and disposal. Waste management policy can play its role in this process, but it should not be used to indirectly address upstream environmental and social issues. Many of these impacts may warrant intervention, but these would be (and often already are) much more effectively and efficiently addressed using direct policy instruments.

Unfortunately, much waste management policy in Australia has been initiated with insufficient consideration of all of the likely financial, environmental and social costs and benefits. Waste disposal problems, and community support for the remedies proffered, are too often simply asserted, rather than demonstrated. Many interventions have certainly gone too far. In particular, landfill levies, direct and indirect subsidies for alternative waste technology facilities, and some extended producer liability and product liability schemes, are not justified.

The Commission advocated reforms that will help achieve a more appropriate balance between waste avoidance, resource recovery and disposal by, among other things:

- requiring a more rigorous approach to identifying environmental problems;
- tightening regulatory compliance; and
- reinforcing the roles of prices and awareness raising in assisting the community to make more informed choices.

As in other areas of environmental policy, the way forward is not always intuitively obvious. But what is clear is that simple rules such as "recycling is good, more is better", are no substitute for sound policy-making procedures. Policy makers and community attitudes need to be guided by open and rigorous analysis of costs, benefits and risks, if waste management policy is to best serve the community.

[139] Productivity Commission, *Waste Management*, Productivity Commission Inquiry, Australian Government, October, 2006.

# CHAPTER 8
# Infrastructure

## SYNOPSIS

While significant investments will need to be made in Australia's transport, water, energy, communications and social infrastructure over the next several decades, with appropriate data and incentives guiding public and private sector decisions there is little concern that Australia will be able to provide the infrastructure required to support a population of some 30 million by the year 2050.

Other chapters of this report focus on individual sectors of the economy that are major users of Australia's physical infrastructure assets. The work in this chapter draws on this sectoral work, together with forecasts for economic growth and other research, and gives implications of expected population, economic and technical developments for Australia's future requirements for major infrastructure.

In assessing the requirements for investment and the ability of Australia to meet these needs, factors such as were considered for each type of infrastructure – population growth, economic growth, technological change in the types of infrastructure and other extraneous factors, including changes in government policy.

In order to derive a snapshot of how the Australian economy may look in 2050, and in turn to understand how economic growth will also impact on infrastructure needs, the Centre of Policy Studies at Monash University used the Monash Multi-Regional Forecasting (MMRF) model to estimate economic growth to 2050. The Monash projections estimate that by 2050 compared to 2005:

- real GDP would be nearly 3.5 times higher;
- real private consumption would be 3.4 times higher; and
- per capita real GDP would be almost 2.5 times higher.

These are very substantial increases and mean that major investment in new infrastructure and brownfields expansions to existing assets will be required in the decades to 2050. On its own, the fact that the economy could be 3.5 times larger than now suggests that a very significant expansion in infrastructure will be required. This, together with the fact that the Australian population will be much older than it is today, suggests that the pattern of investment in infrastructure will also change.

An additional consideration demonstrated by the modelling is that the growth in the Australian economy is not projected to be uniform. Western Australia and Queensland are likely to be the fastest-growing states, and much of Australia's growth will be concentrated in its metropolitan centres.

Drawing on the MMRF projections and work presented in the other chapters, the outlook for each infrastructure category – water, transport, energy, communications and social – is provided. Key findings included:

- **Transport infrastructure** – While road transport will remain the dominant mode of transport for people and freight, policy reform can ensure that there is efficient uptake of rail for the transport of goods and passengers.
- **Energy infrastructure** – Greenhouse policies will be the greatest factor shaping energy infrastructure to 2050. Nuclear energy and renewables will likely play a major role in base-load generation.
- **Water infrastructure** – The key priority of water infrastructure policies will be to ensure that Australia's vast water potential is accessible to the regions in which Australia's population will live in 2050 and that all costs of consumption are included in the price for water.
- **Social infrastructure** – Substantial investment in health, education and aged care infrastructure will be required to 2050, though technological change in medicine will play a large role in the lifestyles and opportunities available to Australia's ageing population.

- **Communications infrastructure** – Growth in demand for communications will be non-linear, and the nature of the investment will rely significantly on technological changes that are difficult to predict. Communications infrastructure, and the cost of access by metropolitan and regional homes and businesses, will shape the pattern of population settlements and influence the competitiveness of Australian businesses in global supply chains.

Overarching all categories, this chapter concludes that the major issue for the future is to ensure that investment in infrastructure is timely and efficient. Governments will play a critical role in this.

First, state and Commonwealth governments can ensure that appropriate signals reach investors in a timely way. This is particularly important for organisations scoping investments in infrastructure assets that require large upfront capital outlays and also have an economic life of up to 50 years. Secondly, despite the growth of private investment and public private partnerships, it is inevitable that governments will continue to be investors in infrastructure themselves, given the large public good characteristics of these assets. In some cases this may require the government assuming greater levels of debt than is currently the case.

In the interests of efficiency, decisions on investment priorities in the main will need to be made on a national basis. This implies a much greater role for the Council of Australian Governments in the future.

## 8.1 THE IMPORTANCE OF INFRASTRUCTURE

The previous chapters of this report focus on individual sectors of the economy that are major users of Australia's physical infrastructure assets. The purpose of this chapter is to draw on this sectoral work, together with other research, to discuss the implications for infrastructure of potential population, economic and technical developments in Australia.

Clearly, Australia will be a very different country in 2050 compared with what it is today. Its population will be nearly 50 per cent larger and much wealthier [140], with living standards potentially twice as high as today. The community's requirements for energy, transport and telecoms will be far greater than today, but some industries will grow considerably faster than others. While breakthroughs in technology will no doubt occur, they are impossible to forecast; nevertheless it seems safe to assume that continuing developments in information technology will continue to require a growing share of the investment "cake" and to change in a fundamental sense the way in which we live. Other unknowns, such as the way in which the world addresses the threat of climate change, will also have an influence on future investment in infrastructure that is difficult to predict.

### 8.1.1 Infrastructure definition

It is fashionable to discuss infrastructure in two dimensions: hard and soft. Soft infrastructure refers to such factors as the quality of a nation's intellectual capital or labour force. This report is concerned with hard infrastructure – ie: assets such as roads, airports, water and energy infrastructure. This chapter is also concerned with hard infrastructure. In addition to the sectors covered in the rest of the report, this chapter also analyses the need for capital assets in the health and education sectors. There is also some consideration of telecoms infrastructure, which is will be so important in the future that it cannot be ignored.

### 8.1.2 Why is infrastructure important?

The quality of a nation's infrastructure provides a good indication of the living standards of the community. The population of a wealthy nation like the US, for example, would not tolerate the quality of the roads, rail services and telephone facilities that are found in many Asian countries. On the other hand, there is a chicken-and-egg issue here to the extent that the quality of its physical infrastructure also plays a critical role in a nation's ability to attract new investment and spur economic productivity. The ability to attract new investment is essential in underpinning living standards in the future. In assessing

[140] In this section 'wealth' is measured by GDP per capita. The growth of this measure is interpreted to indicate a rise in living standards.

different possible locations for new and footloose investment projects, a major factor influencing the decision is the quality of a country's hard and soft infrastructure. This encompasses not merely the ability to get product to market, but the availability of intellectual capital and the quality of life generally.

## 8.2 ISSUES DETERMINING INFRASTRUCTURE INVESTMENT TO 2050

### 8.2.1 Determinants of infrastructure investment

The requirement for investment in infrastructure to 2050 will depend on a number of factors, many of which are difficult to predict. These include:

- Population growth. Other things being equal, the larger the population, the greater the requirement for physical infrastructure. Importantly, the rate of growth of the population is also an important consideration in determining the required level of investment in infrastructural assets. Changes in the composition of the population are also important: older people do not have the same requirements for physical infrastructure as younger ones.
- Economic growth. Perhaps the most important factor determining future investment in infrastructure is the growth in the economy generally. The demand for services such as transportation and energy is closely related to aggregate demand in the economy generally. The pattern of demand will also change as incomes grow. For example, as people become wealthier they tend to spend more on healthcare, tourism and transportation.
- Technological change. Changes in technology will also have an impact on infrastructure investment. For example, cost-effective wireless technology may supersede the trend towards an information superhighway based on fibre optic cable.
- Extraneous factors. There are a number of other factors that may have a major impact on infrastructure investment. The most important of these is the global policy response to the threat of climate change. If Australia participates in global action drastically to reduce greenhouse gas emissions by 2050, for example, this would have a substantial impact on the pattern of investment in the energy and transport sectors.

These issues are discussed below.

### 8.2.2 The Australian economy and population in 2050

In order to derive a snapshot of how the Australian economy may look in 2050, the Centre of Policy Studies (CoPS) at Monash University used one of their computable general equilibrium models to run a "business-as-usual" or "base case" projection of economic and demographic trends. The Monash Multi-Regional Forecasting (MMRF) model that was used for this task is a dynamic economic model of the Australian economy that is widely regarded as the most comprehensive and credible available.

Before discussing the results of this work, it is important to note some important assumptions underlying the modelling. First of all, the rate of technological change, by industry, is assumed to be similar to that of the recent past. The model does not attempt to project any breakthroughs in any technology, nor the growth of "new" industries that are not currently present in the Australian economy. Secondly, the relative rate of growth of the various industries contained in the model is assumed to continue at a similar rate as in the recent past. The overall rate of growth in the Australian economy is projected to be lower than in the past because of the impact of the ageing population. A brief consideration of these assumptions is sufficient to show that the results of economic modelling to 2050 can be highly sensitive to these assumptions. For these reasons most modellers are reluctant to provide projections over such a long period of time. Nevertheless, such estimates are useful because they are the best we can produce based on our current state of knowledge.

The projections support the view that there will be massive change in the Australian economy between now and 2050. Much of this is driven by population growth. As discussed in Chapter 2, report contemplates potential population growth in Australia of 31.4 million by 2050, as projected by McDonald and Kippen. For this chapter, the aim was to understand the link between population and economic growth. The MMRF-Green computable general equilibrium model employed to do this was built using slightly different assumptions about birth rates, life expectances and migration patterns. In total, the MMRF-Green model projects the Australian population in 2050 to be 28.8 million. The projections of this model, which is similarly based on ABS and other population forecasts, was judged to be consistent with the assumptions made in the rest of this report [141].

The headline projections are presented here while the results relating to particular sectors of the economy are shown later in the Chapter. With large population growth to 2050 expected, and given the other assumptions discussed above, by 2050 compared to 2005:

- real GDP would be nearly 3.5 times higher;
- real private consumption would be 3.4 times higher; and
- per capita real GDP would be almost 2.5 times higher [142].

These are very substantial increases and mean that major investment in new infrastructure and brownfields expansions to existing assets will be required in the decades to 2050. On its own, the fact that the economy could be 3.5 times larger than now suggests a very significant expansion in infrastructure will be required. Within that figure, the projection that people will be over twice as wealthy as they are now also suggests that different classes of infrastructure will be particularly important. Goods and services with a high income elasticity of demand include tourism, health care, private education, motor vehicles and private aircraft. This, together with the fact that the Australian population will be much older than it is today, suggests that the pattern of investment in infrastructure will also change.

An additional consideration is that the growth in the Australian economy is not projected to be uniform. Western Australia and Queensland are likely to be the fastest-growing states. Despite the South Australian Government's target of a two million population for the state by 2050, most projections suggest a figure of about 1.5 million, or little different from the current figure. This imbalance in growth between regions means that investment will need to be considerably higher in certain states and sub-state regions than in others.

### 8.2.3 Technological change

Clearly, technology will have a major influence on future infrastructure investment. That said, technological change and the rate at which it is adopted are notoriously difficult to forecast. In the transport sector, for example, we can predict that the future passenger car market will see a gradual move away from petrol powered vehicles and towards diesels, hybrids and ultimately fuel cells. Such vehicles will still need roads, however, so the implications for infrastructure requirements are far from clear. Technological change in the stationary energy sector is currently being driven by government-subsidised research programs into more greenhouse-friendly technologies, mainly focusing on cleaner coal and geosequestration of $CO_2$. Whether or not these technologies will turn out to be more cost-efficient than currently proven processes, such as nuclear power (which is also benefiting from cost-reducing technological change), is an open question.

[141] Chapter 2 of this report outlines population projections for Australia to 2051 as made in *Projections of Australia's Future Population* by McDonald, P. and Kippen, R. By this analysis, Australia's population is assumed to grow to 31.4 million by 2050. McDonald and Kippen also present a range of population projections, with the 31.4 million representing the 'high growth' case. The medium growth case projected Australia's population to grow to 26.4 million by 2050.
Projections are highly sensitive to assumptions about birth rates, overseas migration rates and life expectancies. The CoPS model projections are based on assumptions built into the ABS projections and Intergenerational Report. ABS projections for Series A, B and C are included as footnotes to the McDonald and Kippen projections.
The CoPS model estimates Australia's population to be 28.8 million by 2050. This is within 8.2 per cent of the McDonald-Kippen high growth case projections. It is also the average of the high and medium case projections. Given the length of time considered and the sensitivity of population projections, it was judged that these projections were sufficiently similar to employ the CoPS modelling results in this chapter.
Variations in the total population of less than 10 per cent, if geographically uniform, are unlikely to result in a significantly different implication for infrastructure needs. The distribution of the variation could impact on infrastructure outcomes, however, if say the two alternate projections expected different outcomes for metropolitan areas. As this is not the case the projections are assumed to be aligned.
[142] Projections of the Australian economy to 2050 provided by the Centre of Policy Studies, Monash University, to Insight Economics, March 2006.

### 8.2.4 Other factors

A range of extraneous factors, some of them almost impossible to predict at this stage, may come into play before 2050. Many of these are likely to be policy induced. For example, pressure from increased population and congestion may become a major issue in cities such as Sydney, Melbourne and possibly Brisbane. One possible consequence of this could see Australia moving to implement a population and regional development policy. This may require a skewing of future infrastructure spending towards other centres such as Adelaide, Newcastle, Geelong or other inland cities. In the next few decades it seems almost certain that increased traffic in a number of urban centres may lead to the imposition of congestion charges and an increased use of public transport. Clearly this also would influence spending on infrastructure.

As discussed in Chapter 3, the main area of change that can be foreseen is in regard to greenhouse policy. If, for example, the Australian Government participated in a global effort to stabilise concentrations of greenhouse gases in the atmosphere, this would require a very significant reduction in greenhouse gas emissions by 2050. This will have both macro and micro effects. At the macro level, the policies required to reduce emissions would almost certainly have a dampening impact on economic growth, suggesting that the overall required level of investment in infrastructure would be lower than it otherwise would have been. At the micro level, there would be substantial impacts on certain sectors, particularly stationary energy and transport. In the stationary energy sector, for example, we may turn to nuclear power for base-load electricity generation, which may in turn require major investment in both these plants and transmission systems to deliver electricity from them.

## 8.3 TRANSPORT INFRASTRUCTURE TO 2050

Efficient transport infrastructure will be necessary to underpin the Australian economy's continuing productivity and to ensure its competitiveness against other nations [143]. Globalisation will continue to increase the demands on our national transport networks.

### 8.3.1 Population and economic growth

Growth in Australia's population and economy will increase the need for transport capacity in through both an increase in the number of people and the volume of goods requiring transport.

An increase in the number of people will grow demand for urban and arterial roads. Several factors would indicate that cars will continue to be the dominant mode of private travel to 2050 [144]. First, the wealth of Australians is expected to increase. GDP per capita in Australia today is estimated to be around $40,500 [145]. In 2050, CoPS modelling shows that GDP per capita is expected to grow to roughly $100,300 in real terms, representing a 2.5 per cent increase in living standards for Australians. Historically, improvements in living standards have been associated with increased car dependence. Second, expected growth in urban housing prices will drive greater urban decentralisation. Third, growth in the numbers of persons buying cars will drive greater economies of scale, which will precipitate a reduction in the costs of purchasing cars. With greater wealth, potentially greater need (longer distances needing to be travelled from home to work) and greater ability (through lower car costs), it is expected that the number of cars and passenger miles travelled will continue to grow strongly. Already there is some indication that Australian roads need increased investment to cope with demand. Analysis by the Bureau for Transport and Regional Economics (BTRE), the Business Council, the Committee for

[143] Many studies have been completed to date that show strong growth in private sector output as a result of transport investments. One study has shown that a one per cent increase in road infrastructure increases private sector factor productivity by 0.27 per cent. This same study also showed that an additional $1 billion investment in roads would stimulate GDP and support job creation. See Allen Consulting Group, *Investing in Australia's Economic Infrastructure*, report to the Victorian Government, 2004.

[144] Cars are the dominant mode of travel in Australia, accounting for over 80 per cent of kilometres travelled. Moreover, private vehicles now account for 93 per cent of urban passenger travel. See the Auslink, *AusLink White Paper*, Commonwealth Government; Department of Transport and Regional Services, Canberra, 2004, p.8.

[145] CoPS modelling. This is consistent with ABS data. In 2004-05 the average GDP per capita for Australia was $44,171, Cat.No.5220.

Economic Development in Australia and Engineers Australia have all indicated that underinvestment in road infrastructure is and will continue to contribute to costly urban congestion [146]. Given the expected dominance of road transport over the decades to 2050, road infrastructure planning needs to be made a priority by governments.

Although cars will likely remain the dominant mode of transport, demand for public transport will also increase [147]. As congestion in cities rises, which may be accompanied by the introduction of congestion charges and higher costs for parking, more and more persons will turn to public transport options. Similarly, increases in network coverage could lead to higher rates of public transport uptake.

A growing population with rising GDP per capita will also increase demands for air transport. An increase in international travellers would be expected to propel growth in demand for air transport. This could be particularly true if "open skies" reforms are made to rules governing Australian air freedom rights. Existing forecasting analyses project passenger traffic to grow strongly over the short and long run. BTRE forecasts passenger traffic at major airports to more than double by 2020. Trends of faster-than-GDP-growth rates in demand for air transport services are expected to hold constant in the long run to 2050.

The growth in population and the economy will also increase the volume of freight transported by land [148]. According to Auslink and BTRE projections [149], the total land freight task is expected to double over the next 20 years, and will continue to grow at a faster rate than GDP growth.

Holding all else constant, it is expected that rail's share of the freight task will continue its recent decline and road will continue its dominance into the future [150]. This is in part due to the quality of the infrastructure: the Business Council of Australia has cited poor service as a major factor. Similarly, Engineers Australia has given rail a "C" grading, indicating that the infrastructure stock is insufficient to support current demands and future growth [151]. By Engineers Australia's methodology, a grade of "C" indicates that major investments will need to be made to rail infrastructure to enable it to be fit for its current and anticipated purpose. The BTRE projects rail's share in the interstate non-bulk freight market to drop to just a little more than 20 per cent by 2020 [152]. That said – the total amount of freight haulage is increasing in absolute terms. These studies are also limited in that they cannot predict potential technological changes in rail transport, reforms to pricing or the potential future cost of carbon.

CoPS modelling projects the rail transport sector, which includes the output of all rail infrastructure and service providers, to expand by 3.6 times current levels, which is just ahead of the growth in the

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[146] In its *2005 Australian Infrastructure Report Card*, Engineers Australia assessed Australian roads to be 'C grade' – that is, major changes will be required to enable the infrastructure to be fit for its current and anticipated purposes. While this analysis does not take into consideration the economics of infrastructure investment, it is useful for identifying current and potential weaknesses in Australian infrastructure. See Engineers Australia, *2005 Australian Infrastructure Report Card*, and Engineers Australia, *2001 Australian Infrastructure Report Card*. See also Port Jackson Partners Limited, *Reforming and Restoring Australia's Infrastructure*, prepared for the Business Council of Australia; Bureau of Transport and Regional Economics, 2005, *Predicting Traffic Growth Between Australian Cities*, Staff Paper; Infrastructure Planning Council, 2004, *Final Report Parts A and B*, Victorian Government, 2002.

[147] In terms of passenger demand, the rail sector achieved a transport task of 594.9 million journeys, or 11.2 billion passenger kilometres. ARA, *Australian Rail Industry Report 2003*, Australasian Railway Association, Canberra, 2004.

[148] Rail freight is generally comprised of bulk commodity movements across long distances from the point of extraction or production location to seaports or processing plants. According to the ABS, rail freight travelled 164.4 billion tonne-kilometres in the 12 months ended 30 June 2003, an increase of 7.4 per cent (11.3 billion) over the 153.1 billion tonne-kilometres travelled in the year ended 30 June 2002. The top five bulk commodities shipped on a tonnes basis were coal, ore, grain, alumina and bauxite. On a tonne-kilometre basis, the top five bulk commodities were ore, coal, grain, steel and nickel. ABS, *Rail Freight Movements, Australia,* Summary, Cat.No. 9220.0.55.001, 2005.

[149] See: Auslink, *Auslink White Paper*, Commonwealth Government, Department of Transport and Regional Services, Canberra; and Bureau of Transport and Regional Economics, 2003, *Freight Between Australian Capital Cities 1972-2001*, Information Sheet 22, 2004.

[150] In 1972 rail had a 70 per cent share of the land transport task to road's 30 per cent share; in 2006 the reverse is true. Analysis reaching the conclusion that rail's share of the freight task will remain in decline can be found in reports by Port Jackson Partners Limited (2005), the Bureau of Transport and Regional Economics (2003), the Infrastructure Planning Council (2002), and CEDA (2005). See Port Jackson Partners Limited, *Reforming and Restoring Australia's Infrastructure*, prepared for the Business Council of Australia, 2005; Department of Transport and Regional Services, Bureau of Transport and Regional Economics, *Predicting Traffic Growth Between Australian Cities*, Staff Paper, Commonwealth Government, 2004; Infrastructure Planning Council, Victorian Government, 2002.

[151] Engineers Australia, *2005 Australian Infrastructure Report Card*, Engineers Australia, Canberra, 2005.

[152] Department of Transport and Regional Services, *Predicting Traffic Growth Between Australian Cities*, Staff Paper, Bureau of Transport and Regional Economics, Canberra, 2004.

broader economy. Road transport is expected to see similar total growth, but from a larger base. CoPS modelling projects demand for road transport, which includes the output of all rail infrastructure and service providers, to increase by 3.4 times current levels by 2050.

World economic growth will also increase demand for speciality goods that are largely transported by air, including agricultural goods that may only be produced in Australia. Shifts to just-in-time delivery, greater specialisation of production, increased differentiation of consumer tastes and falling freight prices are also likely to strongly grow air transport demand. Airports will stand as a critical link in the supply chain for many exporting Australian industries, including tourism [153]. CoPS projects the total demand for air transport services to increase 3.7 times current levels by 2050. This will result in large investments in air transport infrastructure, which will be funded in the main by the private sector.

Ports will also represent important national assets in the future [154]. Strong economic growth in Asia is expected to create a long period of demand for Australian commodities, most of which will be exported by sea. Increases in vessel sizes will create continual needs for channel deepening and intermodal terminal expansion [155]. Investments in bulk commodity [156] port infrastructure will be funded largely by the private sector, and planning for future infrastructure needs will also reside primarily with industry. Container port [157] infrastructure will also need to be expanded. This will require government involvement and planning, especially with regard to intermodal expansions that may begin to encroach on urban development areas. Engineers Australia graded Australia's container port infrastructure with a "C+" in 2005, citing the threat of urban encroachment as a potential hindrance on the expansion of port infrastructure to keep pace with future demand. CoPS modelling projects demand for sea transport services to double by 2050. This is reflective of the long-run growth rates observed for the sector. It may, however, underestimate the increase in demand for sea transport that could result from the industrialisation of regional economies.

### 8.3.2 Technological change

It is expected that several new fuel technologies will emerge by 2050. Due to the possibility of future reductions in the availability of oil and the potential for a carbon price to be applied to the transport sector, the costs of vehicles powered by fossil fuels is expected to rise. It is likely that this will drive Australian consumers to increasingly seek out vehicles powered by alternative fuels. The recent introduction and rising uptake of hybrid vehicles indicates that there is an increasing market for environmentally friendly alternative-fuel vehicles. It is likely that a substantial proportion of vehicles in 2050 will run on a non-fossil fuel based power source.

Fast rail technologies are likely to have an impact on the transport mix by 2050. New technologies in heavy rail could significantly alter the competition between road, rail and air transport, making rail a more attractive option for businesses and consumers. For example, new magnetic levitation rail investments are being scoped across the US. Technological change that could reduce the costs of these high-speed trains would likely lead to an increase in their economic feasibility and use in Australia. The economic investment in such a technology in Australia would hinge on having a sufficiently large customer base. Planning for the associated urban and corridor development to underpin investment in these technologies will be essential.

[153] Although air freight accounts for less than one per cent of Australian exports of goods by volume, air freight represents approximately 20 per cent of Australian exports by value. Goods shipped via air freight are typically 'low volume'-'high value' products, such as express parcels and medical supplies as well as expanding niche markets such as live seafood and flower exports.

[154] Sea freight represents approximately 99 per cent of exported goods by volume and nearly 80 per cent of the value of exported goods and services on average since 2000. In 2002-03, 712.0 million tonnes of cargo moved across Australian wharves, with approximately 76 per cent of this representing international exports, and approximately 178,258 international sea passengers cleared Australian customs. See Department of Transport and Regional Services Bureau of Transport and Regional Economics, 2005, *Shipping Statistics*, accessed at www.btre.gov.au/statistics/statsindex.aspx on 9 May 2005.

[155] AusLink, *AusLink White Paper 2004*, Department of Transport and Regional Services, Commonwealth Government, Canberra, 2004, p.6.

[156] 'Bulk commodity' ports have one or two bulk commodity operations in export-oriented industries such as coal and mineral ores. These ports provide little, if any general cargo facilities for the general community or industrial development beyond the bulk commodities.

[157] 'Container' ports service general cargo, container cargo, bulk cargo, recreational and passenger vehicles. Major integrated ports include Adelaide, Brisbane, Fremantle, Melbourne, and Sydney. These five ports account for approximately 90 per cent of Australia's container traffic.

### 8.3.3 Extraneous factors

The major obstacle to efficient investments in transport infrastructure, particularly land transport infrastructure, has been the overlapping of responsibility between local, state and Commonwealth authorities [158]. According to the Australian Transport Council, there is also insufficient data on local road requirements and inconsistent appraisal methods for investments across transport modes [159]. AusLink and COAG's Competition and Infrastructure Reform processes represent major opportunities to ensure priorities are coordinated across jurisdictions and investments made in the most cost-effective assets.

Urban development planning will clearly be a significant factor in determining the level and direction of investment of economic transport infrastructure. As a country with a relatively small population and a large geographical area, strategic planning needs to be developed to ensure that Australia can keep pace with the introduction of new technologies that will be rolled out in Europe and the US. To the extent that population density can be sufficiently achieved, new investments and upgrades to existing transport network infrastructure should aim to take advantage of new technologies. There will a need for substantial investment in Australia's rail network if it is to play a greater role in the land transport freight task. While the private sector may contribute substantially to this, considerable public investment will also be required.

Pricing differentials between road and rail needs to be reformed to promote efficient investments in infrastructure over the years to 2050. The persistence of current pricing distortions [160] may lead to more freight being transported by road than rail than would be the case in a neutral pricing environment. If these pricing issues were subject to reform, it is likely that there would be greater uptake of and relative investment in rail infrastructure by 2050.

Another impediment to efficient investment in rail may be found in a diversity of third-party access regulation. The need for access regulation of rail is not altogether clear since rail transport clearly competes with roads. Problems come at the margin, where a particular category of freight is unsuited to one mode or the other. The Australian Rail Track Corporation (ARTC) sells access to the majority of interstate rail networks, which it either owns or leases from state governments. All states, with the exception of Tasmania, have explicit rail access regimes covering parts of their intrastate networks. There has been a recent trend to consolidate regulatory responsibilities across jurisdictions, in order to streamline applications and ultimately reduce the cost of transporting by rail.

Urban road congestion is expected to become an increasing problem, due to increasing numbers of people, increasing car dependency, and increasing volumes of freight being transported. Congestion will need to be managed through investments in road infrastructure networks, investments in public transport alternatives, and investments in technological infrastructure alternatives, such as Intelligent Transport Systems that re-route travellers to prevent congestion. The ability to re-route travellers to either other forms of transport or other routes, however, relies on alternatives being available. Congestion charges will almost certainly apply in Australia's major cities sometime in the next two decades, as they already do in some overseas conurbations such as London and Singapore.

Air transport infrastructure will be affected by the future process by which air freedom rights are negotiated. To the extent that air freedom rights restrict capacity expansion or access between countries, this could serve as a future infrastructure bottleneck on exports of goods and services. This may reduce the stock of air transport infrastructure by 2050. Conversely, "open skies" reforms to air freedom rights would see an increase in demand for services and the roll-out of air transport infrastructure.

[158] AusLink, *AusLink White Paper 2004*, Department of Transport and Regional Services, Commonwealth Government Canberra, 2004.

[159] Australian Transport Council, *National Transport Data Framework*, National Transport Data Working Group, Report to Commonwealth Government, November 2004.

[160] Currently road transport operators, particularly the heaviest, longest travelling users of roads, are undercharged relative to their use of the infrastructure. Rail is also at a competitive disadvantage because rail transport operators are required to pay a charge for the sunk capital. Road transport prices also do not account for carbon costs. Road transport in 2001 accounted for 12.6 per cent of Australia's total greenhouse gas emissions, while rail accounted for only 0.3 per cent of total emissions in Australia. See AusLink, *AusLink White Paper*, Department of Transport and Regional Services, Commonwealth Government, Canberra, 2004.

As discussed in Chapter 3, climate change will necessitate investments in infrastructure capacity to withstand more severe weather events. Coastal transport infrastructure is of particular concern. Design standards for infrastructure exposed to higher sea levels and more frequent extreme storms will need to be reviewed to ensure these roads, bridges, ports and intermodal terminals will be able to withstand these events.

### 8.3.4 Overall impact to 2050

In its path to 2050, Australia will see road transport remain the dominant mode of transporting persons and goods. It is expected that there will be increased bottlenecks in the rural road infrastructure. The forecast growth in road freight, holding all else constant, would have important implications for road infrastructure investment. If road's continued dominance of the freight task increases to 2050 in line with BTRE base case projections, this would imply a 195 per cent increase in the number of inter-capital freight truck journeys and a 180 per cent increase in articulated truck travel in metropolitan areas. More road capacity will be required and pavements will need to be stronger than in the past to withstand the more frequent and heavier loads being transported through and between cities [161]. Australia will need to support large investments in the eastern corridors where bottlenecks will otherwise persist and increase. Governments will also need to strategically invest in alternative transport in urban areas where congestion and bottlenecks will remain large problems if current infrastructure levels are not improved.

An efficient and extensive public transport network will substantially reduce the costs associated with road congestion. The provision of extensive heavy and light rail public transport to the outer suburban areas would encourage uptake of public transport, as network coverage is one of the key determinants of levels of its usage [162]. This said, such investment may prove cost prohibitive. Urban development policies, such as Melbourne 2030, will be necessary to provide for cost-effective investments in alternative transport. Similarly, road use would have to be priced accordingly to reduce car usage.

Significant investments in intermodal infrastructure, as is envisioned by the Melbourne Port@l Strategy, for example, will need to be made in each city to ensure that congestion at these terminals in 2050 does not frustrate economic development [163]. Corridor planning will also be a requisite for efficient infrastructure investment. As can be seen in Table 8.1 of BTRE estimates [164] for bulk freight movements by corridor by mode, freight movements by road through the Melbourne-Sydney-Brisbane corridor are expected to grow strongly in the future.

Table 8.1– Bulk Freight Movements by Corridor Mode

| Corridor | Road | Rail | Coastal Shipping | Air | All Modes |
|---|---|---|---|---|---|
| | Average annual growth (per cent per annum) | | | | |
| Sydney – Melbourne | 3.5 | 0.3 | 0.7 | 3.7 | 2.6 |
| Sydney – Canberra | 3.1 | 1.1 | na | 1.9 | 2.9 |
| Sydney – Brisbane | 3.9 | 0.5 | 7.0 | 4.0 | 3.7 |
| Sydney – Adelaide | 2.9 | 0.0 | 1.6 | 3.4 | 2.6 |
| Melbourne – Adelaide | 3.8 | 0.6 | 1.2 | 4.0 | 2.6 |
| Melbourne – Brisbane | 3.2 | 3.1 | 0.6 | 3.3 | 2.7 |
| Brisbane – Darwin | 3.4 | na | 1.6 | 4.4 | 3.2 |
| Adelaide – Perth | 1.8 | 3.0 | 1.5 | 1.4 | 2.5 |

161 Port Jackson Partners Limited, *Reforming and Restoring Australia's Infrastructure*, prepared for the Business Council of Australia, 2005.
162 *Infrastructure Planning Council, Final Report*, Victorian Government, August 2004.
163 The Business Council of Australia, the Committee for Economic Development of Australia, the Minerals Council of Australia and the Productivity Commission, have all called for better intermodal planning. Intermodal terminals are where freight or passengers are moved from one transport mode to another, such as from rail to road, air to rail, or sea to rail. Whole of corridor or gateway planning will be key to ensure efficient intermodal transfer of goods.
164 BTRE, *Demand Projections for AusLink Non-Urban Corridors*, Working Paper 66, Department of Transport and Regional Services, Bureau of Transport and Regional Economics, March 2006.

| | | | | | |
|---|---|---|---|---|---|
| Adelaide – Darwin | 2.3 | na | na | 3.0 | 2.4 |
| Perth – Darwin | 3.4 | na | 2.2 | na | 2.2 |
| Brisbane – Cairns | 3.0 | 4.0 | 1.0 | 3.9 | 2.9 |
| Hobart – Brunie | 2.6 | -1.1 | 1.0 | na | 1.3 |
| Sydney – Wollongong | 3.2 | 4.4 | 1.1 | na | 3.3 |
| Melbourne – Geelong | 3.5 | 1.6 | 0.8 | na | 3.3 |
| Townsville – Mt Isa | 1.2 | 1.5 | na | na | 1.5 |
| Sydney – Dubbo | 2.0 | 1.0 | na | na | 1.8 |
| Perth – Bunbury | 5.3 | 4.2 | 3.9 | na | 4.8 |
| Melbourne – Mildura | 2.6 | 2.6 | na | na | 2.6 |
| Melbourne – Sale | 3.5 | -0.5 | na | na | 3.4 |
| Melbourne – Perth | 2.2 | 3.1 | 0.8 | 2.3 | 2.7 |
| Sydney – Perth | 2.7 | 4.3 | 1.7 | 3.0 | 3.1 |
| All corridors | 3.4 | 2.4 | 1.3 | 3.5 | 3.0 |

The FreightSim Adelaide-Darwin rail freight projection is based on projecting from 1999 rail freight traffic levels, which was prior to the completion of the Adelaide – Darwin rail line. The BTRE has not separately projected rail freight traffic growth between Adelaide and Darwin for this exercise, but the extent to which Adelaide – Darwin rail freight traffic grows by 2025 will subtract from growth on the road freight growth. In updating the projections, using 2003-04 freight data, the BTRE will address issues such as this.

Substantial infrastructure investments will be required to support this growth and maintain the competitiveness of Australian business in its path to 2050.

## 8.4 ENERGY RELATED INFRASTRUCTURE TO 2050

As the economy and the population grow, so the demand for energy increases. As noted in Chapter 5, if energy supply is to keep up with the demand indicated by the projections of what Australia will look like in 2050, there will need to be very significant investment in new plant, for electricity generation, gas production and petroleum refining. There will also need to be commensurate investment in the transmission and distribution systems required to deliver the energy to customers. Climate change policy is the major wild card in terms of projecting future investment in energy sector infrastructure.

### 8.4.1 Population and economic growth

As noted in 8.1 above, the economic modelling by CoPS projects on a business-as-usual basis that in 2050 the Australian population will be around 40 per cent larger than now, at nearly 29 million, while the economy will be about 3.5 times larger.

In regard to energy demand, projections from the modelling indicate that:

- electricity sales will be about 2.3 times the current level;
- coal-fuelled generation will increase by approximately the same degree; and
- the gas market will be about 6.7 times the present level.

In terms of electricity, this suggests that demand will increase more slowly than the rate of growth of the economy as a whole. This has nothing to do with climate change (the projection is on a business-as-usual basis). The Australian economy has been becoming less energy-intensive over a long period of time and this reflects a number of factors. First, the industrial markets for electricity have changed considerably over time, with the services sector (which is relatively modest in its demand for electricity) growing faster than other sectors, such as manufacturing and resources, which are heavier consumers of electricity. Secondly, in the household sector electricity is more of a staple good than a luxury and so does not have a high income elasticity of demand – this means that demand for electricity will grow more slowly than household incomes. Thirdly, electrical products are becoming more efficient and so require less power to produce the same output.

Nevertheless, a 130 per cent increase in the electricity market suggests that major investment will be required in generation, transmission and distribution to 2050 [165]. Many of these assets have long lives: generators for example can live for up to 70 years. This means the investment decision needs to be made with great care, particularly as regards the choice of fuel to underpin the new plant. In the present circumstances, a choice of the use of coal, for examples, could be seen as risky given the current debate about the response to climate change. An additional factor is that the state-based electricity sector still exhibits significant excess capacity.

The rapid expansion of the gas market, as forecast by the model, largely reflects a projection of recent trends. Apart from the fact that it is a relatively greenhouse-friendly fuel, which should not affect the business-as-usual projection, gas has become increasingly cheap in relative terms. This is due both to energy market reform and the fact that, notwithstanding rapid growth in the LNG market, gas still does not have a world price and is relatively abundant in Australia. Nevertheless, it is difficult to forecast gas prices, with opportunity cost being a very important factor. Thus in Western Australia, where producers can largely choose (at least when current contracts have expired) between selling gas domestically or as LNG for export, domestic gas prices are likely to increase over time. In south-eastern Australia, on the other hand, the gas price will not be determined by opportunity cost, since reserves are insufficient to support a LNG play. More important here is the possibility of dwindling supply, with PNG gas potentially playing an important role.

### 8.4.2 Technological change

Technological change in energy production and infrastructure has not been rapid over the last century. In the electricity sector, coal still provides the cheapest, most efficient means of producing electricity in Australia. Technological change in electricity generation is occurring at a more rapid rate currently, but this is driven largely by climate change considerations, with air pollution also a driver. Developments have been made in renewable energy, but the costs of generation remain relatively high. Advances are being made in terms of carbon capture and storage.

Despite a movement against nuclear power in reaction to the Three Mile Island and Chernobyl accidents in the 1979 and 1986 respectively, a number of countries are now building new nuclear plants and technological change is occurring in the industry. This is reducing capital costs significantly, so that the likely cost of electricity from new nuclear plants is also lower. For example, the third generation of Westinghouse reactors can be as small as 1100 MW capacity with an expected average generation cost of less than US$35/MWh (equivalent to around A$49) [166]. Figure 8.1 in Section 8.4.4 summaries the long-run average costs for nuclear and alternative sources of generation.

Other technological changes in new materials and building processes can also be expected to reduce the costs of transmission networks for both gas and electricity

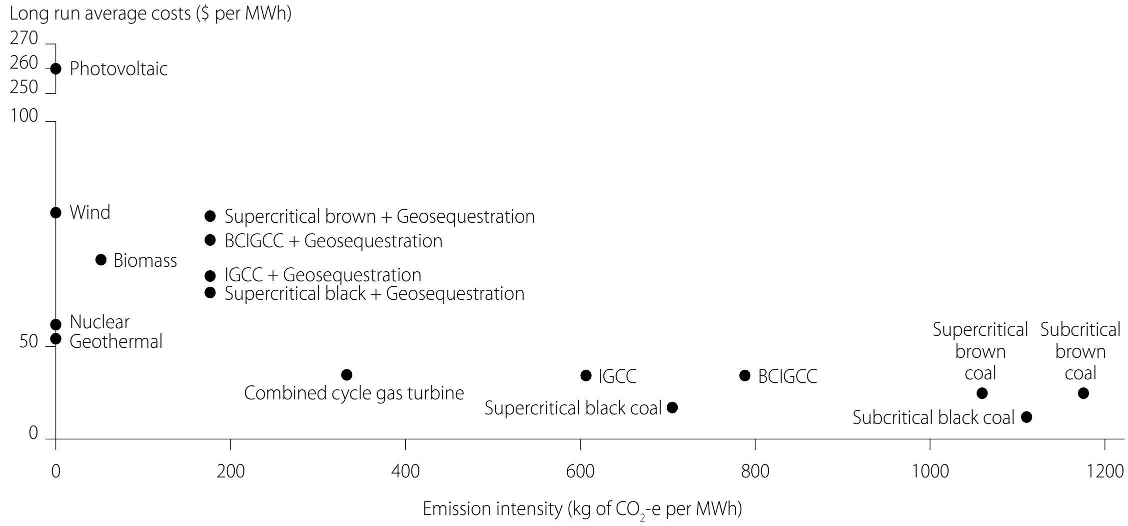
### 8.4.3 Other factors

The most important issue facing the energy sector is climate change, or more particularly, the policy response to climate change. If Australia participates in global action to reduce greenhouse gas emissions, the generation sector will have a very different profile by 2050 as is discussed in more detail below.

Government policies regarding regulation of third-party access will also have an impact on investment in transmission networks. This issue was raised extensively in the Business Council of Australia report cited earlier. That said, however, the gas pipeline network has expanded substantially since national third party access regulations were introduced in the late 1990s.

[165] This supported by the findings of the Engineers Australia, *2005 Australian Infrastructure Report Card*, which rated electricity infrastructure with a C+ grade, reflecting its assessment of distribution problems and the inadequacy of the current stock to provide for future population and economic growth. Again this analysis does not incorporate economic considerations but is a fit for purpose assessment.
[166] *Uranium Information Centre, Newsletter No.1*, Melbourne, January – February 2006, p.2.

## Figure 8.1 – Electricity generation: indicative costs and emission intensity by fuel source[167]




BCIGCC = Brown Coal Integrated Gasified Combined Cycle IGCC = Integrated Gasified Combined Cycle

**Source: McLennan Magasanik & Associates / The Allen Consulting Group**

### 8.4.4 Outlook to 2050

By 2050, none of Australia's existing electricity generators are likely to exist, but generation capacity will be over twice as great as it is now. This will occur whether or not major initiatives to curtail greenhouse gas emissions are introduced. Such policies may well have the effect of reducing the demand for electricity to some degree, but their main impact is likely to be on the choice of fuel for the generation plants. Figure 8.1 illustrates the trade off that exists between generation costs and emissions intensity.

As was discussed in Chapter 5, nuclear energy and renewables are likely to play a major role in base-load electricity generation by 2050, with coal only participating to any significant degree if the costs of carbon capture and storage (CCS) can be reduced. Technological change in electricity generation is expected to increase due to supply side measures, such as those recently proposed by the members of the AP6 pact, and the imposition of a carbon price.

The absence of a carbon price and uncertainty about future greenhouse policy is currently weighing on potential investors in new electricity generation plant. However, this problem may be less urgent than it seems. New base-load capacity is unlikely to be required in the eastern states at least for around 10 years, which allows time for some of this uncertainty to be removed. While new peaking and intermediate plant-capacity will be required much sooner than that, gas, with its low-emissions footprint, is the fuel of choice for such generators.

Clearly, as also identified in Chapter 5, significant investment in new electricity transmission systems will be required by 2050. The fact that future investment will reflect national requirements rather than being on a state-by-state basis as in the past, may mean that more investment in interconnects may be needed. It also may well be that generators are located in different places than in the past, thereby requiring additional investment in new transmission systems. For example, there may be no electricity generation in the Latrobe Valley by 2050 unless economic technologies for CCS in brown coal emerge. On the other hand, nuclear plant may be located in more remote areas, at some distance to major markets.

The response to climate change is likely to involve a greater reliance on gas as an energy source.

[167] Analysis by McLennan Magasanik and Associates and The Allen Consulting Group, *Securing Australia's Future* (White Paper) Commonwealth Government, 2004. Note: Based on assumed cost of geosequestration of $50 per tonne of $CO_2$–e. Key: BCIGCC = Brown Coal Integrated Gasified Combined Cycle; IGCC = Integrated Gasified Combined Cycle; CCGT = Combined Cycle Gas Turbine. See The Allen Consulting Group, *Deep Cuts in Greenhouse Gas Emissions: Economic, Social and Environmental Impacts for Australia*, Report to the Business Roundtable on Climate Change, March 2006.

Greater capacity is needed in both the short and long-term [168]. While Australia has enormous reserves of economically recoverable natural gas, most of these are located in the north-west of the continent, far away from the major markets in the south-west. As reserves in the Cooper and Gippsland basins decline in the future, there may be a need for a transcontinental pipeline, perhaps bringing gas from the Browse basin to major markets around Sydney and Melbourne. The pipeline from PNG is also likely to be required.

## 8.5 WATER INFRASTRUCTURE TO 2050

As discussed in Chapter 4, frequent droughts, combined with some unsustainable uses of water and a reluctance to invest in new water supply options for environmental reasons, has led to water shortages in many parts of Australia. Ensuring adequate supplies of sufficiently safe water for communities and industries in 2050 will require substantial investments in water infrastructure.

### 8.5.1 Population and economic growth

Water scarcity has been a pre-eminent issue in Australia for several decades. With population growth, absolute household consumption will rise. If per capita consumption remains constant to 2050 [169], then Australian households will consume 3,196Gl of water per annum. This would represent an increase of 46.5 per cent above current water consumption levels. Economic growth, however, could impact on household consumption rates in the future. On the one hand, GDP per capita is expected to increase by 2.5 times current levels by 2050. Higher levels of income may lead to larger families, larger gardens, and more swimming pools [170]. On the other hand, demand management and better pricing of water could substantially reduce per capita rates of water consumption. It has been estimated that roughly 30 per cent of water consumption is discretionary [171]. IPART has also shown that there is a strong correlation between high water users and the ability to reduce consumption [172]. Given the increases in water efficiency technologies and demand management regulations, it is unlikely that growth in demand for water will move in parallel with growth in GDP to 2050.

Current commercial water consumption is dominated by agricultural needs (68 per cent), electricity generation (6.9 per cent), water supply (7.3 per cent) and manufacturing (3.5 per cent). With the Australian economy projected to grow by more than a factor of three by 2050, there is likely to be a requirement for significant investment in water infrastructure in the future. With agriculture currently representing a large proportion of total water consumption, future needs for water will be highly sensitive to changes in this sector. CoPS projections of economic growth to 2050, suggests that agriculture is expected to grow at a far slower rate than GDP. By 2050, output from the non-animal agriculture sector is projected to expand by 2.8 times current levels and output from animal agriculture by 2.9 times current levels. Demand will vary by region as well: water use in Western Australia is expected to grow strongly, and the majority of this projected increase in demand is expected to come from agricultural irrigation needs [173].

Reflecting the likely changes in demand from households and structure of economic growth to 2050, CoPS modelling projects output from the water supply industry to increase by 86 per cent by 2050 (CAGR 1.83 per cent). The water supply industry encompasses the output of all types of water products, including storm water, waste water and potable water. This represents a far slower rate of growth than GDP, which is forecast to grow by 248 per cent (CAGR 2.81 per cent). This would suggest that targeted

[168] With gas infrastructure receiving a C+ grade by Engineers Australia, *2005 Australian Infrastructure Report Card*, Engineers Australia, Canberra, 2005, it has also been identified as requiring substantial investment in infrastructure capacity to meet future demand.
[169] With a population of nearly 20 million, this translated into per capita consumption of 0.11 Ml per annum (0.00011 Gl per annum).
[170] South Australian Government, *Water Proofing Adelaide: A Thirst for Change, 2005-2025*, The Water Proofing Draft Strategy, South Australian Government, 2005.
[171] Port Jackson Partners Limited, *Reforming and Restoring Australia's Infrastructure*, Report to the Business Council of Australia, 2005.
[172] IPART, *Residential Water Use in Sydney, the Blue Mountains and Illawarra*, Results from the 2003 Household Survey, Independent Pricing and Regulatory Tribunal of NSW, Sydney, 2003.
[173] Western Australian Government, *Securing Our Water Future: A State Water Strategy for Western Australia*, Western Australian Government, February 2003.

investments in water infrastructure will be able to support economic growth to 2050.

### 8.5.2 Technological change

Chapter 4 provides extensive analysis of technological change in the sector, including the potential for innovations in non-conventional water supply sources such as desalination plants and new forms of recycling [174]. It is likely that the costs of these facilities may be reduced over time, making them more cost-effective investments. Moreover, the uptake of new water efficiency technologies by residential consumers may reduce overall water requirements to invest in this new infrastructure.

### 8.5.3 Extraneous factors

The need for investments in additional infrastructure is expected to be exacerbated by climate change, which is discussed extensively in Chapter 3. This will result in higher rates of evaporation and more frequent heatwaves, and could increase the consumption of water by the agricultural sector. This will increase the need for more water infrastructure in Australia, as has been the case in Western Australia [175].

Climate change is expected to impact more on regions that are already under significant water stress, including Adelaide and Perth. Current projections indicate that in as little as 10 years, the demand for water in Adelaide will exceed available supply during dry periods by 37Gl [176] and Perth is investing in desalination. This will amplify the regional differentials in infrastructure needs expected in 2050. Over the years to 2050, without infrastructure investment or increased demand management, this gap will only grow. Severe rain events due to climate change could also exceed historical design standards, with dam overtopping and failure potentially resulting in significant human and economic costs. Additional investments in the capacity of the more than 500 dams in Australia to withstand the increased threat of severe storms will be required.

Improved definitions of water rights and expanded water trading will be necessary to ensure that water is allocated efficiently to the highest-value uses; this will in turn promote efficient investments in infrastructure, with investments in irrigation and other infrastructure being made only when the social and private returns can justify it. Total water cycle management programs, in which Australian governments are investing significant resources, will drive also efficient investments in water infrastructure.

### 8.5.4 Overall impact to 2050

Estimating and projecting the current profile of water infrastructure is difficult: little data are available on farm dam capacity and average storage levels, while groundwater availability is highly uncertain. In some regions it is expected that water use will more than double by 2050 while in other regions water use is expected to remain relatively flat. If current water usage levels grew by the rate of increase in demand for water services projected by CoPS, then roughly 45,470GL of water would be required in 2050 [177]. If demand management strategies are able to reduce household consumption by 25 per cent on current consumption rates, this will result in 44,454GL of water being required by 2050 [178]. If water consumption grew at the same rate as GDP, this would imply 60,626GL of water would be required Australia-wide in 2050 [179].

While there will be substantial water potential in Australia generally, however, it is clear that

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[174] The planned effluent recycling plant in Toowoomba, Queensland is an example of alternative water supply sources for non-coastal cities that cannot introduce desalination plants.

[175] Western Australian Government, Securing Our Water Future: A State Water Strategy for Western Australia, Western Australian Government, February 2003.

[176] South Australian Government, Water Proofing Adelaide: A Thirst for Change, 2005-2025, The Water Proofing Draft Strategy, South Australian Government, 2005

[177] This calculation was based on current water Usage being projected by 86 per cent to 2050. Current total Usage in 2005 was assumed to be the total presented in Chapter 4. It was assumed that current shares of water consumption by households and industries would be maintained (i.e. no reductions in current agricultural waste).

[178] This calculation was based on the household component of total water consumption reducing by 25 per cent by 2050. No other component of water consumption was assumed to be reduced. This shows the limitations of demand management, although this is also clearly an important tool for total water management.

[179] This calculation was based on current water Usage being projected by 248 per cent to 2050. Current total Usage in 2005 was assumed to be the total presented in Chapter 4. It was assumed that current shares of water consumption by households and industries would be maintained.

metropolitan areas will come under substantial stress without additional investments in water infrastructure efficiency or new sources of supply. Analysis from many sectors of the economy has called for urgent major investment in maintenance, repairs and renewal of infrastructure. Most major metropolitan areas are already planning to invest in new supply sources and have substantial demand management strategies in place. However while demand management will remain an important element to maintaining sustainable water supplies, demand management alone will not be sufficient.

Governments will need to target the most cost-effective investments. This will include substantial investments in water efficiency and new supply which have been canvassed in Chapter 4. In the short run, increased investments in households in rainwater tanks and third pipe infrastructure will be a key source for water, though this will be heavily dependent on rates of government subsidy, the future price of water and the future costs of the technology. This decentralised infrastructure is already being encouraged in some states, including Victoria, with governments providing incentives for consumer uptake.

## 8.6 SOCIAL INFRASTRUCTURE TO 2050

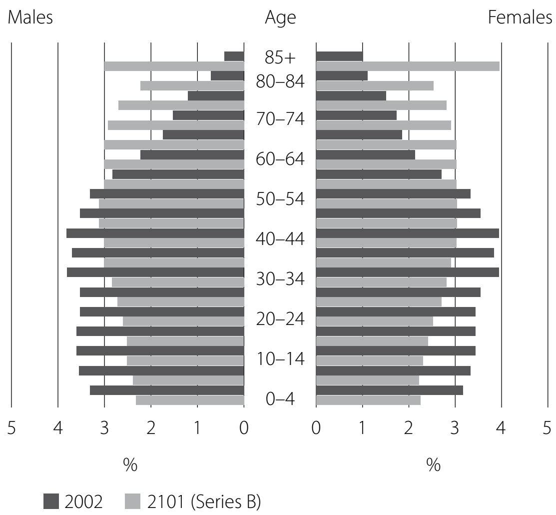
Social infrastructure covers a diverse set of services and facilities. For the purposes of this report, social infrastructure includes all facilities required to provide services provided to the community. This includes educational, health, aged care and welfare facilities.

### 8.6.1 Population and economic growth

As health outcomes continue to improve and mortality rates decline, the life expectancy of Australians is continuing to increase (see Figure 8.2). While previous population projections assumed that these trends would continue only for a limited period, the latest projections include a "high" life expectancy alternative, in which recent life expectancy gains are assumed to continue each year for the full duration of the projection period. Under this alternative, life expectancy is projected to increase to 92.2 years for men, and 95.0 years for women by the year 2050-51.

Low rates of savings, increased use of pharmaceuticals (which improve quality of life and mobility in old age) and increased life expectancy are expected to increase demand for public housing, health facilities, community health services and centres. For example, the *Intergenerational Report* projects demand for Medicare services as a percentage of GDP to grow by 60 per cent of current spending levels

Figure 8.2 – Population projections, Australia, 2002 and 2101[180]




Source: Australian Bureau of Statistics, 2003

[180] ABS, *Population Projections, Australia, 2002-2101*, Cat.No. 3220.0. Australian Bureau of Statistics, 2003. Note that Series B corresponds to a population of 27.5 million at 2050.

by 2041-42, demand for Pharmaceutical Benefits Scheme services to grow by five times current levels of spending, and hospital services by 40 per cent current spending levels. Demand for nursing homes is also expected to increase. Illustrating the potential increase in the demand for aged care, the Australian Institute for Health and Welfare reported that by 2001, the number of aged and disabled care nurses was more than four times its size in 1987, with growth at an average annual rate of 10 per cent during this period. These strong growth trends are expected to hold to 2050.

In 2050 the number of persons of working age is expected to be smaller as a proportion of the total population than in 2002. According to ABS projections the number of people aged 25-54 is expected to decline from 43 per cent of the population in 2002 to between 33 and 35 per cent by 2101. This will result in persons of working age supporting a greater number of people than in the past, and will have implications for investment in both physical and mental health infrastructure in Australia. Investments in infrastructure that encourages labour force participation by older Australians may also be an important component of investment in social infrastructure to 2050.

In 2050 it is expected that there will also be fewer children as a percentage of the total population. This will drive changes in the nature of child care, schools and other children's services. Some education assets may be converted to new uses, and the nature of infrastructure funding for this cohort will evolve, with less emphasis being placed on physical infrastructure investments and greater emphasis being placed on communications infrastructure connectivity and productivity advances.

The growth of the economy will create a need for a growing supply of skilled labour. Moreover, productivity growth in the economy will also create increased demand for educational infrastructure. Higher rates of productivity growth will require workers to continually upgrade their skills and will imply rates of demand for educational services growing at rates faster than employment growth [181]. This will require high standards for education and rates of uptake within the community. However, the expected decline in school-age children will mean that there may be unused capacity in some regions. Therefore the nature of investments in educational infrastructure will change. Emphasis on communications infrastructure to optimise learning environments (through greater interactivity and diversity of curriculum) will be important. This will need to occur in schools, universities, TAFEs and other vocational institutions, and has been identified as a threshold issue for the education sector [182]. Demand for JobNetwork services provided by the Commonwealth is also expected to rise. Accounting for economic growth (see below), the growth in the population (requiring greater education levels) and changes in the structure of the population, CoPS modelling projects the provision of government services to increase by nearly two-times current levels by 2050.

There will also need to be significant investment in preventative health therapies to maintain high rates of workforce participation into what has historically been viewed as "retirement age" and low rates of absenteeism. Investments in sport and recreation facilities will be required to reduce obesity and chronic illness within Australian communities. Apart from the demographic effects, as economic growth translates into increased wealth for Australians, there is also expected to be a significant demand-led expansion in the usage of medical services.

### 8.6.2 Technological change

Improved communications networks, including the increased roll-out of broadband (terrestrial and satellite), may lead to radical changes in social services models. This will make the operation of social infrastructure services more efficient and cost-effective. For example, the emergence of a health web will encourage compliance with prescribed therapies and a decentralisation of health services ("telehealth" applications). GPs will be able to transmit patient x-rays (teleradiaology) and medical records instantly to other specialists (electronic patient health records). On one hand this will increase the need for

[181] In a report for the Department of Education Science and Technology, productivity growth was expected to average 1.9 per cent to 2010. This was slower on average than the previous decade where productivity growth averaged 2.6 per cent per annum. See Access Economics, *Future Demand for Vocational Education and Training*, prepared for DEST, 2004.

[182] Department of Communications, Information, Technology and the Arts, *Australia's Broadband Connectivity*, Broadband Advisory Group, Commonwealth Government, 2003.

communications infrastructure; on the other hand, it might reduce the need for hospital infrastructure expansion.

Communications networks will also be pivotal for the increased uptake and effectiveness of educational services. Video connectivity between classrooms will facilitate greater diversity of curricula. It will also facilitate advances in public sector research by universities, CRCs and other research organisations. In a 2003 Department of Communications, Information, Technology and the Arts report, the Foresight Group noted that "increasing attention is being paid internationally to the development of an advanced distributed infrastructure for science and research, including computational systems, advanced networks, data storage systems and the like, which allow scientists to address collaboratively some of the big emerging research challenges. This 'cyberinfrastructure', will create new opportunities for research, and is increasingly essential for the advancement of knowledge in many areas [183]." Investments in networks such as GrangeNet, CeNTIE and mNet that are supported by the Government funding (such as the BITS Advanced Networks Program) are examples of investments in social infrastructure that will be driven by technological change.

### 8.6.3 Extraneous issues

Shown in Table 8.2 are the areas of funding responsibility by different levels of government for spending in economic and social infrastructure [184].

#### Table 8.2 – Social infrastructure responsibilities by level of government

| Level of Government | Social Infrastructure |
|---|---|
| Commonwealth | Tertiary education |
| | Public housing (shared) |
| | Health facilities (shared) |
| States and Territories | Educational institutions (primary, secondary and technical) (shared) |
| | Childcare facilities |
| | Community health services (base hospitals, small district hospitals, and nursing homes) (shared) |
| | Public housing (shared) |
| | Sport, recreation and cultural facilities |
| | Libraries |
| | Public order and safety (courts, police stations, traffic signals etc) |
| Local | Childcare centres |
| | Libraries |
| | Community centres and nursing homes |
| | Recreation facilities, parks and open spaces |

This overlapping of responsibility may lead to under-investment or inefficient investment in infrastructure. The efficiency and effectiveness of Government investments in social infrastructure would be likely improved if the roles of different levels of Government were reformed.

Efficiency of investment patterns in social infrastructure will be highly dependent on the appropriate collection and analysis of data. For example, with regard to funding for Australian research and research training institutions, such as universities, CRCs and other publicly funded research agencies, the Commonwealth is endeavouring to develop a Research Quality Framework (RQF) that will ideally measure the quality and impact of publicly-funded research, and will determine future funding allocations to Australian institutions. The quality of data collected in other social infrastructure sectors will also determine

[183] Department of Communications, Information, Technology and the Arts, *Australia's Broadband Connectivity*, Broadband Advisory Group, Commonwealth Government, 2003.
[184] Webb, R., *The Commonwealth Government's Role in Infrastructure Provision*, Research Paper No.8 2003-04, Commonwealth Government, Canberra, 2004. (www.aph.gov.au/library/pubs/rp/2003-04/04rp08.htm)

future decision makers' assessments of the cost-effectiveness of social infrastructure investments.

Government purchasing arrangements for high-cost medicines will also impact on the need for health care infrastructure. To the extent that current arrangements might be reformed to enable greater access to new therapies by greater proportions of the population, this might reduce requirements for hospital care. Research in both the US and UK shows that an increase in use of medicines decreases not only the number of hospital admittances but also the average length of stay. Moreover, studies into diabetes, psychotic disorders and cardiovascular disease have also shown that expenditure on new medicines can reduce costs incurred in other areas of the health system [185].

### 8.6.4 Overall impact to 2050

With strong GDP and population growth expected, there will need to be a substantial increase in social infrastructure. This will likely require a reversal of current public sector spending. The Commonwealth and states have substantially decreased their spending on social infrastructure in the past several decades. Aggregate spending on social infrastructure as a percentage of GSP by states and territories has fallen by 29 per cent since 1990. Aggregate spending by the Commonwealth as a percentage of GDP has fallen by 62 per cent over the same time period [186]. Looking to the future, given current population trends, if this low level of spending on social infrastructure is maintained, there is a risk that Australians in 2050 will face a significant under-supply in important social infrastructure. To avoid this, substantial investment in health and aged care infrastructure will be required.

## 8.7 COMMUNICATIONS INFRASTRUCTURE TO 2050

Communications infrastructure, which includes telephone lines, broadband capabilities, cable infrastructure and wireless connections, has become increasingly important for the efficient functioning of the Australian economy [187]. Business productivity has increased substantially in recent years with increased uptake of broadband and wireless infrastructure. Continued investment in this infrastructure is essential to maintain the competitiveness of Australian businesses.

Australians tend to have a high rate of internet access (84 per cent) compared to other countries (for example, the equivalent figure for the US is 82 per cent). However, this apparently high rate of access belies key features of that infrastructure. Penetration of high-speed "broadband" communications in Australia is comparatively low. In terms of internet connection speeds, Australia ranked 12th in the world in 2004 according to DCITA and 18th in the world according to a 2002 OECD survey [188].

[185] Research by Lichtenberg published in the American Economic Review showed that an increase in of 100 prescriptions is associated on average with 16.3 fewer hospital days. Translated into dollars, the study found that an increase of US$1 in pharmaceutical spending was associated with a US$3.65 reduction in hospital expenditures. In the UK, studies have show that pharmaceutical use since the 1950s has contributed to the halving of the number of hospital beds required in 12 disease areas and further reduced the average hospital stay from 45 days to eight days. Related savings were estimated to be 10 billion per year, or twice the amount spent by the National Health System on all medicines. See Lichtenberg, F., *Are the Benefits of Newer Drugs Worth Their Cost?*, Health Affairs, 20(5): 2001, pp.241-251; Lichtenberg, F., *Do (more and better) Drugs Keep People Out of Hospitals?*, American Economic Review, 86: 1996, pp.384-388; Association of the British Pharmaceutical Industry, 1997, *White Paper: ABPI Submission*, quoted in The Allen Consulting Group, *Managing the Benefits and Costs of Advances in Pharmaceuticals*, Submission to the Productivity Commission, December 2004; Glasziou, *Cholesterol-lowering Therapy with Pravastin in Patients with Average Cholesterol Levels and Established Ischaesmic Hearth Disease: Is it Cost-effective?* Medical Journal of Australia, 177: 2002, pp.420-426; Sabatine, M. S. and Jang, I. K., *The Use of Glycoprotein IIb/IIIa Inhibitors in Patients with Coronary Artery Disease*, American Journal of Medicine, 109: 2000, pp.224-237; Pitt, B., *The Effect of Sprionolactone on Morbidity and Mortality in Patients with Severe Heart Failure*, New England Journal of Medicine, 341(10): 1999, pp.709-717; see also studies on Mental Illness, Diabetes and Cardiovascular Disease quoted in Medicines Australia, *Impact of Advances in Medical Technology on Health Care Expenditure in Australia*, Submission to the Productivity Commission Inquiry, January, 2005, pp.73-78; Lexchin, J. and Grootendorst, P., *The Effects of Prescription Drug User Fees on Drug and Health Services Use and Health Status: A Review of Evidence*, International Journal of Health Services, 34 (1), 2004, pp.101-122; RAND Corporation study quoted in Fuhrmans, V., *Higher Co-pays May Take Toll on Health*, Wall Street Journal, 19 May 2004.

[186] Cost shifting by governments on social infrastructure spending is also a factor here.

[187] Communications infrastructure can be broken down into two parts: the backbone carriage networks and the customer access networks. Backbone carriage networks – often referred to as 'trunk' networks – connect users through copper wires, radio links, fibre optic cables, microwave or satellite links. Customer access networks are the cables that connect end-users to trunk – this is often referred to as the local loop or the 'last mile'. Currently in Australia customer access networks are dominated by copper cables, but increasingly these networks are connecting users through high speed technologies, including fibre optic cables, microwave and satellite links.

[188] Department of Communications, Information, Technology and the Arts, Information Economy Index and OECD, *The Development of Broadband in Rural and Remote Areas*, Working Party on Telecommunication and Information Services Policies, 2004.

High-speed infrastructure such as asymmetric digital subscriber lines (ADSL), digital subscriber line (DSL), hybrid fibre coaxial (HFC) cable, LMDS (local multipoint distribution systems, broadband wireless), WLAN (wireless local area networks) and satellite infrastructure (wireless access) will increasingly be needed for Australia to remain competitive in global markets. Australia needs to ensure that it is cost-effectively investing in new communications technologies to facilitate the uptake of low-cost, high productivity tools for businesses and consumers. In the future Australian communications infrastructure will have the following characteristics:

- 'always-on' connectivity;
- high-speed – greater than those made possible by narrowband technologies;
- two-way functionality – this enables interactivity by users; and
- the ability to simultaneously carry multiple content and/or applications [189].

### 8.7.1 Population and economic growth

The growth of the Australian population will generally help to bring down the costs for all users as per unit investment costs will generally fall. This is true for both terrestrial (ADSL and cable technologies) and satellite technologies.

The distribution of the Australian population will be critical and impact on the cost-effectiveness of the infrastructure. Implementation of video teleconferencing, and other services that will underpin Australia's increasingly global economy, will require that businesses and consumers have access to high-speed communications infrastructure. While much terrestrial infrastructure has been built in Australia's urban centres, regional communities have limited access to high-speed communications infrastructure. Generally, in areas of high population density, terrestrial infrastructure is highly cost-effective. Satellite infrastructure is often more cost-effective in areas of low population. The availability of cost-effective communications infrastructure could drive further population spread, which could impact on the cost-effectiveness of other infrastructure investments (such as land transport infrastructure). Australians in 2050 may increasingly work remotely.

Australia's projected GDP growth will be driven by increased usage of communications infrastructure and it will in turn fuel greater demand for more services. Businesses with inadequate access to broadband and associated technologies will be placed at a serious competitive disadvantage to competitors. Advances in communications technology will drive the emergence of the 'global office', with colleagues able to hold virtual meetings with experts and colleagues around the globe. This will drive demand for globally-oriented labour specialisation. Workers will also increasingly be required to be remotely contactable.

Economic growth will increase the need for skilled labour. This will in turn demand that sophisticated communications infrastructure is available in classrooms and research laboratories. According to the Broadband Advisory Group, which has been commissioned to advise the Government on strategic communications infrastructure needs for the future, "all schools and educational institutions should be connected to broadband internet services to facilitate research, support interactive learning and provide access to innovative and varied curriculum content [190]."

Broadband will not only drive extensive economic benefits through the reduction of transaction costs and the enabling of e-commerce, but will also be a primary method of delivering government services to all Australians. The CoPS modelling forecasts demand for communications services to increase roughly five-fold by 2050. This significantly exceeds the projected future rate of economic growth and is an indicator of the magnitude of the investment task in this sector. As more and more businesses and social services are provided through internet services, Australia will also need to ensure its systems are secure. Large investments in communications security infrastructure will also be made over the next several decades by businesses. Systematic investments in data storage and security will be increasingly required.

[189] Western Australian Technology Industry Advisory Council, *Enabling a Connected Community: Developing Broadband Infrastructure and Services in Metropolitan Western Australia*, Technology Industry Advisory Council September 2003.
[190] Department of Communications, Information, Technology and the Arts, *Australia's Broadband Connectivity*, Broadband Advisory Group, Commonwealth Government, 2003.

### 8.7.2 Technological change

Changes in the technology 'mix' and the possible emergence of new technologies will affect the nature of urban and rural Australian broadband infrastructure. Technological change will increase access to communications infrastructure by lowering equipment costs, increasing new entry by competitors and increasing opportunities to access that infrastructure. Technological change that lowers terrestrial and satellite costs will be a key factor in determining the regional uptake of broadband options. In 2003, it was reported that 25 per cent of the population could not access DSL. While these communities may have access to two-way satellite and other alternatives, there was low take-up of these broadband alternatives: take-up of broadband was more than ten times higher in terrestrial broadband enabled areas (cable and DSL) than for the remaining satellite-covered and ISDN areas (3.4 per 100 inhabitants versus 0.35 per 100 inhabitants) [191]. Price and performance were identified as key reasons for the lower levels of uptake. As prices fall and technology improves, these services should be increasingly accessed by regional Australians.

### 8.7.3 Extraneous factors

Several significant factors related to government regulation will influence the future of communications infrastructure in 2050. The first is full privatisation of the sector. This will also result in the future expansion in communications infrastructure in Australia being funded largely by the private sector. A second key factor will be increasing competition. Competition from both domestic and foreign communications service providers will drive down costs, encourage technological innovation, improve service, and result in expanded offerings to Australian consumers. It will also drive rates of broadband uptake and infrastructure roll-out rates within Australia.

Given its population size, Australia will generally remain a 'technology taker'. Technological changes facilitated by growth in other larger markets will generally be adopted in Australia. That said, unique solutions may emerge for regional Australia, and the Government will need to assess the need for assistance in underdeveloped areas. This is particularly true in the short to medium run to 2050. Currently there is limited provision of broadband infrastructure to regional Australia. Over time, the roll-out of terrestrial broadband infrastructure may address this issue, as could technological developments such as satellite and/or wireless delivery systems that reduce the cost to the consumer. However, given the rapid changes in the global information market, there are clear incentives for Australia to ensure that all members of its economy have early access to competitive communications technologies. 'Demand aggregation' has been shown to be an effective tool by governments worldwide, including by Australian governments to date. This has been recommended by the Broadband Advisory Group to be widely employed in Australia:

> "All tiers of government should cooperate to develop demand aggregation strategies to stimulate broadband investment and the provision of services in key sectors, such as health and education, and also in regional areas. Demand brokers could be used to assist rural and regional communities and sectors to develop broadband services."

This was also supported by the Estens Regional Telecommunications Review [192]. Through demand aggregation, Government uses its purchasing power to leverage more cost-effective broadband infrastructure investments in under-serviced areas [193]. This can provide broadband suppliers with strong incentives to undertake additional infrastructure investment. It also helps to defray risks of investment that infrastructure providers face.

[191] OECD, *The Development of Broadband in Rural and Remote Areas*, Working Party on Telecommunication and Information Services Policies, May 2004.
[192] Estens, D., *Connecting Regional Australia*, The Report of the Estens Regional Telecommunications Inquiry, Commonwealth Government, 2002, p.180.
[193] For example, the Queensland Government, using its aggregated spend, was able to attract investment in the establishment of a competitive fibre backbone along the Queensland coast. The Queensland Department of Innovation and Information Economy has estimated that its demand aggregation strategies have yielded savings of approximately 60 per cent.

### 8.7.4 Overall impact to 2050

Growth in demand for communications services is expected to be non-linear and to substantially outpace growth in GDP to 2050. For example, the growth of broadband access across the OECD grew 27-fold in only four years: in December 2003, there were more than 82 million subscribers to broadband services compared to three million at the end of 1999. The increase in modes for accessing communications infrastructure – such as through mobile personal communications devices, home and business computers, and likely television/entertainment units – will continue to drive ever faster rates of exponential growth.

To ensure that Australia does not fall behind, communications infrastructure investments need to be given priority in the short run.

Evidence to date has suggested that terrestrial technologies are more cost-effective in delivering broadband services for consumers and providers alike where a critical mass of demand is achieved. However, there is evidence that in some low-density population areas, satellite technology is the most effective broadband solution. Because Australia has made comparatively limited investments in communications infrastructure in the past, in its path to 2050 Australia may be able to avoid the costs of terrestrial technologies that have been incurred in other countries.

Much of this infrastructure will be funded by the private sector, however, there are clear roles for Government, particularly in the short-term, to act strategically to ensure adequate investment in communications infrastructure occurs. Strategies include demand aggregation and other targeted infrastructure funding schemes. Competition in the sector will also be necessary to underpin lower costs and optimal rates of infrastructure diffusion.

## 8.8 CONCLUSION

Major investment in Australia's infrastructure will be required to overcome current areas of weaknesses and to progressively meet the growth needs to 2050.

As discussed in previous chapters and noted by other analysis – including by Engineers Australia, the Business Council of Australia, the Committee for Economic Development of Australia, the Infrastructure Planning Council and the Commonwealth – Australia's current infrastructure stock is potentially inadequate in some sectors, and risks becoming a limitation on future growth. Infrastructure investment, given the expected growth in the population and the economy to 2050, needs to be a priority for Australia.

There are clear weaknesses in Australia's existing infrastructure base, with transport, water and electricity infrastructure standing out as areas requiring substantial short- run investment to overcome existing deficiencies. There are also threats to Australia's ability to meet future infrastructure needs, including inefficient planning processes and policy settings.

However, Australia is well-endowed with the resources and capital required to invest in the infrastructure required to support its economic and population expansion to 2050. With adequate planning and appropriate policy reform, there is little concern that Australia would be able to provide the infrastructure required to support its growth over the coming decades.

The major issue for the future is to ensure that investment in infrastructure is timely and efficient. Governments play an important role in this. First, state and Commonwealth governments can ensure that appropriate signals reach investors in a timely way. This is particularly important for organisations scoping investments in infrastructure assets that require large upfront capital outlays and also have an economic life of up to 50 years. Secondly, despite the growth of private investment and public private partnerships (PPPs), it is inevitable that governments will continue to be investors in infrastructure themselves given the large public good characteristics of these assets. In some cases this may require the Government to take on greater levels of debt than is currently the case. In the interests of efficiency, decisions on investment priorities in the main will need to be made on a national basis. This implies a much greater role for the Council of Australian Governments (CoAG) in the future.

# CHAPTER 9
# Meeting the challenges of the future

It should be borne in mind that there is nothing more difficult to carry out, nor more doubtful of success, nor more dangerous to handle, than to initiate a new order of things. For the reformer has enemies in all who profit from the older order, and only lukewarm defenders in all those who would profit by the new.

**Machiavelli N, *The Prince*, Chapter VI**

## SYNOPSIS

If governments develop sound policy and set clear directions, sustainable development, economic growth and a population growing to more than 30 million by 2050 can all be successfully accomplished. Sound policy and decision making and well-integrated planning is needed to deal with the challenges as well as future uncertainties, which can influence the rate and pace at which a growing population is absorbed.

This chapter draws attention to many public policy considerations that require serious and parallel attention to the issues explored elsewhere in this report. For instance, these are times characterised by dramatic changes in the nature of jobs and work, significant shifts in requirements for public health, housing, communications and education, and increasing demand by an ageing population and work force for continuing roles and improved services. The way these issues are analysed and policies are developed and implemented will clearly influence the degree of success in building a cohesive, growing and prosperous country.

This chapter points out that robust public policies need to be considered and debated by all stakeholders if environmental, economic and social shifts are to be fully understood and accommodated in ways that solve problems, rather than create major new constraints on growth and on the nation's capacity to accommodate increased population.

Whether government is focusing on cities, infrastructure, transport systems, climate change or responses to disasters, a prime challenge is to carry through strategic and integrated planning in a timely and non-bureaucratic way and to plan for and mobilise the necessary levels of investment. For example, it may be necessary to introduce new infrastructure and services in some regions and towns that currently experience few development constraints, in order to deal in future with an increasing proportion of a growing population.

Both economic growth and the increasing role of advanced communication and information technology systems and services in the nation seem likely to continue to drive demand for skilled labour. The nation must continue to invest heavily in skills formation and the necessary communications and information technology infrastructure so the education system is better-equipped to contribute to the heightened demand for advanced skills. In this way increasing population can contribute to improved national wellbeing.

Australians expect government to guide the introduction, review and reform of the major national systems and institutions so they operate in predictable ways and serve their vital interests, from anti-terrorism to reconciliation, from immigration to child welfare. While governments should lead, the quality of their decision making can only be enhanced by vigorous and informed debate within the community at large.

That means that government, business and citizens alike must pay greater attention to the needs and management of whole systems – technological, social or environmental. This is not easy and seldom occurs, because ministerial portfolios and public authorities are structured around particular segments or issues rather than systems as a whole. The outlook of both industry and local communities tends to reinforce this approach, because it is much easier to focus on the specific or the local rather than the systemic.

Another barrier to effective planning and management lies in the failure of stakeholders to recognise, and then to remove, institutional blockages to necessary reforms – for example, in securing better catchment and water management. These are not simply bureaucratic or management issues but rather challenges that must be met if a growing population is to be successfully accommodated in an advanced and prosperous nation.

This chapter shows the context in which scientific and technical capabilities can be applied to support the development of the nation's infrastructure and institutions and to support the sustainable management of the nation's natural systems and resources.

## 9.1 INTRODUCTION

This report addresses the implications of a larger population for Australia by building on the known space, climate, land and resources of the nation as well as the determination and capacities of its people. It recognises the uncertainties of the future and acknowledges that there may well be changes in lifestyle, climate, global relationships between countries or global disasters that could influence the rate and pace at which a growing population is absorbed. The report notes these uncertainties, and where practicable takes account of them, in analysing how to harness science, engineering and technology in overcoming barriers to steady population growth.

If population growth is to play a constructive role in building a prosperous and cohesive nation, and if future constraints and blockages are to be avoided, there are many public policy considerations that require attention in parallel to those treated thus far in this report [194]. These range from getting the policy settings right for health and education to dealing effectively with the needs of an ageing community, while advancing the cause of a 'clever country'. While it is acknowledged that both the Academy and the Foundation have significant and continuing interfaces with governments, Commonwealth and state, this chapter seeks to remind readers and articulate for them some of the major challenges ahead and some of the hard decisions and difficult trade-offs needed if a smooth transition is to be negotiated to a productive and cohesive nation with a larger population. This chapter also draws together and extends the concluding remarks and the analysis of the preceding chapters in ways that frequently link to critical policy questions and associated decisions and trade-offs.

## 9.2 IMPROVING CITIES, INFRASTRUCTURE AND TRANSPORT

This report deals with various aspects of cities, infrastructure and transport and some of the technological responses that are practicable in accommodating both economic progress and population growth. The report does not suggest, however, that there are ready or direct technological responses to all the challenges associated with population growth and city redevelopment and growth. For example, as cities grow in size and change in population distribution, the public/private transport infrastructure must be reshaped, by harnessing good science, engineering and technology. That is happening at the same time as dramatic changes in the nature of jobs and work, significant shifts in requirements for public health, housing, communications and education, and increasing demand by an ageing population and workforce for continuing roles and improved services. All concerned seek sustainable towns, cities and settlements,

[194] Crawford, Peter J., *Captive of the System! Why Governments Fail to Deliver on Their Promises and What to do About it*. Richmond Ventures. 2003.

including improvements in amenity, such as reduced traffic congestion and noise and improved services, such as public transport and low-cost communications technology.

Chapter 8 reveals that by the year 2050 it is likely that the Australian economy will be substantially larger and individual prosperity and life expectancy greater, and people of working age will each be supporting more of their fellows. (That is, unless, the nation invests heavily in the services, infrastructure and inducements that will keep older Australians in the workforce for longer.) It follows that the demands on infrastructure and services will change, leading eventually to changes in the class of infrastructure and types of service to be provided. That will occur whether the arena is, for example, modified power generation and distribution systems to meet increased demand, or improved rail freight services and increased urban and arterial roads to meet changed and increasing freight and transport demands. New infrastructure and services will be needed if towns and cities, that face less in the way of environmental, housing and cost constraints, expand to deal with an increasing proportion of a growing population.

All those considerations that accompany town and city growth place heavy demands on governments in what are highly dynamic and changing environs. That, in turn, places pressure on service providers and those involved in city planning and redevelopment. Robust public policies are needed by all parties, government, industry and commerce and citizens alike, if environmental, economic and social shifts are to be accommodated in ways that solve problems rather than create major new constraints on growth and on the nation's capacity to accommodate increased population. For example, national experience reveals that in the absence of integrated city planning, urban freeways speed the flow of traffic not only away from city centres but also into the cities, thereby increasing congestion and creating difficulties in coping with increasing population.

This is a time characterised by wide-ranging debate about future city planning and governance. That makes the job of formulating responses to the above challenges associated with cities, infrastructure and services even more difficult. In the 1960s and 70s public planning and governance of cities was more centralised and system-wide than today, including government-focused delivery of services and infrastructure. That provided an effective response to some issues but very frequently failed to deal with the scale, urgency or priority of necessary developments.

So, it is not surprising that such an approach was progressively replaced by less comprehensive public planning and governance; greater corporatisation and privatisation of infrastructure, utility and service provision; heavier reliance on competition and non-public funding; reduced regulation; and more market-led patterns of urban expansion and development. All have been carried through in the name of efficiency, expedient delivery and reduced bureaucracy. But, governments nationwide have become very concerned that contemporary city planning, in the hands of a variety of agencies, authorities and committees, has failed to give priority to, and deal adequately with, future demands for water supply, energy, education, health and transport infrastructure and services.

So, neither the old nor the present mix of strategies has adequately met the needs of Australian cities and towns or the multiple demands placed on them by communities and their industry and commerce. Of course, across the nation, public and private partnerships have made significant contributions in road and transport infrastructure and build-own-operate projects have provided much needed road, energy and water infrastructure. Nonetheless, lively public debate is taking place about the way costs, profits and risks are being shared in these arrangements and reservations have been expressed about a few high-profile projects, such as the Sydney cross-city tunnel. This has led to increasing calls for more public sector investment in city growth and water, energy and transport infrastructure, for greater deficit funding by government, and for public provision of enhanced community services and amenity of assorted kinds. These concerns about integrated planning and better-targeted public funding have already influenced state governments and city councils in the development of a series of strategic plans that foreshadow the future shape and settlement patterns of major Australian cities. These plans are designed to provide clear directions for the public sector and help build confidence in those in the private sector who must make critical investment decisions.

Both economic growth and the increasing role of advanced communication and information technology systems and services in our lives seem likely to continue to drive demand for skilled labour. The nation must continue to invest heavily in communications and information technology infrastructure so schools, the home, the workplace, business and commerce and regional centres are all equipped to meet the demand for those skills.

Transport plays a critical role in advancing individual and commercial interests as well as national prosperity. While the community is outspoken about transport reliability, speed and efficiency, it also makes clear that it expects transport outcomes that are sustainable in terms of environmental, lifestyle and social cost. In such a large country geographically, it is not surprising to find transport systems that are outmoded or lack capacity to serve the current population, most of whom are urban dwellers. Provided that there is timely and forward-looking city and transport planning to overcome these problems, periods during which population is increasing can provide a good opportunity and the right environment in which to mobilise people, funds and resources to carry through systemic change.

Chapter 6 of this report opens the door to transport modes and systems, present and future. It shows that for the nation to prosper and grow in population, there are many transport problems and bottlenecks that must be overcome. Better transport hubs, improved public transport and reduced road, rail and port congestion in our principal cities are examples of known priority needs. These priorities and longstanding problems must be faced and met because raw materials and finished products, people and their goods all need to be moved around the country and across cities in ways and by modes that are cost-effective and timely. The nation will always depend on very efficient land, sea and air transport links as it exports its products into a highly competitive global economy.

Whether government is focusing on cities, infrastructure or transport systems, a prime challenge is to carry through strategic and integrated planning in a timely and non-bureaucratic way, and to plan for and mobilise the necessary levels of investment. This is essential if service, utility, transport and infrastructure costs are to be contained; arable, recreational and environmentally sensitive land conserved; and quality of life maintained – while at the same time drawing on the innovative and entrepreneurial strengths of the private sector and the market to help overcome key obstacles to sustainable urban development. The nation must also continue to invest in relevant pure and applied research, including research into energy and greenhouse-efficient power generation and modes of transport. That calls for governmental and other stakeholders to become actively involved in technology uptake and to stay the course in establishing the right business climate and in providing sufficient incentives to encourage progressive and necessary change.

All these changes in the way cities are shaped, transport operates, utility and transport services are delivered, and infrastructure developed and updated will require access to adequate levels of both public and private funding to support targeted and major, long-term investment.

## 9.3 CHARTING THE ENERGY FUTURE

Australians are fortunate in the extent and mix of energy resources, both renewable and non-renewable, and in the scope of energy options available to the nation. Nonetheless, the nation faces some difficult decisions ahead in deciding which scenario to follow in charting the energy future and how to keep the various interested parties and stakeholders linked in common endeavour. This report demonstrates very clearly the complex interplay between future energy options and population growth and distribution. But those energy options are influenced, in turn, by shifting energy demands to meet industry needs and increasing community standards and demands; the scope and nature of both energy planning and regulation; the energy prices set and the way energy markets operate; the structure of ownership of generation and transmission; and the way the international community responds to major global, economic and ecological change.

Contemporary Australians, and their industries, have become accustomed to both security and reliability of energy supply. There are, however, growing signs of pressure on generation, supply and transmission infrastructure. At the same time it is important to work through how to share the available lower-priced energy equitably, manage demand more effectively and fund energy expansion, as per capita demand is rising and population continues to grow. Technology can help by playing its part in the efficient development and use of resources, both renewable and non-renewable, in large-scale power storage, in greenhouse gas reduction, improved energy transport technology and so on.

Once again this must be accompanied by the right policy settings and directions. That must include better integrated national energy planning, more unified and considered national regulation and more intensive efforts to contain demand (including recognition of the importance of pricing signals). Greater incentives are needed to foster use of renewable resources and to link both energy use and export to emerging international standards. Given its central role in policy setting, government must lead in much of this endeavour, but, since much generation and transmission infrastructure is in national and international private sector ownership, government and industry must work together if national and international energy scenarios are to be met.

## 9.4 RESPONDING TO CLIMATE CHANGE AND OTHER CRITICAL EVENTS

The nation must always be prepared to face natural and man-induced disasters and critical events, firstly to predict, secondly to avoid or moderate the impact, and finally to restore, rebuild and overcome where the disaster proves to be unstoppable or inevitable. The recent tragedies of New Orleans, the South-east Asian tsunami and terrorist attacks on infrastructure and people simply reinforce the need for continued priority attention. That entails effective planning, robust predictive and assessment tools and effective disaster relief coordination, funding and management, all in the face of the scale, shock and the uncertainty associated with these events. While it has not been the place of this report to examine this area in detail, the reality of global climate change is now so widely recognised as globally significant that it has been made the subject of a chapter and further commentary below.

Disaster prediction and response remains a critical national agenda where government must be alert in providing guidance and support, and where technology and technologists can and will continue to play an important part at all stages in dealing with disaster.

This report shows how critical it is for the nation to continue to contribute actively to global efforts to manage and secure progressive reductions in greenhouse gas emissions. While there is growing national awareness of these emissions and their potential impacts, it is now imperative that the nation plan and resource efforts to mitigate and adapt to these impacts in the short to medium term. That means moving beyond current efforts that focus on reduction of the rate of deforestation and applying improved emission abatement technology as well as early efforts to use economic instruments, such as carbon trading.

Government is again called on to lead in developing the right mix of economic, social and environmental strategies directed at adaptation to and amelioration of these impacts, while the long-term global efforts are under way. The matter is now urgent for many in government, industry and the community who must plan and take decisions in areas as diverse as regional and city planning, foreshore management, major industry and infrastructure development and immigration and population settlement. They are increasingly called on in their planning and decision-making to give greater attention to the likely impacts of greenhouse change on health, the environment, coastal and semi-arid locations, the incidence of natural disasters, energy and water availability and food production and agri-business. The very competitiveness of a variety of primary and secondary industries and the national economy is potentially in play.

## 9.5 SUSTAINING THE ENVIRONMENT

In the course of development of the nation it is only relatively recently that governments and citizens have started to undertake assessments and audits of the current condition of the airsheds, lands, forests and rivers of the nation. There are many urban and rural situations where such assessments have not been completed, either in relation to the current conditions of large regions or catchments or the capacity of these areas to sustain existing or modified patterns of human activity.

Completion of such assessments and then effective decisions, informed by a much better understanding of the needs of these natural and modified systems, will require a blend of government commitment and action, expert analysis and advice, and the continued involvement of interested parties, including local interests. Greater emphasis is needed on how to use less water, energy and non-renewable resources and how to moderate major impacts on natural systems. Technology can help ameliorate and reduce environmental impacts and contain the emergence of some environmental problems. Technology is, however, not the usual key to strategic and integrated environmental management or to success in changing the behaviour of citizens or industry. Instead, effective settlement policies and planning are needed to achieve more sustainable patterns of land and water use and transport, energy and infrastructure development. The way energy and water resources are priced and markets developed represent prime determinants of the sustainability of current and proposed patterns of resource use. The way mixes of educational programs, regulatory controls, business undertakings and government incentives are crafted and introduced will also contribute very significantly to behavioural modification.

In many cases there must be a shift in emphasis from specific responses to specific issues. That requires actions that focus on the needs and management of whole ecological systems, such as air sheds, land-based regions, river basins and remaining forest areas. That is not easy and seldom occurs because public authorities are structured around particular segments or issues rather than systems as a whole. At the same time industry and local communities are more comfortable dealing with the specific or the local rather than the systemic. For example, while the nation is working hard to determine appropriate ways of managing the nation's limited water resources, in both rural and urban surrounds, greater effort must be directed at securing better integrated, catchment and region-wide management and planning. In part, because that will determine and limit the success of efforts to manage the nation's water resources, a section dealing with catchment management follows this section.

Once again, all this is difficult and calls for effective public policy and government commitment, if science, engineering and technology are to assist government and citizens in shaping a sustainable future. All concerned need to be realistic because the deserts and arid lands of the nation are continuing to increase, while in the neighbouring more productive plains, there is acute difficulty in changing the nature of primary industry activity to more sustainable industries and practices, from both an economic and environmental perspective. The coastal catchments, especially those where significant towns and cities have developed, are, as pointed out in Chapter 2, under intense environmental pressure, calling for better land, vegetation, water and effluent management. As population grows and the community seeks higher standards that pressure is increasing.

To overcome these issues, new strategies are required if natural systems are to be drawn on in ways that allow the systems to recuperate and adapt. Equally, the strategies must ensure sufficient conservation of scarce and non-renewable resources, and, that the ways in which these natural systems and resources are used do not limit the choices of future generations. If this becomes the norm, the outcome of resource use, economic growth and development will be much more sustainable and greater populations will be better able to be absorbed, without either major economic or ecological dislocation.

## 9.6 TOWARDS MORE EFFECTIVE WATER AND CATCHMENT MANAGEMENT

The way catchments are managed is not just a critical part of *Sustaining the Environment* but an important determinant in its own right of how successful the nation will be in absorbing a growing population.

In much of our examination of catchments, rivers and their natural resources we have failed to appreciate the idiosyncrasies and needs of each natural system. These systems are dynamic and change over time. Changes made over the past 200 years have led to highly modified and even more idiosyncratic systems. If we are to focus on how to improve catchment and river systems to the point where they can sustain the increasing water demands of an increasing population, we must overcome problems that have often existed for decades and determine new approaches that can be carried through at tolerable cost.

That calls for assessments of the conditions of catchments and rivers and their capacity to sustain existing patterns of human activity. Then, we can make informed decisions firstly to improve current conditions and secondly to meet future challenges. Such assessments usually require a mix of government commitment, expert analysis and the advice of local interests. We also need to recognise that no two systems, whether modified or not, are the same. Rural systems have been modified in quite different ways to urban and urban-fringe systems. Inland rivers supporting extensive irrigation are different from irrigated coastal river systems. The challenges in managing major river systems vary markedly from one state to another.

In each case, short-term analysis and applied research can help to determine the primary threats to sustainability or, in much-modified systems, to determine the potential to ameliorate some problems. Thus, improved water flows may be the priority for the Murray River system, whereas changes in the pattern and location of effluent release are necessary in critical reaches of the Hawkesbury-Nepean system. In other cases significant changes are needed in the patterns of township expansion if healthy oyster growing and fish spawning areas are to be maintained in coastal estuaries and lakes.

To succeed, government, industry and the community must work harder to understand these natural and modified systems and to devise strategies that focus on catchments and river systems as whole systems. The sustainability of these natural systems must become the focus of critical planning, management and decision making.

Once a whole-system view is developed, it is imperative to develop effective mechanisms to link the exercise of powers by public bodies to the attainment of common system-based goals. Effort is needed to integrate water supply, water trading, stormwater, sewerage and drainage, energy services, flood mitigation, agricultural and land use extension services around common themes and targets, as opposed to the frequent practice of post-hoc, weak coordination. One consequence of the failure to do so, can be that a region may have difficulty absorbing more people and in providing their preferred occupations and lifestyles.

There are no easy generic solutions, whether they are prescriptive regulatory approaches or market-based approaches to catchment and river management. In the former case, the setting of standards for water quality, river flows or vegetation cover is most effective where the dynamics and needs of the whole system are understood. In the latter case, a good understanding of major catchments and rivers, including reliability of supply, is also important in establishing the basis for water-sharing and allocation and in determining the structure and boundary conditions for new and expanded water markets. While agreement on how to achieve inter-regional and inter-state trading in water is an important national priority, success will ultimately be determined not only in terms of increased allocation of water to more efficient, higher value-adding users and greater certainty in supply for primary producers but also in terms of the impacts of sharing and trades on catchment and river condition, the quantity and quality of river water and the impacts on existing water infrastructure.

Australia faces deeper and longer droughts, reduced water run-off and growing salinity in areas valuable for primary production and in many town and city environs. This makes the job of those involved in water planning and management difficult as they strive to provide adequate supplies for towns and cities and primary and secondary industry, while trying to take account of the needs and demands of both future populations and nature. As storage levels, aquifers and groundwater come under progressive challenge in many populated areas of the nation there are very considerable problems to be solved by government, water utilities and other stakeholders in providing adequate water supply.

As a consequence, much contemporary effort has been focused on controlling and curbing water demand and driving greater efficiency and value-adding in use. This has led to a mix of policies being introduced from restrictions on usage to incentives favouring introduction of water-efficient appliances, from improved metering of usage to better detection and management of system wide leakages. Some progress has been made in encouraging recycling and re-use, but both cost and public health barriers continue to slow more widespread adoption. The prospects of more comprehensive and rapid progress have been improved since authorities across the nation have introduced pricing regimes that better reflect water value and usage, and as water markets have progressively been introduced, thereby encouraging moves to higher value-added use of the existing resource base.

One of the greatest barriers to effective water planning and management still lies in the failure of stakeholders to recognise and then to remove institutional blockages to catchment and water reform. Too much current effort seems to anticipate that the next wave of reforms will force unproductive arrangements and processes into productive alignment. This seldom occurs, so in urbanised and more populated coastal environs institutional barriers, often built up during past unsuccessful cycles of reform, represent a prime threat to sustainability, to current intergovernmental and state water reforms and consequently to the smooth absorption of an expanded population.

## 9.7 MANAGING AND REDUCING WASTE

Not only are there challenges in dealing with high, and some argue unsustainable, patterns of resource use in present-day Australia, but there continue to be substantial challenges in managing waste and the residuals of economic activity. As governments strive to contain urban sprawl and direct the creation of both habitation and jobs to those denser population centres (in part to reduce the rate at which the costs of infrastructure development and service delivery are growing) they are also continually confronted by the rapidly escalating cost of waste disposal and management. Incentives for, and emphasis on, recycling and waste segregation are playing their part in overcoming the growing waste problems. However, government, industry and the community are increasingly recognising the need to give greater emphasis to the environmental and economic benefits of internalisation of waste generation at source.

This also reflects growing concern that excessive and costly waste disposal can represent a limitation on city and town development and hence limit successful absorption of increasing population. It is only very recently that some governments in Australia have begun negotiating with business and consulting with citizens as to how to reduce, at source, the entry of many wastes and residuals into the environment. Ultimately, that may involve progressive replacement of some products, including some chemicals and plastic bags, that are widely used but are hazardous to people and/or the environment; and, the return of products, such as computers and TV sets, to manufacturers at the end of their useful lifecycle. This would have the dual benefits of encouraging industrial-scale recycling of useful materials and components, as is already occurring in Europe but just beginning in Australia, and more responsible management of hazardous waste materials.

The process of sharing the burden of these changes equitably and of finding the right blend of regulation, standards and market incentives/disincentives requires further effort and tough negotiations on the part of both government and industry. This issue is serious enough today for it be clear that it will continue to represent a significant challenge as the nation works to absorb an increasing population, with all its likely demands.

## 9.8 FACING SOME OF THE BROADER POLICY CHALLENGES IN A CHANGING NATION

This study, for the Scanlon Foundation, examines the contribution science and technology can make to managing population growth in ways that facilitate both sustainable development and economic growth. There are, however, many other issues to be evaluated and faced, that lie beyond the scope of this report, if an increased population is to benefit the nation. While most of these issues are in the domain of government, they are briefly introduced below in order to demonstrate the wider context against which the findings of this report need to be considered.

Contemporary government must consider the interests and needs of many groups in the community in developing policy and setting directions. It is not easy for government to advance the public interest, human rights, social cohesion and environmental protection, while it harnesses the strengths of the competitive and global marketplace in building a competitive economy. It is difficult to balance the needs of a competitive economy, to reallocate scarce resources and to contain public expenditure while responding to increased demands for services, enhanced lifestyles and calls for greater equity in the distribution of jobs, educational opportunities and national wealth. Government must also strive to balance the growing costs of health care, education, policing and aged and disability care against the needs of a growing and competitive national economy. The trade-offs are hard and many of the problems associated with unemployment, poverty, inequality in income distribution, ageing and Aboriginal reconciliation appear, at times, to be intractable.

Of course, population will have an influence on all these issues, dependent on age and job distribution, as population increases and major social, settlement and environmental strategies are introduced.

The nature of education, work, the economy and society are all significantly impacted by the information age, with serious implications for government, commerce and society. In fact, the extent of social, technological and economic change is so great that the mode of governing and the mix of governmental responsibilities are changing, with considerable implications for parliaments and governments in decision making and in introducing legislation.

Citizens rely on government leadership and call on government to plan, manage and act effectively. This should assure their rights to contribute to the building of a cohesive but pluralistic society and to put in place the necessary checks and balances. Australians expect government to guide the introduction, review and reform of the major national systems and institutions so they operate in predictable ways and serve their vital interests, from antiterrorism to reconciliation, from immigration to child welfare.

It is hard for government to meet the varying expectations of an increasingly educated and articulate citizenry or to deal with intense media focus on its shortcomings. Frequently it is government that must mediate the various strongly held and divergent values and interests of citizens and groups in setting national policy directions. Yet government must recognise in its actions and planning that there are many competing sources of power and powerful interests in contemporary Australia. New strategies and dedicated effort will be needed if both government and its citizens are to respond effectively to both economic and population growth.

## 9.9 GETTING THE POLICY SETTINGS RIGHT

All the partners in creating a cohesive, forward-looking nation have an interest in maintaining effective government, a globally competitive economy and high standards and quality of life for all Australians. Government has the responsibility of meeting this challenge by setting key policy directions, notably in critical areas such as those described below, and in ways that allow an increasing population to be absorbed without major dislocations.

For example, government must create the framework for lifelong education and health care, articulate the critical policies and guide the national processes so that high quality services and opportunities are made available to all. In particular, there is an urgent need for government and the community to focus harder on what is needed to become the 'clever country', while population grows and while much of the existing educational infrastructure and educational institutions find it increasingly difficult to cope with contemporary pressures and demands. There are also widespread calls for the health system to be restructured around 'streams of care', for public funding and management to be merged, for the roles of Commonwealth and state governments to be clarified, for greater efforts to be made to contain the costs of advancing medical technology, and for prevention to be favoured over cure.

A growing and ageing workforce and community simply increases the urgency and the priority associated with carrying through what must be systemic and transforming change in education and health.

Over past decades there has been almost continuous debate about the role of the state in the provision of social services – how much support, for whom, by whom? Government must decide how and when to harness private supply mechanisms and the extent to which it can and should call on the capabilities of families, communities, charities and corporations to help. Government must set the direction, paying regard to the needs and capacities of those on whose services and goodwill it draws.

Various reviews have been carried out into rural social and economic conditions, weakened rural industries and regional economies. Such reviews have shown that global economic and technological change represent a primary cause of significant impacts on rural communities and economies, rather than microeconomic and competition reform. Nonetheless, many Australians want to know what national policies can be implemented to sustain communities in rural and regional Australia and whether directed immigration and other policies can better guarantee rural and regional futures.

Some of those regions also suffer from desertification, salination and increasing incidence of arid and drought conditions. To live and work productively in those locations will require wide-ranging cooperation between government and industry experts, the research community and current producers in forging new conservation and production strategies. These strategies, when implemented, must lead to a more sustainable mix of primary and conservation strategies and industries, so that such regions can play their part in future domestic food production and exports, jobs and quality of life, thereby enhancing the prospects for both the nation and those regional communities.

## 9.10 CONCLUDING REMARKS

While this report shows how science, engineering and technology can support a more populous future, this chapter points to some of the critical areas where all stakeholders need government to develop sound policy and set clear directions, so the path to a sustainable future will be a smooth one. There are long-standing problems to face up to and resolve and clear signals and feedback from current strategies to which it is important to respond. Science and technology can play a significant part in advancing sustainable development or health care or care for the aged but setting the direction and creating the impetus lies in the hands of government and key stakeholders.

There are also challenges in preparing then dealing with events and incidents that are unforeseen. At times infrastructure and services come under serious pressure, including at times of natural disaster or major incidents. The nation and its services must stand ready to cope with such stress on its assets and capacities. The better the national preparation, the more effective science, engineering and technology can be in contributing to renewal and restoration.

This chapter shows the context in which scientific and technical capabilities can be applied to support the development of the nation's infrastructure and institutions and to support the sustainable management of the nation's natural systems and resources. In this way, sustainable development, economic growth and a population growing to more than 30 million by 2050 can all be successfully accomplished.

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30/50 – The Technological Implications of an Australian Population of 30 Million by 2050
Report of a Study for the Scanlon Foundation



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